A HOUSE BUILT IN A MATTER OF DAYS BY 3D PRINTING THANKS TO THE BATIPRINT3D™ METHOD
The BatiPrint3D™ project brings together a unique consortium of scientific, industrial, public and socio-economic actors.
In the course of Nantes Digital Week in September 2017, the University of Nantes, Nantes Métropole, Nantes Métropole Habitat, Ouest Valorisation and their partners, pooled their know-how and expertise to enable the construction of an experimental social housing building in Nantes, directly on site in a district of Nantes.

The "YHNOVA™" project, with a surface area of 95m², will consist of 5 rooms, rounded walls, corners, doors, windows, doors... a set of complex architectural shapes, produced by means of a revolutionary robotic additive manufacturing technology: BatiPrint3D™, patented by the University of Nantes.

The result of an interdisciplinary effort between the research teams of the Laboratoire des Sciences du Numérique in Nantes (University of Nantes, CNRS, Ecole Centrale, Inria, IMT Atlantique) and the Institute of Civil and Mechanical Engineering Research (CNRS, Ecole Centrale), this innovative triple-wall formwork/insulating/structural additive layering system now makes it pos-
sible to construct the walls of a house using 3D printing, directly on site and in just a few days.

YHNOVA is an opportunity to tackle and solve all technical, phonic, thermal, regulatory, environmental, urban constraints etc., with the support of the various experts involved in the project. The development of YHNOVA is supported by Caisse des Dépôts as part of its support for Smart Cities projects and the national Smart City demonstration initiative, which aims to support experimental projects. In addition, the Ouest Valorisation TTO, the sole representative of research institutions, is fulfilling its role as a technological investor by reinforcing the protection of research results and developing an ambitious valorisation strategy for the BatiPrint3D™ industrial method.

Over the course of the Nantes Digital Week event, held in Nantes in September, the University of Nantes, Nantes Métropole, Nantes Métropole Habitat, Ouest Valorisation TTO and partners will construct a social housing building in a district of Nantes using 3D printing.

**YHNOVA BATIPRINT3D™ AT THE HEART OF AN INNOVATIVE LOCAL AREA**

With its simple yet ambitious Nantes CityLab scheme, Nantes Métropole is asserting itself as a testing ground for those looking to develop and test innovative solutions, helping to build the city of the future and facilitate daily living. Start-ups, SMEs, large groups, public actors, researchers, schools, associations and other actors in search of an urban laboratory are invited to get involved: Nantes Métropole provides them with a range of sites, equipment, data and engineering services to trial and accelerate their full-scale concepts.
Thanks to an innovative technology developed by the University of Nantes, a social housing building has been “printed” in a district of the city.

Researchers from Nantes have broken new ground in the field of 3D printing. For several months, the teams of the The Nantes Laboratory of Digital Sciences (University of Nantes, CNRS, Ecole Centrale, Inria, IMT Atlantique) and the Civil and Mechanical Engineering Research Institute (University of Nantes, CNRS, Ecole Centrale) have worked with Nantes Métropole Habitat and Nantes Métropole to build social housing in a few days, using advanced 3D printing technology adapted for the purposes of the project: BatiPrint3D™.

BatiPrint3D™: state-of-the-art technology for a ground-breaking robotic method.

Patented by the University of Nantes, BatiPrint3D™ is the result of a joint effort by two Nantes laboratories: LS2N (specialising in robotic systems development), and GeM (research of materials, formulation and characterisation). Its aim? to build affordable housing that can be adapted to local conditions, customised, delivered quickly and is inexpensive to run.

This advanced technology consists of depositing 3 layers of materials using a polyarticulated industrial robot: two layers of expansive foam serve as formwork for a third layer of concrete. Once the walls have been constructed, the foam is kept in place in order to insulate the house without thermal bridging.

The movements of the robot are guided by a laser sensor, based on a digital model of the house, directly on the concrete foundations. Mounted on an AGV (Automated Guided Vehicle), it is adapted to the external environmental limitations of the construction site, and stable in order to allow the controlled injection of the material.

At the end of the operation, the mobile robot emerges through an opening provided for the fitting of the joineries. It can then be transported to another site to perform other construction jobs.

