INTESA SANPAOLO
INNOVATION CENTER

INDUSTRY TRENDS REPORT
SMART BUILDINGS

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FROST & SULLIVAN

The majority of the data and commentary in this publication was developed and provided by Frost & Sullivan. It draws on proprietary information and a range of other sources including the companies, organizations and academics that are referenced in the text.

CONTENTS

ENERGY MANAGEMENT

The homes and buildings industry recorded a 8.6% growth in 2022, driven by demand for facility management services, smart home devices, customer experience platforms, and construction management solutions[1].

According to the International Energy Agency[2] , energy consumption stemming from the buildings industry reached 132 Exajoule (EJ) in 2021 or 30% of total global final energy consumption, a jump of 0.5% per year since 2010. The increased frequency of extreme weather conditions and the subsequent growing ownership and use of air conditioning (AC) systems are the major factors behind this trend. In 2021, emissions from the building industry reached 3 gigatons of carbon dioxide (Gt CO2) which corresponds to growth of more than 15% of total emissions from end-use sector.

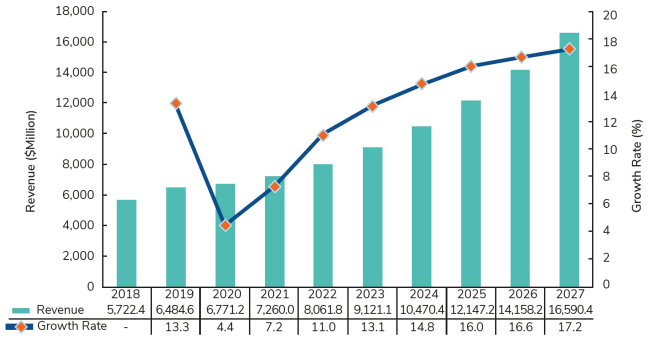
Building and Home Energy Management solutions (BEMs/HEMs) offer the potential to reduce electricity consumption by over 50%

Inefficient processes and poor energy management result in commercial buildings wasting 30% of the energy that they consume. Advanced BEM solutions can provide savings of between 13% and 66% in terms of costs due to their detection, historical analysis, diagnostic and predictive capabilities.

BEM typically refers to a computerized system that monitors, manages, and optimizes commercial and industrial buildings' performance in areas such as heating, ventilation and air conditioning (HVAC) and lighting. It consists of **hardware** such as controllers and Internet of Things (IoT) gateways which send field-level data to the cloud by interfacing with the system's management layers and **software** which includes dashboard applications and cloud-based optimization.

HEM is defined as a technology platform that monitors, manages, and optimizes residential buildings' performance in the same areas but increasingly extends to also take in solar photovoltaic (PV) and other integrated sources of renewable energy (RE). It encompasses **hardware** like hub devices, smart plugs, and clamps as well as in-home displays which are incorporated into wireless mesh networks (which are also known as home area networks). Typically, HEM systems enable bi-directional communication between the end-user and his/her utility through a smart meter and are reliant on software such as dashboard application that are used to view home functions remotely through a desktop or a mobile device. This enables the management of energy consumption. Vendors do not usually sell the **software** separately as they bundle it with the hardware as a full package.

BEMS AND HEMS MARKET REVENUE, GLOBAL, 2018-27



	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Revenue	5,722.4	6,484.6	6,771.2	7,260.0	8,061.8	9,121.1	10,470.4	12,147.2	14,158.2	16,590.4
Growth Rate	-	13.3	4.4	7.2	11.0	13.1	14.8	16.0	16.6	17.2

Overall, Frost & Sullivan estimates that the market was valued at $6.8b in 2020 and will grow at a CAGR of 13.7% to $16.6b in 2027

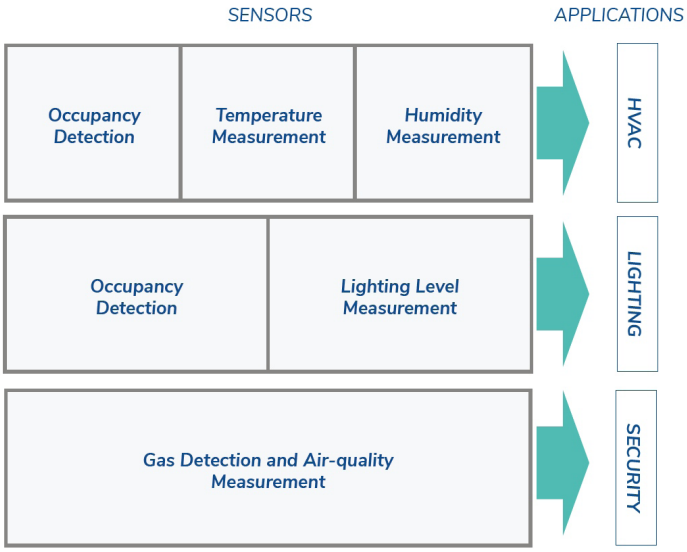
The **BEMs** market is expected to reach $9.0b in 2027, at a compound annual growth rate (CAGR) of 7.9% from 2021 to 2026, also because could be used for large, complex and multi-occupancy buildings (hotels, hospitals, schools, universities, malls and retails parks, heavy industry…)

Revenues in the **HEMs** segment will exceed $7.5b in 2027 from $2.3b in 2020, a 18.8% CAGR.

Global programs such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment and Environmental Assessment Method (BREEAM) and Excellence in Design for Greater Efficiencies (EDGE) certification help to reach green credential for building owners and occupier.

[1] Source Frost Sullivan
[2] IEA-World Energy Outlook 2022

Source: Frost & Sullivan



BEMs and HEMs are notably benefitting from the integration of a range of sensors which test parameters such as occupancy, temperature, and humidity.

Occupancy sensors identify if a room is occupied or not while advanced occupancy sensors count the number of people in the area. Parameters that are used to measure their performance are their sensitivity and their resistance to "false triggering". Generally, there is a trade-off between the two which BEMs/HEMs developers need to manage.

Key occupancy sensor manufacturers are Johnson Controls, Leviton Manufacturing and Lutron Electronics (all US) with examples including Passive Infrared (PIR), Ultrasonic, Microwave, Acoustic and Dual-Tech solutions.

Temperature sensors measure the atmospheric temperature in the room and send the data to the BEMs' automation system. This then uses the inputs that it receives to optimize HVAC (Heating, Ventilation and Air Conditioning) equipment conditions.

Key temperature sensor manufacturers are Honeywell (US), Siemens (Germany) and TE Connectivity (Switzerland) with examples including the commonly used thermocouple and resistive solutions (RTD temperature detectors).

Humidity sensors assess the humidity content in an indoor environment. Controllers use the data that they generate to manage HVAC working conditions, maintain the optimum level of humidity in a room and enhance the comfort of its occupants. Elevated humidity conditions can speed up mold formation and generate other unwanted complications in HVAC equipment. Data from humidity sensors allows BEMs to identify and alert the user about the need for maintenance.

Key occupancy sensors manufacturers are Sensirion (Switzerland), PCE Instruments (US) and Bosch (Germany) with examples including relative and absolute solutions. Indoor and human comfort applications typically use relative humidity sensors as they are based on simple mechanisms and are quite inexpensive.

In addition to occupancy, temperature and humidity, other sensors that are used in HEMs ad BEMs applications include **gas, lighting,** and **air** sensors.

In parallel, the widespread deployment of new Internet Protocol (IP) networks is enabling superior wireless BEMs and HEMs communication and control.

IP has multiple advantages over conventional BEMS networks that use cables to connect sensors, transducers, controllers, and actuators. As a result, they now account for most of the solutions that are currently being deployed in the BEMS industry.

The pros of IP networks include:

Cost efficiency

IP networks are almost omnipresent in commercial buildings to enable data sharing and provide internet access. Commonly used platforms can transmit up to 10 billion bits per second (Gbps). This high capacity allows IP networks to connect devices using compact and inexpensive infrastructure. To achieve the same

bandwidth and quality, conventional BEMs networks would require many different types of expensive cables.

Centralization

Typically, BEMs require separate cables for every sensor as they each send a different signal. In IP-based systems, all data from is transported through the same network. This centralized approach favours the collection and consolidation of information and is a crucial advantage for the smooth working of BEMs controllers. Optimized HVAC operations are only possible when humidity, occupancy and temperature can all be measured together.

Personalized control

With IP networks, the use of common scripting languages such as XML allows users to monitor BEMS from devices such as smartphones and personal computers. These interfaces also facilitate the remote control of platforms enabling owners and occupiers to personalize HVAC and/or lighting settings across different rooms.

Flexibility

IP networks support the use of computer programming with modern BEMS suites considering, for example, the prices set by utility companies to dynamically control electrical equipment (such as water heating systems) and minimize energy bills. Increasingly, BEMs also consider current and forecast weather conditions to optimize HVAC and lighting use.

The combination of embedded sensors and IP connectivity is making the application of IoT a reality with a focus on the energy-intensive HVAC segment.

Frost & Sullivan estimates that by 2027 between 7% and 8% of global HVAC revenues will stem from subscription-based services also pushed by IP networks usage.

The pandemic greatly affected companies that lacked resiliency and flexibility in their business models. Outcome-linked and as-a-service business models add robustness on the supply and demand side, allowing the vendor to provide comprehensive offerings and capture recurring revenues. HVAC-as-a-Service (HVACaaS) is a subscription-based model for HVAC equipment and can be a game-changer.

For innovative suppliers, an HVACaaS approach supports improved customer service and offers greater resilience via recurring sales.

Under the HVACaaS model, manufacturers offer the use of equipment which is wholly owned and operated by them. It is therefore the supplier's responsibility to schedule preventive maintenance and service calls. All of the equipment connects to the cloud, allowing the manufacturer to operate it remotely and monitor the data that it generates to ensure the HVAC systems' correct functionality.

Cooling-as-a-Service (CaaS) and Heat-as-a-Service (HaaS) models are like HVACaaS in terms of their execution and financials. In 2019, the Global Innovation Lab for Climate Finance recognized CaaS as one of the most innovative new financing instruments.

Frost & Sullivan expects the HVACaaS market to grow rapidly in the next five years. Building owners stand to make significant gains in terms of operational efficiency and cost reductions without the need for large initial capital investments which are typically associated with purchasing expensive machinery like chillers, boilers, pumps and air-handling units.

Service providers offering HVACaaS need to include preventive maintenance by integrating IoT services with the systems and hardware. IoT-enabled HVAC equipment can attract a higher price than conventional HVAC equipment with the service provider able to generate additional revenues and ensure the health of its assets while building owners and operators can be confident of system uptime and performance.

BEMs and HEMs enhance the potential of Automated Demand Response Systems (ADRS) and for effective peak shaving.

Power infrastructure evolves continuously. Renewables

Source: Frost & Sullivan

now account for a significant share of power generation in Europe with other regions witnessing similar trends. To address the intermittency issues of RESs, utility companies are installing digital distribution systems comprising of smart meters and ADRS. Therefore, the deployment of renewables will indirectly generate further demand for BEMs and HEMs.