Economic and environmental advantages

This process reduces construction time and improve thermal insulation, as well as reducing the operating costs of construction. The use of a mobile robotic system makes it possible to rethink the working methods of the construction industry, which, as in manufacturing, are crucial in reducing the arduousness of work and limiting hazardous or MSD-inducing jobs.

According to Benoît Furet, a professor at the Nantes University Technology Institute, researcher at the Nantes Digital Sciences Laboratory (LS2N) and BatiPrint3D™ project leader, “It is clear that construction robotics will bring drastic changes to digital technology in the construction industry. BatiPrint3D™ is a construction concept that will find a wide variety of applications and one for which we will be expanding the possibilities of use.”
"Our goal is to meet the challenge of excellence and interdisciplinarity in university research, which can be distinguished by its impact on society. The scientific influence of our university depends on cutting-edge projects such as the ‘Yhnova’ project, which is entirely in keeping with the new university model that we are offering in Nantes, and has just been awarded the Isite label for its NExT project".

Olivier Laboux, President of the University of Nantes

The Nantes Laboratory of Digital Sciences (LS2N) and the Civil and Mechanical Engineering Research Institute (GeM) have been working together for a number of years. In addition to the development of the revolutionary BatiPrint3D™ process, they are also conducting several other research projects on Additive Manufacturing, Robotics and new construction principles or materials.

The flagship project of the Yhnova demonstrator is an opportunity to strengthen collaborations between the University of Nantes and actors in construction (builders, housing associations, architects etc.) with the help of the Ouest Valorisation TTO. As such, a YHNOVA 2 project is already being considered in collaboration with Nantes Métropole, with a Start-Up to be created in the near future around the BatiPrint3D™ construction principle. Substantial work is underway on the industrialisation of robotic methods and the machinery associated with the construction principle...

THE ORGANISATIONS OF THE UNIVERSITY OF NANTES INVOLVED:

The LS2N and GeM teams are also considering new experiments, such as the construction of one-storey houses or the possibility of working with bio-sourced materials (a project is currently in planning stage with Norwegian colleagues from SINTEF, and another with French raw earth suppliers), or the development of robotic site solutions (with partners including PRB, Manitou, Bouygues etc.).

So the future of BatiPrint3D™ lies in varied types of valorisation in terms of research, value creation, industrialisation, generation of commercial activities, etc.
Innovation in social housing

Nantes Métropole Habitat is part of the "Nantes Citylab" scheme, led by Nantes Métropole through the YHNOVA project: the first social housing building constructed in the world using the BatiPrint3D™ process, a concept developed by the University of Nantes. This 95m2 house was built in a few days, in September 2017, during Nantes Digital Week in the Bottière district of Nantes.

An innovative project manager

Nantes Métropole Habitat brings its expertise in project management by bringing together key players in the construction industry to solve the many questions involved in this innovative process. Architectural firm TICA has taken advantage of the new robot printing process to design a house that fits into a woodland setting, respecting the existing vegetation while deploying a living space that is elegant and open to the environment.

The scientific expertise of the CSTB, the technical analyses of SOCOTEC and the consulting firm EGIS working with architects TICA, have all brought essential added value to the team of the University of Nantes in order to suggest solutions as to the classification and resistance of materials, the coordination of trades, acoustic comfort and energy efficiency. This substantial technical effort also saw the involvement of SMA BTP, the project insurer for Nantes Métropole Habitat. Over the course of the project, each professional is therefore able to contribute their know-how, develop new solutions and innovate in their practices in order to meet the challenge of progressing from a 3D printing robot to the construction of a sustainable and habitable home.

YHNOVA assessed and analysed

At a pre-tax cost of €195,000, including specific development costs, YHNOVA will be equipped with multiple sensors and home automation equipment in order to assess and analyse the behaviour of materials and thermal/acoustic quality during the first year of use.

At the end of this testing period, during which YHNOVA will also serve as a space for education and meetings with professionals and residents, the house will be rented to a family selected by the NMH Housing Allocation Commission according to standard criteria for social housing.
Bruno Lineatte, Director R&D Building Construction Methods/ Bouygues Construction

For us, YHNOVA is fully in line with our research into the construction methods of the future. In fact, the digital transition currently underway offers new opportunities, either to improve existing solutions (prefabrication, industrialisation etc.) or more significantly to develop new ways of building, using 3D printers or robots. Our primary focus is on heavy or hazardous tasks, with the aim of making our jobs even safer and more attractive. In this aspect, the wider project offers a priority area for experimentation. In the medium term, we are hoping that these new construction methods will allow for the productivity gains that the building will need in order to build sustainable, high-quality housing and workplaces that are accessible to as many people as possible. This first step will be a steep learning curve as we imagine the future methods of construction for many types of structure.

Charles Coiffier, Architect/TICA Arc

We have looked to take advantage of the freedoms offered by the use of a robot to build the walls of this house. This freedom can be seen in the spacious interior, in which large openings onto the landscape reveal generous curved living spaces through the light they offer. The innovative process also allows us considerable "contextualisation" of the project. For this house in particular, we were able to achieve a project that is highly respectful of the setting in terms of existing vegetation. The rooms of the house effectively fit in between the trees, at a sufficient distance to preserve the root network, and are connected by long walls in extended curves, marking out a large central living area with views out onto the woodland. The project was eventually sited in a highly constrained wooded area, but we managed to do so without cutting down a single tree. This innovative construction process ultimately gives designers the means to take better account of the context of buildings and their future inhabitants.

Nantes Métropole Habitat is a driving force behind innovation and energy transition, supporting and trialling a number of innovations in its 25,000-unit housing stock, and in doing so, contributing to the development of social housing in France:

- Energy-positive social building (the Grand Carcouët - in 2014).
- Digital boiler (Stimergy), providing heated water for showers through computers (2015).
- Smart thermostats (with the Nantes start-up QIVIVO) to regulate and optimise energy consumption (2015).
- Assessment of all the fluids in a dwelling to optimise thermal insulation (Véolia - 2016).
- Measurement of the impact of global warming on buildings with the use of probes and thermal cameras (with the City’s Science and Technology Research Institute - 2017).
- Wood construction, geothermal power, wood-fired heating etc.
The Ouest Valorisation TTO invests heavily in a new additive manufacturing method (3D printing) for construction and housing

The BatiPrint3D™ project brings together a new consortium of partners from the scientific, public, industrial and socio-economic sectors around 3D printing for housing.

TTO - mission
Ouest Valorisation - Technology Transfer Office (TTO) was created as part of the "Investissements d'Avenir (Investments in the Future)" call for projects, issued by the French Ministry of Higher Education and Research.

Its mission: to offer companies attractive innovation resources resulting from public research.

The Ouest Valorisation team detects, evaluates and protects inventions and finances and supports the resulting innovation projects through to their adoption by companies, by assuming the technological and financial risks inherent in these projects.

The Ouest Valorisation TTO, the sole representative of research institutions, is fulfilling its role as a technological investor by consolidating the protection of research results and developing an ambitious valorisation strategy for the BatiPrint3D™ industrial method.

BatiPrint3D™: investing to create value
As part of the BatiPrint3D™ project, the Ouest Valorisation TTO invests in the development programme, thus increasing the economic value of its results. The objective is to structure and formalise both a tangible offer with high added-value, but also a source of skills for the socio-economic players brought together within the consortium.

The detection and protection phases make it possible to secure innovation and as such, the Ouest Valorisation TTO makes a significant contribution in the filing of patents and management of brand extensions or domain names.

For projects with high potential for economic spin-offs such as BatiPrint3D™, the TTO invests in technical and economic development in order to improve the reliability of scientific results and facilitate the project's transfer to market. It achieves this using external resources, recruiting engineers and technicians specialising in the management of R&D projects who contribute to these development programmes alongside the researchers.

The aim of the development programme is to validate the industrial feasibility of the technology, allowing the production from start to finish of a full-size housing unit on site: YHNOVA™.

The Industrial Market
3D printing by additive synthesis of materials is a rapidly expanding field that is beginning to affect all manufacturing sectors.

Additive manufacturing challenges the methods used in design and implementation, particularly for the construction industry. This new in-situ construction process will dramatically re-shape the traditional production line.

In a global additive manufacturing market worth approximately $19 billion in 2020, growth forecasts for this new market agree on an average annual growth of around 25-30%, a true indicator of an acceleration in the digital transformation which is affecting all sectors.

In the Construction and Architecture sector, the needs expressed are many. The growth of 3D printing is part of the downstream deployment of digital design technologies and is now firmly anchored in the downstream thanks to BIM and CAD.