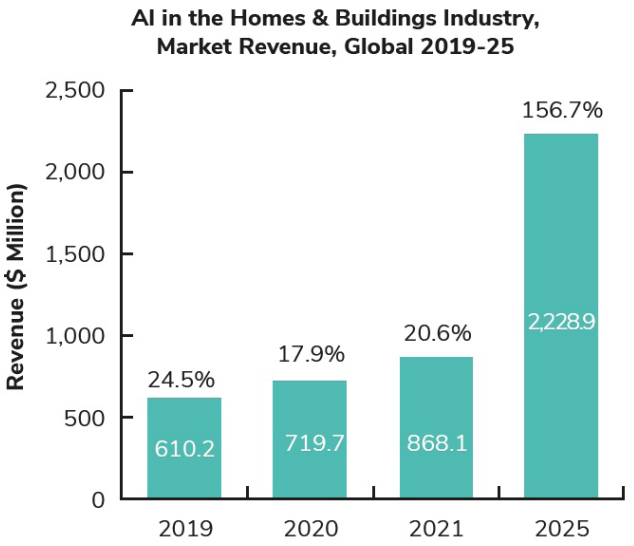
Overall, Demand Response (DR) is a common way for businesses to contribute to grid resilience, reduce their energy costs and create a sustainable culture. DR is a mechanism by which to alter electricity consumption patterns through pricing signals and incentives thereby reducing peak demand and improving grid flexibility.

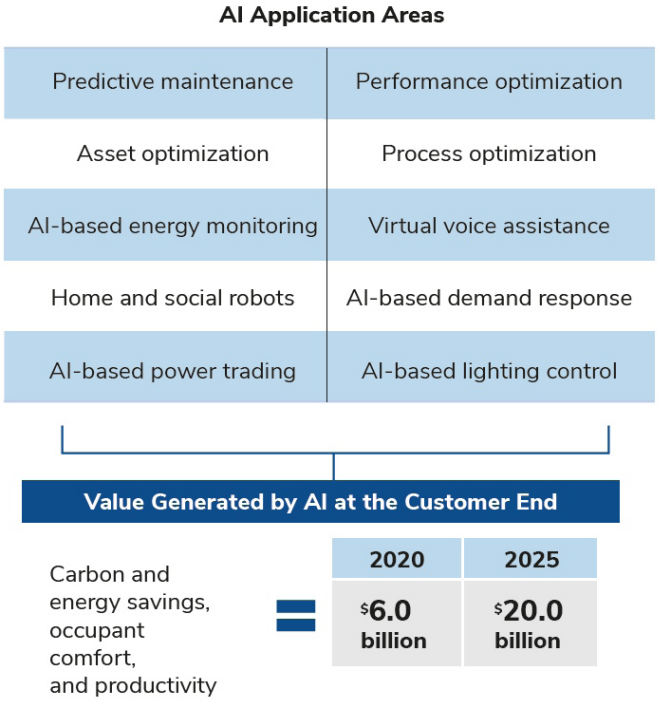
DR leverages modifications to customers' demand patterns by altering the time and duration of electricity use. The concept is in a nascent stage of development in Europe, with pilot programs underway in the residential sector, while North America is the main hub for DR initiatives and activities.

Frost & Sullivan recommends that companies use best practices from HVAC manufacturers as guidelines to leverage DR partnerships with utilities. A clear example is the partnership between smart thermostat manufacturers and power providers. Combining DR with onsite energy storage also offers additional cost savings to the consumer.

Companies need to develop predictive building management systems that can produce HVAC energy savings and peak load reductions during DR events. These systems will have to take into consideration weather forecasts, electricity prices, daily peak load times and equipment performance to minimize HVAC usage inside buildings.

MOVING FORWARD, ARTIFICIAL INTELLIGENCE-POWERED AND 100% HOLISTIC BUILDING OPTIMIZATION SOLUTIONS REPRESENT THE NEXT STAGE OF BEM/HEM MARKET EVOLUTION.





Source: Frost & Sullivan

When integrated with AI, building systems and IoT devices have the potential to enhance operational efficiency and improve occupant experience as well as optimize asset and space utilization. AI-enabled BMS systems can result in the development and deployment of comprehensive energy management systems which involve all aspects of a building and start to play a role in active facility management.

A cognitive scan can, for example, predict asset failure and enables planned downtime and maintenance, protecting asset health. Insights delivered through AI support the transition from a reactive to a prescriptive model to the benefit of building owners, facility managers, building engineers, service providers and tenants.

Frost & Sullivan believes that solution providers should increasingly offer AI-based solutions, and also provide training to customers on how to leverage their capabilities thoroughly. Software providers must incorporate ML algorithms into their products while, overall, creating the right balance between improving technology and managing cost is a challenge for companies as end users' price sensitivity remains high.

AI-based building optimization solution providers such as Fog-Horn, BrainBox AI and BuildingIQ and incumbent building technology players like Siemens, Honeywell and Johnson Controls represent tough competition for any new market entrants. In order to succeed, companies must develop a competitive edge by supplying offerings that integrate all building systems under a single platform.

Beyond one-to-one partnerships, the most successful players in the future BEM/HEM market will need to establish ecosystems around their products and develop concrete offerings which fill the supply-side gaps and offer compelling end-to-end solutions to customers.

Asset digitalization, for automation and/or energy management purposes, is enabling a radical shift in building maintenance practices.

Conventional reactive, planned, or proactive approaches are being replaced by proactive and increasingly prescriptive solutions.

Where **predictive maintenance** provides information about a binary decision, such as the choice to perform or defer asset maintenance, **prescriptive maintenance** offers a suite of options and outcomes from which to select.

Prescriptive maintenance is a step ahead of predictive in that it has the ability to advise on a building's optimal operational performance.

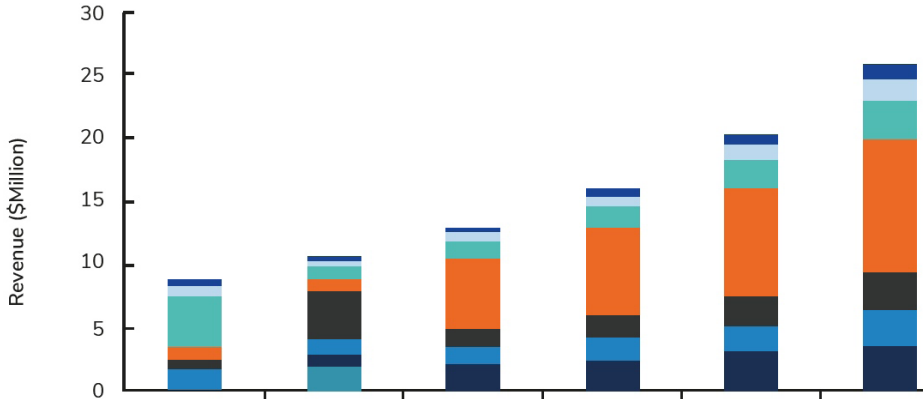
A key prerequisite for prescriptive maintenance is the presence of **connected equipment.** Installing sensors on building assets and linking them to an IoT platform creates a stream of data about their real time health. This also allows **remote monitoring** with the information generated being followed off-site to ensure that the building system is operating correctly. Finally, **predictive analysis** is enabled and is reliant on ML modules which build models using historical data to foresee failure and create system alerts that inform building manager of any future maintenance needs.

Prescriptive maintenance itself is part of an emerging integrated building management and maintenance ecosystem which provides automated recommendations on the performance of a building. It has the capacity to kick off remedial work before a field technician attends an incident based on the information collected and to oversee the entire maintenance workflow. In addition, prescriptive maintenance allows collaboration between experts and technicians through a connected community.

Frost & Sullivan expects the market for predictive maintenance in the global homes and buildings space will reach $2.8b in 2025.

The pandemic has accelerated the digital transformation initiatives in the built environment with building owners starting to invest in some of the key solutions that will be needed to achieve overall sustainability goals and improve

DIGITAL SOLUTIONS IN THE HOMES & BUILDINGS INDUSTRY, MARKET REVENUE, GLOBAL 2020-25



	2020	2021	2022	2023	2024	2025	CAGR
Workplace Optimization	0.25	0.32	0.42	0.55	0.75	1.03	32.7%
Healthy Building Services	0.31	0.42	0.59	0.83	1.20	1.77	41.8%
Digital Twin	0.85	1.07	1.37	1.75	2.33	2.97	28.4%
Remote Monitoring	3.93	4.64	5.55	6.74	8.31	10.35	21.4%
Energy Optimization	1.01	1.21	1.48	1.86	2.38	3.09	25.2%
Predictive Maintenance	0.77	0.96	1.21	1.57	2.10	2.83	29.7%
Fault Detection & Diagnostics	1.78	2.01	2.31	2.68	3.13	3.64	15.4%

occupants' comfort, productivity and health and wellness.

In 2025, Frost & Sullivan forecasts that **remote monitoring** and **fault detection** will contribute 64% of the digital solution revenue stemming from the homes and building industry globally. These services are adopted in small- and medium-sized buildings as the price points are lower than for more advanced solutions involving AI/ML.

Over 40% of remote monitoring services revenue is accounted for by the residential segment in the form of smart thermostats, energy management systems and home automation and control systems.

Predictive maintenance and **energy optimization** are high growth service components and will contribute 20% to the overall market in 2025. These services require AI/ML capabilities for real-time building performance optimization are usually adopted in large buildings with floor areas of more than 50,000 square feet and as they are considered expensive due to the sophistication of the platforms and the value they offer.

Revenues generated from predictive maintenance alone will increase from less than $1b in 2021 to reach $2.83b in 2025, a 29.7% CAGR.

Digital Twins, workplace optimization and **healthy building** services are other areas of activity within the broader digital solutions space. The former will contribute 10% of the total in 2025 with increased adoption in the commercial and institutional segments to address overall sustainability-related goals and improved building performance. Digital Twin projects require a collaborative effort from both the building technology players and Digital Twin providers in both new-build and retrofit projects.

Source: Frost & Sullivan

THERMOSPHR

COMPANY OVERVIEW

Industry Segment:
Energy Management

Brief Description:
Thermosphr has developed a Software as a Service – SaaS solution to manage the energy efficiency of buildings.

Maturity:
Commercialization currently

Multimedia:

https://www.youtube.com/watch?v=HlOJlAxjLio

COMPANY STRUCTURE

FOUNDED: **2020**

COUNTRY: **GERMANY**

OF EMPLOYEES: **5-10**

TOTAL FUNDING: **N.A.**

REVENUES: **N.A.**

PRODUCT OVERVIEW

Technology Focus

- Thermosphr has developed a Software as a Service – SaaS solution that allows real-time automation of Heating Ventilation and Air Conditioning - HVAC systems.
- The Thermosphr system can predict different parameters of HVAC regulations. The software is designed as a plug-and-play add-on for Building Management Systems - BMS to monitor HVAC systems and increase their efficiency.
- Thermosphr solution combines broad compatibility with building communication protocols, high data security standards and AI-powered thermal digital twin technology. The solution developed by the company is customized for different types of buildings.

Main competitive advantage:

Thermosphr has developed a Software as a Service – SaaS solution to manage and real-time monitor Heating Ventilation and Air Conditioning - HVAC systems in different types of buildings, increasing their efficiency by more than 30%. The solution continuously adjusts HVAC systems output according to the thermodynamic conditions of a building, also considering external weather conditions. Thermosphr efficient control can prevent problems from occurring.

Value Proposition

- Thermosphr offers property managers a Software as a Service – SaaS solution to reduce building energy costs by optimising the operation of Heating Ventilation and Air Conditioning - HVAC systems in real-time.
- Thermosphr is committed to having a positive impact on the environment and accelerating the decarbonization of the planet by reducing CO2 emissions from buildings. The company aims at improving health and comfort in buildings.