"Additive manufacturing has now entered the market to a point beyond the manufacture of prefabricated components in the factory and on to the construction of housing directly on site (in situ). A pioneering world-leading process, BatiPrint3D™ demonstrates the breakthrough potential of technology", concludes Bruno Westeel, Marketing Manager of the Ouest Valorisation TTO.
Long-standing city actor Caisse des Dépôts aims to become the leading partner for projects related to smart cities, having launched a national “smart City demonstrators” initiatives in 2016 to provide support for experimental projects. Nantes Métropole has benefitted from the scheme with the hosting of a “smart city” demonstrator: 6 projects for the development of the smart city have emerged in this local area and are currently being developed with the aim of achieving the Caisse des Dépôts Demonstrator programme label.

The YHNOVA project is the first project to be awarded the label, receiving €250,000 in support from the Caisse des Dépôts. This support, provided to Nantes Métropole, is helping to finance the construction of the first demonstration building for social housing using innovative Batiprint3d™ technology, built in Nantes in the Bottière Pin Sec district as part of the 2017 Nantes Digital Week.

Based on feedback from this pilot, the Caisse des Dépôts Group also intends to contribute to the development of the applications of this new construction solution, and particularly the construction of social housing. »
Based on a transdisciplinary approach, YHNOVA is one of a number of projects developed as part of the Nantes CityLab, launched in March 2017. The Nantes CityLab scheme is both simple and ambitious: the local area is asserting itself as a testing ground for those looking to develop and test innovative solutions, helping to build the city of the future and facilitate everyday life.

Launched in March 2017, the Nantes CityLab aims to:
• identify and support innovative projects in all fields (cultural, social, art in public spaces etc.) via a set of tools that has itself been trialled for a year
• gather private, public and citizen momentum within the framework of a collective governance
• develop successful trials and innovations across the local area
• make Nantes a local area that accelerates innovation, paving the way for the city of tomorrow and anticipating energy, digital, democratic and demographic changes.

From concept to reality: how does it work?
The Nantes CityLab provides practical resources for project managers:
• Sites in the city to trial projects: roads, buildings, public spaces, street furniture, parks and gardens etc.
• A support system throughout the project: labeling, research of the optimal testing ground, partnerships, trial follow-up, assessment and valorisation.

Nantes Métropole launches the first network of City labs in France
Nantes Métropole launches the first network of City labs in France at Nantes Digital Week. The aim of this day is to bring together, for the first time, the views and experiences of French actors involved in supporting full-scale urban experimentation.

For more information: nantescitylab@nantesmetropole.fr and nantesmetropole.fr/citylab

“The Nantes City Lab is a different way of building the city by working with innovators and on the basis of end-use. We first trial in localised areas in order to establish where the needs are before a wider roll-out. In this system, which is based on shared governance around Nantes Métropole, the local authority acts as a trusted third-party in the public interest”

Johanna Rolland, Mayor of Nantes and President of Nantes Métropole
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IN A MATTER OF DAYS WITH THE “BATIPRINT3D™” 3D PRINTER

With the emergence of new electronic technologies, and the increasing concerns of light pollution, limited budgets etc., urban lighting is changing. It is becoming essential to provide lighting when (lighting control) and where needed (high performance LED lights) and at a reasonable cost. The company Caméon, with the support of Bpifrance, has adapted one of its broadcast technologies by re-purposing analogue FM radio networks. A project developed jointly with Nantes Métropole allowed the company to trial a system that allows street lighting to be controlled remotely, optimising the operating costs of the lighting and bringing significant energy savings.

The ethos of the Nantes CityLab and the city, namely of promoting exchange between citizens, private and public initiatives and companies of all sizes already exists in Nantes through several innovative large-scale projects for the local area. A few examples:

**Nantes in my pocket**: an application that offers a set of highly customisable services for daily life, created in collaboration with citizens, a large group and start-ups

**MySMARTlife**: Alongside the cities of Hamburg and Helsinki, Nantes is piloting a European project in mobility, digital technology and energy. The test area is the Ile de Nantes, with the help of 9 local partners from the public and private sectors.

**Zen bus**: an application created by company Joul to optimise waiting times for public transport through real-time geolocation of the buses, initially on on two Semitan bus routes.