Source: Frost & Sullivan, THERMOSPHR

ENERSEM

COMPANY OVERVIEW

Industry Segment:
Energy Management

Brief Description:
Enersem has developed a Software as a Service – SaaS energy management system to analyze the energy performance of buildings.

Maturity:
Commercialization currently

Multimedia:

https://www.youtube.com/watch?v=rJNcHa29Kn4

COMPANY STRUCTURE

FOUNDED: **2016**

COUNTRY: **ITALY**

OF EMPLOYEES: **10-20**

TOTAL FUNDING: **N.A.**

REVENUES: **N.A.**

PRODUCT OVERVIEW

Technology Focus

- Enersem has developed a Software as a Service – SaaS energy management system to analyse a building's energy efficiency and to detect inefficiencies. The software checks consumption trends and predicts the impact of future energy measures taken by property managers.
- Enersem has developed Knolval, a cloud-based patented Building Management System – BMS solution. Knolval is an integrated system in which smart valves, IoT gateways, and AI-powered software work together to optimally manage Heating Ventilation and Air Conditioning - HVAC systems.

Main competitive advantage:

Enersem has developed a Software as a Service – SaaS energy management system to scan the energy performance of a building, facilitating heat recovery and utility optimization. The company relies on artificial intelligence algorithms and data analysis techniques with the aim of creating cross-use software that is increasingly adaptable to different contexts

Value Proposition

- Enersem leverages the possibilities offered by Industrial IoT – IIoT and artificial intelligence to enable energy reduction costs by analyzing and monitoring buildings.
- Enersem is committed to helping companies reduce the environmental impact of air conditioning by detecting and optimizing Heating Ventilation and Air Conditioning - HVAC system inefficiencies.
- The company aims at improving building occupants' health and comfort both in commercial and residential environments.

Source: Frost & Sullivan, ENERSEM

QEA Tech

COMPANY OVERVIEW

Industry Segment:
Energy Management

Brief Description:
QEA Tech is developing a Drone-based solution to monitor buildings.

Maturity:
Under development

Multimedia:
https://youtu.be/W2gybF1OyyQ

COMPANY STRUCTURE

FOUNDED: **2018**

COUNTRY: **CANADA**

OF EMPLOYEES: **15-20**

TOTAL FUNDING: **$1.7M**

REVENUES: **N.A.**

PRODUCT OVERVIEW

Technology Focus

- QEA Tech is developing an AI-based drone platform that uses thermography, computer vision and infrared cameras to detect and quantify energy losses analysing buildings' facades. QEA Tech uses its AI patented software to collect and elaborate reliable data about energy losses to improve building's energy consumption.
- The software under development by QEA Tech provides a 3D model of buildings: thermal and visual images come from a drone inspection. The software aims at creating a cloud-based dashboard with building data collection, accessible 24/7.

Main competitive advantage:

QEA Tech is developing proprietary technology to monitor buildings and to maximize their life expectancy. The company uses drones with infrared cameras and AI-powered software to analyze buildings' facades. The drone-based solution allows monitoring from the outside without disturbing the occupants inside. The solution developed by QEA Tech allows to save up to 51% of the energy consumption.

Value Proposition

- The company is committed to improve indoor air quality and solving airflow issues by monitoring the buildings' facades and optimizing the Heating Ventilation and Air Conditioning - HVAC systems.
- The inspection aims at improving energy consumption and reducing energy loss by detecting problems and inefficiencies in the building's external layers.

Source: Frost & Sullivan, QEA Tech

VOCSens

COMPANY OVERVIEW

Industry Segment:
Energy Management

Brief Description:
VOCSens has developed cheap and small gas sensor.

Maturity:
Commercialization since 2021

Multimedia:
https://www.youtube.com/watch?v=3LvJJeDVa3w

COMPANY STRUCTURE

FOUNDED: **2018**

COUNTRY: **BELGIUM**

OF EMPLOYEES: **10-20**

TOTAL FUNDING: **$2.91M**

REVENUES: **N.A.**

PRODUCT OVERVIEW

Technology Focus

- VOCSens has developed EnviCam, a multi-sensor module that measures the presence of various gases and Volatile Organic Compounds - VOC, fine particles, humidity and temperature.
- The microsensors developed by VOCSens are designed to connect to existing IoT and Industry 4.0 networks and can work to monitor Heating Ventilation and Air Conditioning - HVAC systems in buildings.
- The acquired data are transmitted via a wireless Bluetooth connection to a platform that stores and processes data.

Main competitive advantage:

VOCSens has developed EnviCam, a gas microsensor that integrates polymeric and nanocomposite materials to detect various gases in the air with great accuracy. The patented solution developed by VOCSens is modular, compact, affordable and has low energy consumption.

Value Proposition

- The solution developed by VOCSens aims at monitoring a different range of industrial and commercial domains. Microsensors developed by VOCSens allow environmental parameters to be actively monitored to improve health and safety of occupants in buildings.
- The main applications of the EnviCam concern environmental monitoring and control of industrial emissions. The VOCSens solution can be implemented in Heating Ventilation and Air Conditioning - HVAC systems in buildings to reduce CO2 emissions by shortening wastage of energy.

Source: Frost & Sullivan, VOCSens

BRAINBOX AI

COMPANY OVERVIEW

Industry Segment:
Energy Management

Brief Description:
BrainBox AI leverages on artificial intelligence to make buildings smarter and more efficient.

Maturity:
Commercialization currently

Multimedia:

https://www.youtube.com/watch?v=vIHSaKflQEY

COMPANY STRUCTURE

FOUNDED: **2019**

COUNTRY: **CANADA**

OF EMPLOYEES: **150-200**

TOTAL FUNDING: **$32.59M**

REVENUES: **N.A.**

PRODUCT OVERVIEW

Technology Focus

- BrainBox AI has developed a technology that combines deep learning algorithms and cloud computing. The solution can be implemented to manage and optimize existing Heating Ventilation and Air Conditioning - HVAC systems.
- Artificial intelligence developed by Brainbox AI constantly collects data and learns the behaviour of each area of the building.
- The solution merges together internal and external information to feed the AI engine to forecast the future state of each zone in a building with an accuracy of up to 99.6%.

Main competitive advantage:

BrainBox AI has developed an AI-based technology for the existing Heating Ventilation and Air Conditioning - HVAC systems. BrainBox AI's technology enables a building's HVAC system to run autonomously by using Artificial Intelligence to predict a building's heat load. The AI becomes smarter over time to save energy consumption and increase efficiency. The solution aims at extending the life of HVAC systems by up to 50%.

Value Proposition

- The company solution aims at reducing the energy consumption of existing Heating Ventilation and Air Conditioning - HVAC systems and improve occupant comfort.
- The company is committed to reducing CO2 emissions from ventilation and air conditioning systems in buildings.
- The company allows property managers saving energy cost of up to 25%, with up to 40% reduction in carbon footprint.

Source: Frost & Sullivan, BRAINBOX AI

HYDRONIC Shell

COMPANY OVERVIEW

Industry Segment:
Energy Management

Brief Description:
Hydronic Shell is developing a panel that integrates HVAC systems into an insulated outer shell.

Maturity:
Under development

Multimedia:
https://youtu.be/oPU2CMT_R7Y

COMPANY STRUCTURE

FOUNDED: **2020**

COUNTRY: **USA**

OF EMPLOYEES: **2-10**

TOTAL FUNDING: **N.A.**

REVENUES: **N.A.**

PRODUCT OVERVIEW

Technology Focus

- Hydronic Shell is developing a high-performance integrated facade panel inside a super-insulated shell. The panel includes all the components required for complete and modular Heating Ventilation and Air Conditioning - HVAC systems in each room.
- The patented panel can be installed in place of windows in existing buildings. The panel provides ventilation, heat and air conditioning thanks to electric heat pumps installed on the rooftop of the structure.
- The prefabricated panel allows the integration of other external components such as photovoltaic and exterior lighting.

Main competitive advantage:

Hydronic Shell has developed a patented panel that includes Heating Ventilation and Air Conditioning - HVAC systems in an all-in-one panel solution, fully integrated within a super-insulated shell, which allows it to be installed in existing and new buildings. The panel reduces heating loads due to an envelope improvement

Value Proposition

- The low-temperature heating system enables efficient operation that reduces consumption costs and gas emissions. Simplified maintenance of the Heating Ventilation and Air Conditioning - HVAC system and facades provide cost savings.
- The company is committed to transform and modernize buildings while contributing to the decarbonization of the planet by reducing wastages and emissions.
- Hydronic Shell aims at improving the building's occupant health and conditions. The continuous ventilation with fully conditioned outside air and silent operation provide a marked improvement in indoor air quality while heating and cooling provide superior thermal comfort.

Source: Frost & Sullivan, HYDRONIC Shell

ENERDRAPE

COMPANY OVERVIEW

Industry Segment:
Energy Management

Brief Description:
Enerdrape is developing a geothermal panel to generate energy from underground spaces.

Maturity:
Under development

Multimedia:
https://www.youtube.com/watch?v=M6gmHuxe3hU

COMPANY STRUCTURE

FOUNDED: **2019**

COUNTRY: **SWITZERLAND**

OF EMPLOYEES: **5-10**

TOTAL FUNDING: **$260K**

REVENUES: **N.A.**

PRODUCT OVERVIEW

Technology Focus

- Enerdrape is developing special geothermal panels capable of capturing heat from underground spaces (such as underground car parks or metro tunnels) and reusing it in the air conditioning of buildings. The solution can be integrated with existing Heating Ventilation and Air Conditioning - HVAC systems.
- The system absorbs heat energy from the surrounding ground and directs it to a heat pump. The heat pump transmits it to the thermal systems of the buildings above or alternatively can be connected to urban district heating networks.
- The system in the testing phase consists of ten blue and white panels measuring 1.3 meters high by 0.7 meters wide for minimal thickness.