**Nantes Métropole, a local area of innovation in housing**

The Yhnova collaborative project is an excellent example of the Nantes CityLab system as it illustrates the City's partnership innovation initiative.

Nantes Métropole has set itself the goal of 6,000 dwellings per year, with a particular emphasis on social housing, which represents 1/3 of all annual construction, a total of 2,000 new social housing units. It was in the context of the implementation of the housing policy action plan that the Yhnova project was conceived: the elected officials' ambition is to make housing - and social housing - an enhancer of the attractiveness of the local area, a showcase of architectural and environmental quality and a demonstrator of technologies, while responding to the major challenge of reducing construction costs in order to create accessible housing for all.

Creating the city of tomorrow is about committing to transition: the ecological, energy, digital and social challenges are an ongoing concern, included in all of Nantes’ public policies, providing a regional stimulus in the construction and rehabilitation of housing. They orient the objectives established by all 24 mayors of the Nantes urban area in terms of housing (Housing Policy voted unanimously, Solidarity and Urban Renewal quotas pooled): to respond to the demographic growth of the urban area, tackle urban sprawl, meet the housing needs of all, bring nature back into the city, make it enjoyable for all and offer access to housing at all stages of life.
COMMITTED LOCAL PARTNERS:

LafargeHolcim, resulting from the merger of the Lafarge and Holcim groups in 2015, is the world leader in cement and concrete, employing 115,000 people in 90 countries. The Lafarge Research Centre, located in the Lyon region, is a central hub for the the Group’s research teams and is the world’s largest laboratory in the field of construction materials.

The French leader in AGV intralogistics systems, BA Systèmes supports manufacturers in the overall automation of their flows. Engaged in a continuous innovation approach, BA Systèmes also offers its expertise in mobile robotics to offer its customers the latest technological advances.

Innovation in confidence with CSTB. Won over by the project’s ambition, the CSTB has been involved since the summer of 2016, alongside researchers from the University of Nantes. The concept is pioneering in its integrated approach to the insulation-bearing structure, which makes it possible to aim for, in the first instance, the application of 3D printing to the additive manufacturing of insulating formwork. Regular interaction with the CSTB allowed the project lead to choose a construction system that focuses on the non-standard parts at the points of interface with the formwork printed by the robot. From the outset, the project partners expressed a desire to ultimately achieve Technical Appraisal of Experimentation (ATEX) certification for this prototype. This trial, which fulfills the conditions for successful accreditation, represents an initial stage.

Large-scale construction company CARRETERO-MEYER specialises in the construction and renovation of housing and major refurbishment projects. Experts in complex structures and projects. Working on occupied sites.

Covestro, with a revenue of €11.9 billion in 2016, is one of the world’s largest producers of polymers. Its primary activities are the production of high-tech polymer materials and the development of innovative applied solutions for many areas of our daily life. Its main customer sectors are the automotive, electrical and electronics, construction and sports and leisure goods industries. Covestro has 30 production sites worldwide and employed some 15,600 people by the end of December 2016.

PRB, a family business based in Vendée, is a major player in the manufacture of industrial mortars in France. (coatings, glues, ITE, paints, technical mortars etc.). A forerunner in façades, PRB has been innovating for 40 years and naturally took to the futuristic concept of “BatiPrint3D”, lending its expertise to this innovative and revolutionary housing project.

Saunier Duval is a leading brand in innovation and production technology for heating and hot water. The company was established in 1907 and has been based in Nantes since 1965. It specialises in the design and manufacture of home comfort products, including boilers, heaters, air conditioners, solar thermal panels and heat pumps. Saunier Duval has been the French leader for over 6 years in the condensing boiler market. It is currently focusing its efforts on the development and manufacture in France of products using renewable energies such as thermal solar panels and heat pumps.

Since 1992, BAUDET has designed, manufactured, installed and provided maintenance and servicing of ready-to-install bathrooms. We offer our customers a service that includes: design tailored to their needs and budget, the installation of fully equipped, connected, tested and guaranteed bathrooms. The BAUDET solution is a turnkey solution that combines innovation, quality and trade expertise for your construction or renovation projects.

A major French player in carpentry (PVC, aluminium and mixed), BOUVET consists of 680 employees, with a turnover of €750 million. Based near Angers, the group has for many years made innovation a major focal point for its growth. So it is with great pride and interest that we are collaborating on this pioneering project.
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