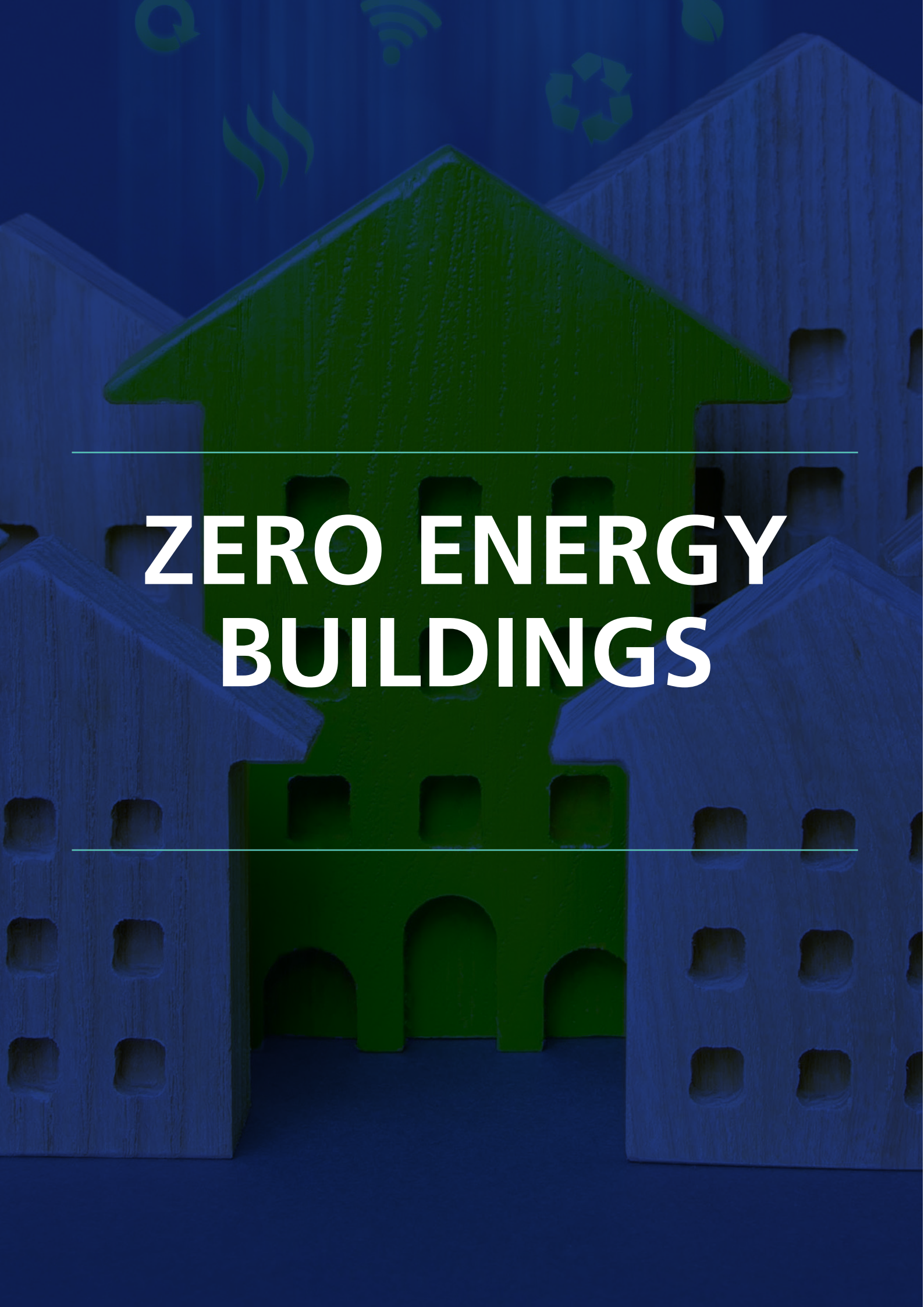
Main competitive advantage:

Enerdrape is developing a technology that transforms underground infrastructure into renewable heat sources for the heating and cooling needs of buildings. The panels are modular, prefabricated, and easy to install. They are designed for underground spaces, such as underground car parks or metro tunnels.

Value Proposition

- Enerdrape is working on a solution to reduce CO2 emissions from buildings to have a significant impact on global emissions. The company aims at using waste heat to provide the building's Heating Ventilation and Air Conditioning - HVAC systems with a clean and cheap energy source.
- The system developed by Enerdrape involves the use of existing underground structures to create a system for the reuse of dispersed energy.

Source: Frost & Sullivan, ENERDRAPE



ZERO ENERGY BUILDINGS

A ZEB[3] is self-sufficient building the total energy consumption of which can be met on an annual basis by reducing energy consumption and increasing green power.

In a conventional construction, energy is purchased and supplied directly from the grid.

With ZEBs, new elements such as energy feed-ins are introduced to the building ecosystem. A ZEB is different to a "green building" in the following ways:

- **ZEBs** are concerned by the operational output/energy performance of a building with the aim of reducing their impact by 100%
- **Green buildings** evaluate the overall lifecycle of a building, including its ecological impact, but are ultimately concerned only with consuming less energy than current conventional constructions (rather than aiming for a 100% reduction)

In the long run, ZEBs bring benefits in terms of operational costs and carbon footprint.

Currently, less than 1% of all buildings globally are considered to be ZEBs.

The growing interest in ZEBs stems partly from the industry's commitments and also the need to comply with increasingly stringent codes and legislation

A range of national, regional, and international bodies have set ambitious targets.

The World Green Building Council, in its global project "Advancing Net Zero", laid out two goals: by 2030, all new buildings must operate at net carbon zero and by 2050 all buildings – including existing ones – must do the same.

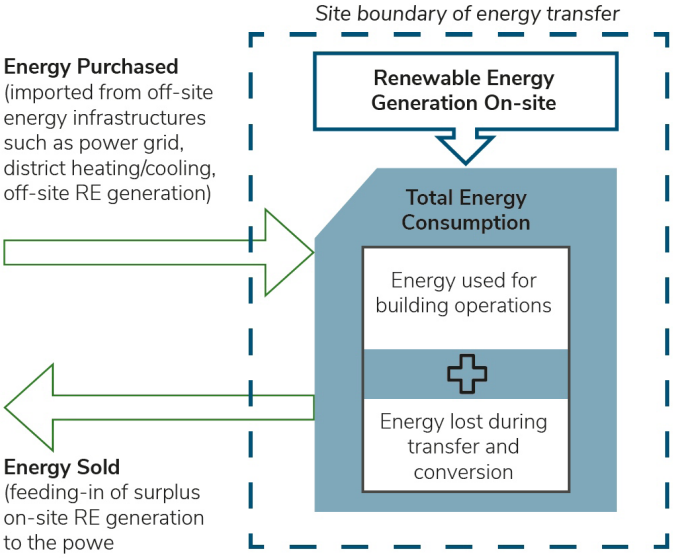
Similarly, as part of Architecture 2030's "2030 Challenge", all new constructions and major renovation projects must be designed to meet 70% of the regional average for similar buildings in terms of Greenhouse Gas (GHG) emissions and energy consumption.

By 2010, the programme was aiming for an overall reduction of fossil fuels by 60% which extends on a sliding scale to 100% in 2030.

The New Building Institute (NBI) has also joined with the International Living Future Institute (ILFI) to streamline and strengthen the system for ZEB tracking, registration, certification, and evaluation in order to boost broader market adoption, codification and standardisation of ZEB technologies. Under the partnership, the ILFI continues to act as administrator of Zero Energy Building Certification while the NBI has become the lead certification auditor and, as a result, the number of projects registered in the ZEB category has seen an uptick.

Country policies related to ZEBs have existed since 2007. Currently, the global target is to achieve ZEB status for all new buildings by 2030 and all buildings by 2050.

ZERO ENERGY BUILDINGS, ENERGY FLOWS, GLOBAL, 2021



[3]According to the US Department of Energy (DOE), a Net-Zero Energy Building (NZEB) is "an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy."

In Europe, the EU Energy Performance of Buildings Directive (EPBD) defines a nearly Zero Energy Building (nZEB) as "a building that has a very high energy performance with nearly zero or very low amounts of energy required [which is] covered to a very significant extent by energy from renewable sources produced onsite or nearby.'

According to the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (SHASE), a Zero Energy Building (ZEB) is "a building that has high energy saving through load reduction, natural energy use and efficient appliances without decreasing the environmental quality both indoors and outdoors. With the introduction of onsite renewable energies, the on-site energy generated [is expected to] be equal to or greater than the actual energy consumed within the building in the course of a year."

Source: Frost & Sullivan

Despite inconsistencies, the existing regulatory framework clearly steer the industry in the direction of energy-efficient, cost-effective, and fully decarbonised buildings.

By 2019, 69 countries had developed national building energy codes. This is an increase of 54 compared with 2010. However, two thirds of countries worldwide still do not have a mandatory system in place, including many in APAC, Africa, or Latin America.

Globally, the ZEB market was valued at $86.1m in 2019 and is developing at 7.4%

Driven by the successful demonstration of ZEBs in small-scale residential projects, market participants are becoming increasingly confident in rapidly scaling-up enabling technologies to larger floor areas of more than 50,000 square feet.

The upsurge will be driven by the ever-growing global building stock with more than 180 billion square meters by 2025 as well as the pressing demands from governments and global leaders to meet targets.

Public awareness and acceptance of ZEBs have also improved in recent years with a survey by Johnson Controls finding that 70 percent of US organisations are either very or extremely likely to have one or more facilities that are nearly zero, net zero or have a positive energy or carbon neutral status in the next ten years – an increase of seven percent from 2019.

Significant tier I suppliers to the space include Kingspan (Ireland) and SunPower (US).

Currently, the ZEB market is dominated by large, technology-specific players mostly based in the US, Europe, and Japan although the space is gradually attracting new Asian entrants which offer sustainability-focused solutions.

Global companies with a share of between 10% and 15% include Daikin, Johnson Controls, KB Home, Kingspan, Sekisui House, Signify and SunPower.

From a product perspective, the energy efficient building envelope materials segment is the largest contributor to total ZEB revenues with a 53% share followed by solar PV at 33% and high-performance HVAC systems at 10%.

In the coming years, solar PV is expected to remain a key technology, but energy efficient lighting and HVAC systems are expected to gain ground with the product categories showing annual growth rates of 13%, 13% and 12% respectively up to 2024.

A number of factors combine to explain this growing demand:

- For solar PV, already high levels of overall market penetration will be supported by continued low cost manufacturing
- For energy efficient lighting, the phasing out of incandescent lamps in many countries will coincide with the falling price of LED replacements
- For HVAC systems, efficiency improvements of between 300% and 600% will bring strong energy saving performance

At a national and international level, up-to-date data on the number of existing and certified ZEBs is lacking. In North America, the New Building Institute has set a good example but the exact situation in other regions is unclear.

The main obstacles to better documentation are the diverse definitions of ZEBs, a lack of relevant building codes and the asymmetric pace of development across countries.

With the increasing number of successful projects and global commitments as part of the Paris Agreement to reduce impact of construction, a streamlined tracking and monitoring process is required for planning purposes.

The establishment of platforms that enable the sharing of government policies and building best-practice will help to create a common and effective approach to ZEBs globally.

Influential international organisations such as World Green Building Council (WGBC) are in a position to play a key role in encouraging collaboration, facilitating data collection and enabling reporting on ZEBs across regions.

RIBES TECH

COMPANY OVERVIEW

Industry Segment:
Smart building - Sustainability

Brief Description:
Ribes Tech is a renewables and environment company that specializes in manufacturing flexible plastic foils that convert light into electricity

Maturity:
Commercialization since 2017

Multimedia:

www.youtube.com/watch?v=kiULxwQVwd0

COMPANY STRUCTURE

FOUNDED: **2016**

COUNTRY: **ITALY**

OF EMPLOYEES: **2**

TOTAL FUNDING: **N.A.**

REVENUES: **€29K in 2019**

PRODUCT OVERVIEW

Technology Focus

- Ribes Tech's photovoltaic modules are light-weight (a few hundred grams per square meter), flexible and can be bent multiple times, allowing the adaption to any curved surface.
- Ribes Tech's production process uses printing techniques to deposit the conductive and semiconductor materials that make up the photovoltaic cell. Semiconductor materials can be dissolved in suitable solvents, creating special inks compatible with traditional rotary printing methods used for newspapers or bottle labels.
- By printing organic semiconductor materials on PET, Ribes Tech do not use toxic substances or rare materials like other photovoltaic technologies, thus its modules are compatible with the disposal and recycling methods used for general plastics.

Main competitive advantage:

Ribes Tech's photovoltaic modules results more efficient than silicon panels in capturing energy from artificial light, making them suitable for powering electronic sensors in home automation field or the Internet of Things.

Value Proposition

- Ribes Tech's unique process of production allow to scale-up the production of custom harvesting solution in a short time, delivering quickly prototypes to test in real conditions.
- Ribes Tech's solution transforms any surface in a photovoltaic panel and allows any device to be powered directly by light.
- Ribes Tech's solution reduces the needs of batteries for sensors and devices with a considerable economic saving, as well as a significant environmental advantage, since the batteries contain toxic materials.

Source: Frost & Sullivan, RIBES TECH

INDRESMAT

COMPANY OVERVIEW

Industry Segment:
Smart building - Sustainability

Brief Description:
INDRESMAT is a chemical company that specializes in thermal insulation for the construction market with know-how in biologic Polyurethane formulation

Maturity:
Commercialization since 2017

Multimedia:
www.youtube.com/watch?v=kiULxwQVwd0

COMPANY STRUCTURE

FOUNDED: **2017**

COUNTRY: **SPAIN**

OF EMPLOYEES: **1-10**

TOTAL FUNDING: **€ 979K**

REVENUES: **N.A.**

PRODUCT OVERVIEW

Technology Focus

- INDRESMAT produces an innovative framing material entirely made from Polyurethane foam, that can be obtained from renewable raw materials. It is a fully recyclable material, thus creating circular economy solutions.
- INDRESMAT's insulation foam for roofs, walls and doors significantly reduces the flammability of these elements and the toxic smoke emission as well.
- INDRESMAT frames manufacturing process has a specific energy consumption of 0.13kWh/kg, 10 times lower than PVC and 50 times lower than aluminium.

Main competitive advantage:

INDRESMAT unique know-how in biological Polyurethane Chemistry allowed to create an envelopment material for the next generation of Nearly Zero Energy Buildings, providing higher energy-saving (up to 75%) that reduce by 20% the direct CO2 emission associated with the building's overall energy consumption.

Value Proposition

- INDRESMAT innovative framing material allows window frames to increase thermal, acoustic and moisture barrier properties.
- INDRESMAT solutions are easily repairable, require low maintenance and have an extended lifespan of 35-45 years, 15 to 20 years longer than wood and 10 to 15 years longer than PVC and aluminum.
- By employing bio-Polyurethane as a single structural & functional material, INDRESMAT facilitates the windows recycling at the end-of-life as any separation step among elements is needed.

Source: Frost & Sullivan, INDRESMAT

SKYCOOL SYSTEMS

COMPANY OVERVIEW

Industry Segment:
Smart building - Sustainability

Brief Description:
SkyCool Systems develops a rooftop, radiative sky cooling panel that improves the efficiency of air conditioning and refrigeration systems, thanks to a passive method for cooling that is enabled by a patented multilayer optical coating.

Maturity:
Commercialization in 2021

Multimedia:

www.youtube.com/watch?v=CMaZfulnd9c

COMPANY STRUCTURE

FOUNDED: **2017**

COUNTRY: **USA**

OF EMPLOYEES: **1-10**

TOTAL FUNDING: **$4.3M**

REVENUES: **N.A.**

PRODUCT OVERVIEW

Technology Focus

- SkyCool's core innovation is a radiative cooling material combined with a panel system to improve the efficiency of any vapor-compression based cooling system.
- SkyCool panels temperature can drop by up to 15°F below the ambient temperature with zero electricity input.
- SkyCool's patented technology involves the application of a dual-mode film to the top surface of each of its panel in order to reflects sunlight and to avoid the heating up during the day. Furthermore, it avoids the emission of infrared heat to the cold sky, thus keeping cool the fluid flowing into the panels and in air conditioning and refrigeration systems.

Main competitive advantage:

SkyCool's panels achieve energy savings between 15% and 40% for the cooling of a venue as a function of the application and number of panels deployed.

Value Proposition

- SkyCool's panels are designed to connect into new and legacy cooling systems with minimal risk to the underlying system operation.
- As temperatures get hotter, cooling systems lose capacity. SkyCool's panels provide additional cooling capacity to existing refrigeration and air conditioning systems through a simple retrofit, avoiding the reach of costly energy consumption picks.
- SkyCool's Panels save two to three times as much energy as a solar panel generates given the same area of covering.

Source: Frost & Sullivan, SKYCOOL SYSTEMS

ANDLUCA TECHNOLOGIES

COMPANY OVERVIEW

Industry Segment:
Smart building - Sustainability

Brief Description:
Andluca Technologies is a Princeton University spin-out that develops easy-to-install wireless smart glasses powered by UV solar energy to improve the energy efficiency of buildings.

Maturity:
Commercialization in 2021

Multimedia:

https://vimeo.com/453084165

COMPANY STRUCTURE

FOUNDED: **2017**

COUNTRY: **USA**

OF EMPLOYEES: **2-10**

TOTAL FUNDING: **$100K**

REVENUES: **N.A.**

PRODUCT OVERVIEW

Technology Focus

- Andluca Technologies offers ultrathin flexible power source, i.e. wireless smart glasses that can be installed everywhere.
- Andluca Technologies' active layer of luminescent solar concentrators comprise UV-absorbing semiconductors embedded in a polymer host that collects light.
- Andluca Technologies' active layers of organic photovoltaic cells convert photons to charge carriers within, with charge collection occurring in-plane to produce approximately 10 - 15 W per square meter under direct sunlight.

Main competitive advantage:

Andluca Technologies's patented technologies can reduce building energy use by up to 40%, converting ultraviolet light into useful energy at the point of use and enhancing occupant comfort and productivity.

Value Proposition

- Andluca Technologies leverage the competences developed during over 12 years of research on light-responsive materials and films by the Organic and Polymer Electronics Laboratory at Princeton University.
- Unlike available wired smart glass products, which require major renovation and installation by an electrician, Andluca's wireless smart glass can be installed quickly and without disruption.
- These flexible power sources can conform to any shape and disappear into their environment to enable discreet, wireless operation of smart glass.

Source: Frost & Sullivan, ANDLUCA TECHNOLOGIES

BUILDINGS AUTOMATION

Building Automation Systems (BAS) centralise the remote monitoring and control of a building's mechanical and electrical functions.

These systems include lighting, power and Heating Ventilation and Air-conditioning (HVAC) as well as water supply and drainage.

BASs are a part of a wider group of other Building Management Systems (BMSs) which typically also include so-called Building Energy Management Systems (BEMSs) and Emergency Security and Automation Systems (ESASs).

As previously said **BEMSs** control and optimise energy usage and the indoor environment of a building by maintaining a complete log of the energy consumption of different equipment in various parts of the construction.

ESASs are responsible for alerting the occupants of a building in case of an emergency and for guiding them to the nearest and safest exits. ESAS security systems include anti-theft, alarm and access control systems and CCTV surveillance.

On the supply side, uptake is being driven by the promise of cost savings as well as abundant brown and greenfield opportunities.

The average saving generated from the installation of a BAS is around 37% for heating, water heating and cooling and ventilation and about 25% for lighting.

The roll-out of smart meters will complement BAS and allow buildings to become capable of interacting with the energy market while the overall move from smart to cognitive buildings is a key plank in building a sustainable energy future.

As countries increasingly move towards Distributed Energy Resources (DERs), BASs will help achieve higher efficiencies than would have been gained by using conventional systems. BAS solutions significantly reduce energy consumption and operating costs. Scheduling and performing tasks is, for example, one of the notable features of BASs which in turn enable accurate assessment and measurement of efficiencies.

More generally, the growing demand for electricity and, therefore, the need to solutions to manage its use will drive the BAS systems market. This trend is only likely to be reinforced as regional initiatives, conferences and summits spread awareness and mandate change. The State of Massachusetts, for example, has set targets for low energy buildings and all new constructions will need to be compliant by 2030.

Brown and greenfield opportunities.

The need to reduce energy consumption and optimise the efficiency of all building systems encourages the retrofitting of BAS systems into existing constructions.

Although new building projects typically attract the most attention, the current stock will represent the largest customer group for BASs in absolute numbers over the coming years. The impact of this is will, however, remain limited as retrofitting initiatives are typically slowly implemented and time is needed to see the benefit.

In parallel, new buildings are increasingly being fitted with sophisticated BAS systems. Smart buildings are engineered to generate large energy and cost savings in themselves and are also seen as an enabler of smart cities which leverage a multitude of technologies. In the commercial segment, the development of smart cities is one of the prime drivers behind the further adoption of building automation technologies.

The most established communication protocols for BASs remain wired solutions but wireless systems are also facilitating growth.

Increased digitisation is gaving the way for new communication solutions.

The expansion of the Internet of Things (IoT) and its emerging application in BASs demands real-time communication and opens the door to new standards which improve interoperability amongst the devices.

In addition, the advent of the IoT has caused traditional wired and conventional wireless communication protocols to move to Internet Protocol (IP) and therefore Internet-enabled connections including BACnet/IP, BACnet/IPv6, LON/IP and KNX IP.

Emerging communication standards in the BASs space include the following:

• **AMQP** is best used in server-based analytical functions. It is an open-source protocol which is regarded as reliable, secure and interoperable

• **MQTT** is a simple and lightweight IoT protocol designed for constrained devices and low network bandwidth. It can be deployed for systems which are focused on automated metering and energy control or sensor-based smart parking

• **LPWANs** are suited to industrial applications which require devices to send small amounts of data over great distances for many years on a single battery

• **WebSockets** can be applied in an IoT network where chunks of data are transmitted continuously within multiple devices

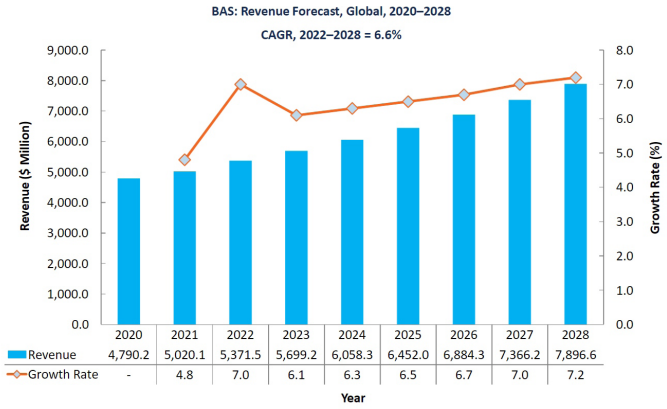
• **CoAP** was specially created for connecting devices with constrained resources such as small memory or short battery life

• **XMPP** can help to connect home thermostats to a web server which can then be accessed from a smartphone. It is used in consumer-oriented applications

The global BAS market is on an upswing and is expected to have a compound annual growth rate (CAGR) of 6.6% from 2022 until 2028[4]

The global BAS market is at the growth stage, generating revenues of $5,371.5 million in 2022. Building Automation Systems are creating a sustainable environment for both existing and new buildings.

The European Union's (EU) Cohesion Policy for 2021 to 2027 will further support local development strategies



focused on sustainable urban constructions as well as capacity building programmes for municipalities. The European Urban Initiative will also enable Member States, local governments, and cities to make investments in the construction of energy efficiency buildings, renewable energy, smart distribution networks and sustainable urban transport all of which will support BAS procurement.

On the supply side, cutting-edge technologies involving big data and cloud platforms have made it simpler to gather and normalise data from buildings which helps in analysing parameters such as energy usage along with facilitating, for example, fault detection. This convergence of building technologies with IoT is driving the market for BASs dynamically forwards overall while differences and variations in regional and country-specific construction activity continue to have a strong impact at a macro level.

Honeywell, Siemens, Schneider, and Johnson Controls hold a 59% share globally.

Tier I is made up of the four leading participants in the BAS market all of which have a global presence and a long history in the space. **Honeywell, Siemens, Schneider**, and **Johnson Controls** also invest in continuous product innovations which help them sustain and consistently maintain their positions across world markets.

Tier II participants include suppliers with regional or local presence, or which are specialised in specific building types. Some of these increasingly boast an international footprint and are expanding globally to challenge the Tier

[4] Frost & Sullivan

Source: Frost & Sullivan

I participants for market share.

Smaller participants are likely to increase in number and disrupt the market as they are able to cater to local requirements and manage price sensitivity. Their expertise lies in niche areas such as data analytics and other ICT segments which, given the convergence between IT and BASs, are likely to grow in the longer term.

Competitive pricing and proven experience are key success factors, providing the four leaders with a platform to defend their position.

With a wide range of products and associated services launched by participants, cost is an important factor which influences demand. Vendors are, therefore, constantly focused on offering attractively priced solutions.

In regions such as Asia where buildings are typically made of concrete, there is a greater need for controllers, sensors and nodes which drives up overall BAS costs, with end-user expecting a Return on Investment (RoI) but perceiving little difference in most products' performance and technology abilities.

When systems extend beyond their lifetime, there is a need to combine legacy solutions with new ones. Participants will, therefore, need to develop and adopt open protocol-based building automation platforms which are technology- and vendor-agnostic so that customers are able to upgrade existing systems.

Given the need for retrofits and upgrades, together with the requirement to minimise system downtime, service capabilities also form a significant competitive factor. The latest generation of smart and cognitive BAS systems is more expensive that conventional solutions, but the as-a-service model can help overcome customers' financial limitations whilst providing high levels of performance.

Proven expertise in existing building automation projects is another key differentiator. This is especially true in Asia, the Middle East and Latin America where a higher proportion of sales are made via indirect channels with consultants and other intermediaries favouring tried and tested technologies with strong brand names.

In the future, new IoT-enabled solutions are expected to both boost vendors' technology abilities and revolutionise their business models.

Market growth is driven by the uptake of BAS contracts, but new business cases lie in IoT-enabled solutions which offer additional functionalities. The IoT will play a key role in the sector's development with hardware and supervisory software becoming part of wider building projects and devices all communicating through a single IP platform.

IoT-enabled solutions will progressively establish themselves in new construction projects whereas retrofitting IoT solutions in legacy systems is expected to remain low due to a lack of demonstrable cost-effectiveness. IoT-enabled devices are expected to pave way for new opportunities such as voice-over technology in the building automation market.

Companies enabling auto-configurations, a higher range of connected devices, service mechanisms and advanced levels of security will stand to gain a competitive advantage as features such as reliability, security and network availability will grow in demand.

Traditional BAS participants will need to incorporate IoT solutions while bringing down prices as customers are expecting to recover some of their initial investments. Wireless control is essential as it will impact the uptake of IoT in the retrofitting business segment.

Platform-as-a-Service (PaaS) systems will, for example, allow suppliers to engage with their customers over the long term.

With IoT becoming commonplace and everything in a building's network being connected and communicating, data analytics is becoming a core offering in energy management markets. The primary focus is on reducing

energy bills and improving operational efficiency in buildings amidst a variety of demands stemming from the grid.

New opportunities exist in customer engagement, centralised data repository, energy benchmarking and demand response applications. Commercial buildings need to be treated like critical environments with near real-time control of a building's infrastructure. With the transition to smart buildings, traditional stove-piped subsystems need to work together.

Commercial customers will have to partner with established utilities to proactively seek and tap into new revenue streams. The networking of buildings, building systems data and portfolio-wide energy management will be the key developments.

Energy management software providers need to incorporate Machine Learning (ML) algorithms to address the dynamic requirements of energy management. Systems will be required to interface with people's schedules and building's assets. The installation of software and apps will make buildings more intelligent but the move towards more human-centric buildings, an increase in buildings' flexibility and the whole concept of smart buildings, which leverage data and information, will be key BASs market developments.

Overall, however, equity investment in Smart Buildings is relatively low, the trend is positive since 2019[5] , With USA and China top investors.

Building owners and managers are also now more concerned about sustainability and the circular economy because of the environmental targets that they need to meet.

In the West, customers are more inclined toward smart building solutions that offer not only cost efficiencies but additional value in terms of reducing emissions, saving energy and increasing occupants' comfort and productivity.

AI is increasingly the enabler which allows building solution providers to meet these multiple needs which suggests that technology is well set for further future penetration.

More broadly, the roll-out of the IoT, data analytics and the cloud has in buildings has accelerated dramatically over recent years. New and existing constructions are therefore turning into data-rich environments with owners and managers increasingly looking for solutions which can leverage the information to provide actionable intelligence and enable building performance optimisation. AI-driven solutions tap into this greater connectivity and empower buildings with autonomous intelligence. The growing penetration of other transformative technologies in buildings is therefore also expected to support and indeed increase the demand for AI-specific solutions.

Improved sustainability and delivering greater value to users in the form of comfort and wellness are the three main values which are sought from AI.

The unprecedented and unforeseen outbreak of COVID-19 has led building owners and managers to rethink their investment strategies with AI-driven value addition being sought more than ever before.

AI solution providers can leverage this opportunity and need to primarily focus on customers that are committed to sustainability and understand the benefits of leveraging AI for the benefit of both the immediate occupants and the wider environment.

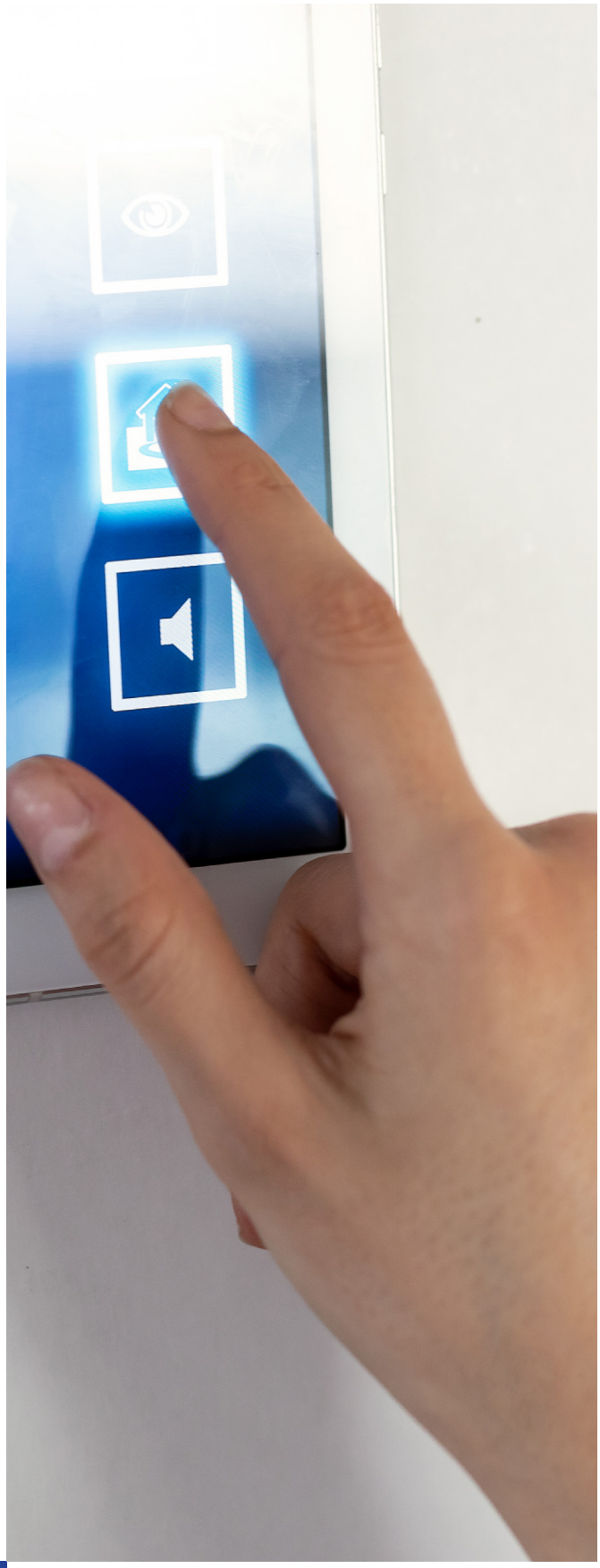
Currently, the main sources of the data exploited by AI in buildings include:

- **HVAC equipment** with metrics including temperature, humidity, fan speed …
- **Lighting systems** e.g. occupancy, energy consumption, motion, lumen levels …
- **Fire safety and security platforms** e.g. video footage, fire spread …

In Europe, many countries have adopted a proactive approach to upskilling talent with a view to developing sophisticated AI-base solutions. Local smart building and

[5] Internal elaboration on CBInsights data

Source: Frost & Sullivan



smart home system vendors strongly advocate retraining existing employees and hiring new talent.

Overall, Western Europe dominates in terms of business opportunity whilst Eastern Europe stands out with respect to technology provision. Russia, in particular, has strengths in AI-based security engineering and data science generally.

The uptake of AI in homes and buildings is also supported by a well-established legislative framework which is compelling owners, managers and occupiers to look for innovative solutions to, in particular, "decarbonise" building stocks.

These include the Energy Performance of Buildings Directive (EPBD) (2010/31/EU) and the Energy Efficiency Directive (EED) (2012/27/EU). The amended EPBD (2018/844/EU), including a much stronger emphasis on deploying effective renovation strategies.

Participants include automation and tech giants like Siemens and Amazon.

Siemens' "Smart Infrastructure" aims to drive forward digital transformation in the buildings industry by creating open-standards-based products and services and by connecting its existing installed base of systems and solutions to the new digital offerings of its "Comfy and Enlighted" programme.

The company's global team of data scientists is involved in the development of a next-generation AI platform for data-driven building applications. Siemens' MindSphere platform, for example, collects data from factory equipment and provides digital solutions such as remote diagnostic services, performance optimisation, remote maintenance, and digital whiteboards. The company is expected to leverage its experience in the industrial domain to build out its AI offering for new and existing buildings.

Amazon, in contrast, has a B2C approach and shipped about 82m[6] units of its Echo devices in 2022, holding top spots in all the quarters. The company faces strong competition from its Chinese counterparts, Alibaba,

[6] Statista

Baidu, and Xiaomi but stays ahead of its competitors by launching new devices.

Demand for **predictive maintenance** capabilities is high as building owners and managers look to reduce the downtime of building systems and increase their lifetime.

Performance optimisation is a more recent evolution with BEMS offerings now including AI. Vendors mostly deliver this for closed-loop control of HVAC and lighting systems.

Process optimisation involves the autonomous release of work orders to field agents when an issue arises while **asset optimisation** is an AI application that involves self-learning.

AI-enabled **power trading** is a subset of autonomous DR. It maximises power trading profits by forecasting price and asset behaviour and operating in multiple markets.

Intelligent **lighting control** is currently offered by very few lighting suppliers. This involves self-learning and continuous optimisation of systems with autonomous commissioning.

Voice assistance is part of the smart speaker solutions offered by tech giants that not only entertain customers but also provide advanced home automation and control.

Demand response is also currently provided by very few providers but has the potential to leverage AI for asset optimization and lower bills by adjusting production schedules.

AI is also shaping the Building and in particular Home Automation (BA/HA) industry.

Air quality systems are a hot spot for growth as consumers look for solutions which can detect and monitor bacteria and pollution.

With countries such as China and India battling pollution, Indoor Air Quality (IAQ) is fast taking center stage. COVID-19 has increased the focus on IAQ which had in any case become a point of discussion before the pandemic.

Current key applications are predictive maintenance and performance optimization

Key applications of AI in homes and buildings, Existing, Global, 2021

Application	AI-enabled outcomes	Market readiness Future Value	Future Value
Predictive Maintenance	• Improved asset life time • Lower costs • Reduced downtime	Medium to High	High
Performance Optimisation	• Increased energy efficiency • Reduced cost • Reduced carbon emissions • Greater comfort for occupants	Medium to High	Medium to High
Process Optimisation	• Improved operational efficiency • Reduced response time during critical issues	Low to Medium	Medium to High
Asset Optimisation	• Improved asset lifetime • Real-time optimisation of assets • Lower cost • Reduced downtime	Medium	High

Indoor allergens and other air quality issues such as mold and mildew are known to cause health-related problems, posing risks to occupants' comfort and well-being while good IAQ has proven to significantly increase their productivity.

IAQ will continue to gain prominence in the smart building market in the coming years. Systems that handle air quality issues will be the way forward with buildings expected to be equipped with a wider range of wireless sensors that monitor carbon dioxide and other harmful pollutant levels, send alerts, and adjust ventilation as needed.

Manufacturers have an opportunity to add further value by deploying smart systems that can indicate when the filters need to be changed and adjust ventilation levels based on the quality of the air outside.

Until recently, air quality systems in buildings have been limited to basic observations, monitoring and control. By including wireless smart solutions, new systems will be created that ensure low energy consumption and a healthy indoor environment.

There is also room for innovation in respect of filtration techniques and filters that monitor external climatic conditions to alter Clean Air Delivery Rates (CADR) and Air Changes per Hour (ACH). Manufacturers could employ predictive analytics via AI/ML algorithms to assess environmental pollution.

Source: Frost & Sullivan

In longer term, AI-based power trading and lighting control will come to the fore

Key applications of AI in homes and buildings, Emerging, Global, 2021

Application	AI-enabled outcomes	Market readiness	Future Value
Power Trading	• Flexibility in power trading • Increased power trading profits	Low to Medium	Medium
Lighting Control	• Increased energy efficiency and cost reduction • Enhanced comfort for occupants • Reduced commissioning time	Medium	Medium
Voice Assistance	• Home entertainment • Improved comfort and convenience for occupants	High	High
Demand Response	• Lower energy bills • Production schedule adjustment • Optimised assets	Medium to High	Medium

Touch free operations are rapidly gaining ground.

Hygiene concerns have created an urgent need for the touch-free operation of buildings in their entirety, from entry to exit.

While some touch-free sensors had already been deployed in commercial and industrial buildings with the aim of raising productivity and easing manpower concerns, COVID-19 is expected to give rise to a wave of opportunities for sensor manufacturers and new to provide new and added impetus for next-gen contact-less technology.

Market participants will need to develop solutions to facilitate the contact-less operation of essential building equipment like access control systems and elevators. This can be achieved by incorporating automatic doors and elevators that can be operated via smart phones, voice controls or face recognition.

The advent of the a "new normal" is expected to boost prospect for this segment and BA/HA solutions more generally as the concept gains acceptance – and makes more sense – as individual pieces of building equipment become automated.

Elevator companies have been front-runners in developing touch-free options.

Home Automation, in the context of the emerging smart home, is a real focus area for innovation.

Frost & Sullivan forecasts that the space will witness a CAGR of 13.5% through to 2027 and reach a value of close to $13b globally.

Concerns remain about interoperability, ownership and cybersecurity remain, but technological advances are promising consumers "frictionless convenience".

Interoperability

A truly frictionless experience can only emerge when connected devices across the home are able to freely communicate with one another and third-party services. The currently disjointed ecosystem reaches across numerous protocols and communications standards. Large manufacturers and technology giants are building integrated ecosystems but participating in them remains cumbersome or impossible for many small device makers and application developers. Similarly, on the demand side, users can feel overwhelmed by the number of options that are available and disinclined to adopt more smart home functions when each device requires management in another app or across a different network.

Ownership

Many smart home devices operate on an as-a-service basis and consumers have been surprised in some instances to find that they cannot operate a device or system without the permission of or input from the subscription service provider.

Recent examples of this scenario include **Peloton** (US) pushing mandatory Tread+ membership, **Sonos** (US) retiring legacy speakers or Pebble smart watches being "made dumb" when new owner **Fitbit** (US) shut down their platform.

Increasingly, users of smart home devices find themselves at the mercy of the specific terms of service agreements as well as large corporates' strategies and business models.

Even in situations where the question of ownership is clearer, the service provider often exercises significant control over customers' ability to use Home Automation devices by managing the software, cloud platforms and repairs on which they rely. For many smart home

Source: Frost & Sullivan

Smart Homes: Growth Metrics, Global, 2021

functions, users depend on the company maintaining an application while the hardware becomes only a vessel for the service. As connected models expands consumers and service providers may increasingly find themselves at loggerheads over policy instead of performance.

Homeowners and occupiers have also voiced frustration with opt-in programs that grant them savings but allow electricity providers to remotely change the temperature of their home's smart thermostats during calls for energy conservation. In Texas in 2021, where extreme weather instigated acute energy crises, instances such as this revealed terms that consumers had agreed to but of which they were largely unaware.

Cybersecurity

Connected devices in the home inherently place residents' personal data or credentials at risk of a breach or a cyber-attack. Domestic networks are vulnerable to hackers eavesdropping, taking control of or implanting ransomware on devices or accessing sensitive personal information. Devices connected via WiFi ZigBee and Z-Wave have been particularly targeted when malicious actors recognize weak security.

Frictionless convenience

Smart home technologies are connecting more and more online devices with one another with the aim of making household tasks and entertainment easier for users to control. Ideally, this increases convenience and allows the owner or occupier to seamlessly manage their environment.

Up to now, IoT into the home has been about connecting devices.

A truly smart home should however bring more than simply connectivity. The latest innovations in the space revolve around optimizing and personalizing experiences. Leveraging big data analytics, AI and embedded security will enable smart home products to unlock the potential held back by siloed and unconnected devices.

Smart home startups are applying technologies to make devices more self-sustaining and optimized for each individual's preferences, usage and efficiency.

Through ubiquitous connectivity and automation, the smart home promises to deliver to users' feedback, recommendations, and efficiencies across a broad spectrum of measurable and manageable aspects of living in and maintaining their homes.

Market leaders will need to differentiate themselves by offering an effortless experience, supporting for example the integration of electric vehicles.

Homeowners, forced inside by the pandemic and made aware of their home's energy and water use by natural disasters, are increasingly interested in more effectively monitoring and optimizing their resource consumption.

As electric vehicles and backup batteries gain more widespread adoption, owners and occupiers will need help implementing the renovations and systems installations required to support such significant new purchases.

Similarly, adding digital services and devices to a home network naturally increases the complexity of both installing and managing the myriad applications and use cases.

Consumers may feel overwhelmed by the options that are available and the number of services to manage while numerous stakeholders want access – for analytics and

insights – to the vast amounts of data generated by more persistent gateways into the home.

As much digital transformation moves to a pay–as–you–go consumption model, service providers are nudging consumers and users towards subscription models. An easy-to-use and seamless experience may be the defining factor for homeowners when choosing among a range of home devices and services.

Incumbents and start-ups should design user-driven Home Automation solutions which take into account customer feedback to iterate and provide an experience that integrates software to minimize pain points and ease the learning curve. Early-stage companies could partner with more mature stakeholders to drive adoption, making their device and service integral to the homeowner's peace of mind and maintenance and operations strategy rather than just a novel or "nice-to-have" add-on. As the complexity of smart home environment grows, it opens up opportunities for service providers to deliver a full and increasingly customized end-to-end installation and configuration value proposition.

They will also have to (responsibly) leverage data to be able to stack value propositions, providing fully customized and bundled end-user platforms.

Smart technologies have the potential to transform how homeowners manage and monitor their properties and relate to service providers.

Increasingly, the collection and use of personal data will give rise to concerns about user privacy. The threat of data breaches necessitates greater investment in embedded security measures to safeguard customers but potentially cuts spending on other areas.

Large home automation stakeholders are planning and creating integrated platforms with massive data collection potential. As set out, greater interoperability between devices and platforms will spur wider adoption and, with a persistent drive for optimization, devices in the home have the potential to expand their remit by leveraging connected health and wellness services to fine-tune personalization measures.

Startups should leverage architectures that allow for scalability and extensibility and create the possibility of partnering with additional devices and services. Allowing for interoperability increases the likelihood that homeowners will pair services and gain more value.

Moving forwards, bundling experiences with, for example, health and wellness or electric vehicle providers, will allow smart home product and service providers to simplify and optimize the management of their systems and supply insights to homeowners.

IoT solutions can combine local data with other relevant sources, such as social media activity, web browsing patterns and advertising, and industry forecasts to create predictive trend models. This will allow service providers to implement strategies in anticipation of emerging needs while new levels of data access will enable them to offer customized products like personalized offers and discounts and dynamic pricing.

Suppliers should design software to allow for continuous integration and Over The Air (OTA) delivery to support users immediately and evolve offerings over time

SOFIA LOCKS

COMPANY OVERVIEW

Industry Segment:
Smart building - Automation

Brief Description:
Sofia Locks provides IoT and cloud-based access control solutions that support security and collaboration.

Maturity:
Commercialisation since 2016

Multimedia:

https://www.youtube.com/watch?v=DWCiGC5HhiM

COMPANY STRUCTURE

FOUNDED: **2015**

COUNTRY: **ITALY**

OF EMPLOYEES: **10**

TOTAL FUNDING: **Accelerator/Incubator**

REVENUES: **€1.6M**

PRODUCT OVERVIEW

Technology Focus

- Sofia Locks offers a PropTech solution, i.e. intelligent and digital access control system based on IoT, cloud and virtualization.
- Sofia Locks platform leverages the usage of smartphones to access doors and gates eliminating and dematerializing physical tokens such as keys and cards, thereby providing enterprises with secure security management solutions.
- Its cloud-native access control system can be instantly and seamlessly integrated on any building or structure without laying cables, or masonry work.
- The cloud-based technology pilots any number of smart locks in real time, managing access with smartphones (mobile credentials), with RFID cards, and with PIN.

Main competitive advantage:

Sofia Locks enables cost savings and new business models through automation. It is fully compatible with legacy systems and provides real-time control with a full wireless solution. Moreover, integration is its strongest feature: it develops all services and products over cloud technology in order to achieve full integrability and scalability.

Value Proposition

- Part of ISEO and thanks to seamless integration with technology partners like Serrature, Cisco and others, Sofia Locks is able to deliver highly functional solutions that enable new business streams and maximize the return on investment.
- The solution is ideal for flexible workspaces, such as co-working and pro-working spaces.
- In the residential market, it becomes an enabling factor for the new models of social housing, co-living and co-housing.

Source: Frost & Sullivan, SOFIA LOCKS

ENVIO

COMPANY OVERVIEW

Industry Segment:
Smart building - Automation

Brief Description:
Envio Systems develops cloud-based technologies for existing commercial buildings.

Maturity:
Commercialisation since 2018

Multimedia:
https://www.youtube.com/watch?v=t0llK4LO5jo

COMPANY STRUCTURE

FOUNDED: **2016**

COUNTRY: **GERMANY**

OF EMPLOYEES: **50**

TOTAL FUNDING: **$6.2M**

REVENUES: **$5M**

PRODUCT OVERVIEW

Technology Focus

- Envio Systems, acquired by JLL, connects and enables an affordable IoT system for any existing commercial building regardless of the facility's size, age, or infrastructure.
- Envio offers a fully integrated Decentralized Direct Digital Control System, with a low-cost, self-learning, Plug & Play, IoT controller integrated with energy and environmental monitoring sensors.
- The system enables seamlessly connectivity with its open cloud platform in order to allow remote management, analytics, real-time alerts, integration with third party devices.
- Moreover, it provides customized operating updates delivered automatically and based on pattern recognition and predictive algorithms.
- Finally, Envio offers a proprietary algorithm that uses historic sensor and energy use data to make smart efficiency decisions in the future.

Main competitive advantage:

Envio solution is end-to-end: it is universally compatible, integrates existing systems, and enhances both monitoring and control capabilities. It is affordable too, costing 25% of competitor products and saves up to 60% of energy waste/consumption, providing a ROI in 12-24 months. Furthermore, wireless communication through concrete (without repeaters) minimizes new equipment and installation/labor cost.

Value Proposition

- Envio addresses all aspects of concern from energy to comfort, security and operations, while keeping costs low and solutions accessible for buildings of all sizes.
- Envio's solution features are scalability, affordability, compatibility, and intelligence.
- The startup partnered with many sensor companies, such as Airthings and Disruptive Technologies, that specialize in monitoring different health and comfort factors within the built environment.

Source: Frost & Sullivan, ENVIO

AMBERSEMI

COMPANY OVERVIEW

Industry Segment:
Smart building - Automation

Brief Description:
AmberSemi develops patented solid-state technologies for the digital control of electricity.

Maturity:
Commercialisation in 2021

Multimedia:
https://www.youtube.com/watch?v=CEub68QhcwQ

COMPANY STRUCTURE

FOUNDED: **2017**

COUNTRY: **USA**

OF EMPLOYEES: **25**

TOTAL FUNDING: **$20.7M**

REVENUES: **$4M**

PRODUCT OVERVIEW

Technology Focus

- AmberSemi has developed a ground-breaking AC/DC enabler and AC switch that allows the digital control of electricity within a solid-state architecture.
- AmberSemi enables IoT features in products like smarter and safer switches, outlets, ground-fault circuit interrupters, circuit breakers and more.
- Amber's core innovation is a programmable solid-state power system that has a clear path to an even-smaller silicon chip version.
- The result is the transformation of electrical products from single-function products to multi-featured dynamic smart nodes within a building electrical grid end-point.
- Amber's size reduction for power management ensure to add sensors, expand connectivity, and more, with virtually no change in universal footprints.

Main competitive advantage:

AmberSemi' patented solid-state electrical architecture replaces antiquated electro-mechanical designs, resulting in faster, safer, smarter and more reliable building electrical end-points, thus providing benefits far beyond their traditional functions.

Value Proposition

- Amber's modernization of electrical end-points enables any building to become substantially "smarter" replacing light switches, outlets, circuit breakers and more.
- With 33 patents grants, Amber is building out a portfolio of product lines on top of its core technologies.
- Amber's technologies are rapidly driving demand for the development of intelligent solid-state based products including two-wire dimmer switches, ultra-efficient commercial LED light fixtures, smart light switches, smart outlets, smart circuit breakers, and so on.

Source: Frost & Sullivan, AMBER SOLUTIONS

DIGITAL CONSTRUCTION

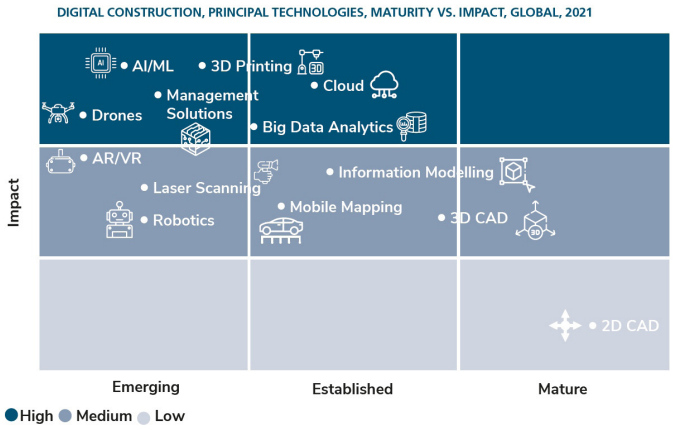
Buildings are not only becoming smarter in the way that they are operated but also in the way in which they are built with digitisation reshaping construction.

From a technology point of view, solutions such as 2D and, increasingly, 3D Computer Assisted Design (CAD) and mobile mapping are already relatively mature.

Big data analytics and the cloud could also be considered to be established.

In the longer term, technologies such as AI/ML, 3d printing, Augmented Reality and Virtual Reality (AR/VR) and laser scanning are expected to play a significant role.

Construction companies are however gradually looking to leverage emerging systems such as Information modelling, Robotics and Management solutions.



INFORMATION MODELLING

Building Information Modelling (BIM) and, increasingly, Digital Twins have succeeded CAD as the industry's solution of choice for creating building models.

BIM software and services are used for creating virtual 3D static models of built environments enabling collaboration and the visualisation of design and construction across value chain stakeholders.

Digital Twin software and services help create **dynamic** and digital replicas of buildings' physical assets, such as HVAC and lighting systems, elevators, escalators, fire safety and security systems, manufacturing industry equipment and water and wastewater industry equipment. These platforms combine real-time spatial, occupancy, asset and environmental data with analytics, converting building data into building intelligence and supporting decision making for overall building performance optimisation and lifecycle management.

The possibilities offered by static and dynamic 3D mapping as well the opportunity for stakeholder interaction has piqued end-users' interest.

Back in 1990, 2D/3D CAD was the norm with solutions enabling 2D drawing and 3D CAD modelling as part of a highly siloed process which created vast volumes of paperwork. The focus was only on the built environment and there was a lack of accurate design transition to third-party software.

From **2010**, BIM began to offer 3D static models but there was still no real stakeholder integration. BIM nonetheless acts as a repository of building and built environment data and can be used in the design and construction phase of buildings. It also supports integration with third-party data.

In **2020**, BIM combined with Digital Twins has become a reality to allow 3D dynamic modelling and a high degree of stakeholder integration. The tools support real-time building lifecycle management (design to maintenance) and the virtual simulation of building assets using real-time inputs. They also enable customers to reach sustainability targets.

From **2025**, Digital Twins will start to connect with smart building platforms, building on the capabilities of today's solutions to also help with real-time building performance optimisation using feedback from the Digital Twins.

In addition to Digital Twins, AR, big data and AI are also changing the game.

The use of **AR** in information modelling ensures a smooth interaction between architectural firms and their clients, helping to minimise potential defects at the planning stage and saving costs. VR also enables real-time BIM

Source: Frost & Sullivan

visualisation.

Big data analytics helps construction managers to keep track of large sets of quantitative information and to generate insights from them that help to complete projects on time. Major construction industry participants such as Skanska and AECOM are turning to big data to add value to conventional BIM by increasing efficiency and reducing errors.

Integrating **AI** with BIM is expected to take the construction industry forward. Advanced prediction capabilities significantly improve decision making with AI facilitating areas such as forecasting project risks, assessing constructability and evaluating structures' sustainability and therefore potentially saving millions of dollars.

Moving forwards, continuous innovations in BIM technology will continue with the next-generation of 4d, 5d and (eventually) **6d and 7d** solutions expected to enable the flawless execution of construction projects. 6D and 7D BIM will digitise the process at every stage and provide real-time visualisation and enable robust facility management.

Adoption has also been aided by the penetration of enabling technologies.

Most of the leading companies offer cloud-based BIM solutions to facilitate and enhance collaboration among the stakeholders across the industry value chain as well as to streamline workflows throughout the project lifecycle and expedite project delivery.

Greater uptake has been driven by digitalisation overall in the private sector with increasing penetration of IoT solutions aiding Digital Twin market growth.

The growing focus on sustainable building techniques is also an important factor whilst government support for BIM implementation in public sector projects has helped, in particular, in the context of rapid and continued urbanisation in developing countries.

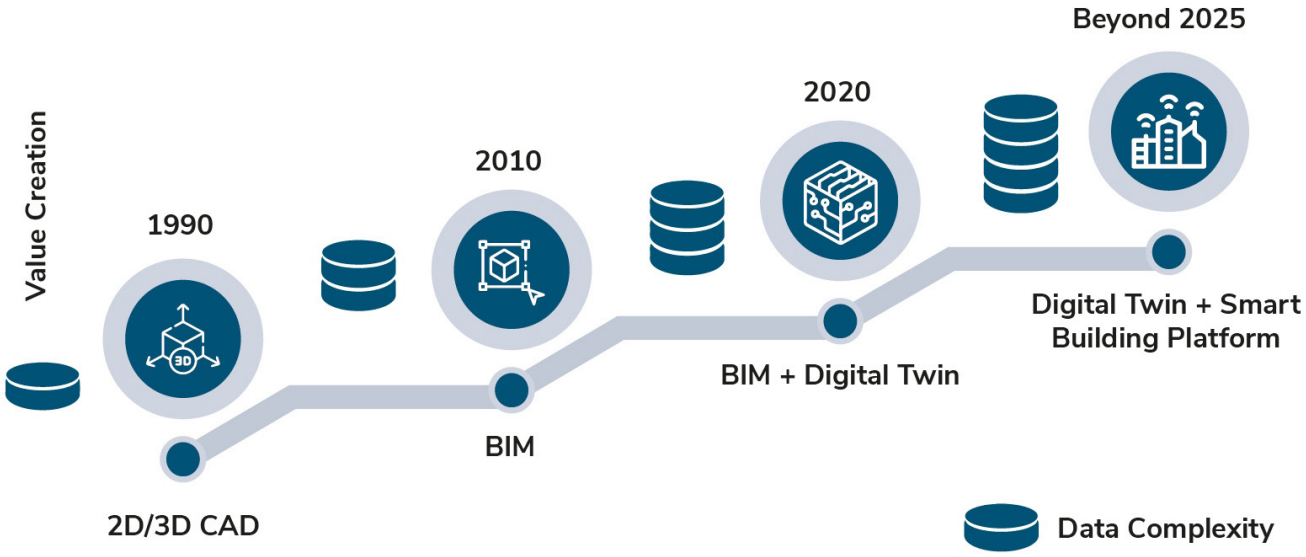
High capital costs, a lack of awareness and the fragmented implementation of BIM across the value chain are challenges to be overcome.

This is notably true amongst small and medium-sized companies which have been left behind in the BIM and Digital Twin transition with a lack of standardisation also making it challenging for them to select appropriate long-term solutions.

More broadly, mega infrastructure projects are also driving growth in the BIM market globally with notable examples in North America, the Middle East and Asia:

• The $20 billion **Hudson Yards** real estate development centre in a neighbourhood of Manhattan (US) includes residential apartments, offices, schools, hospitals, retail spaces, public parks and cultural venues. The first phase

BUILDING INFORMATION MODELLING, TECHNOLOGY DEVELOPMENT, GLOBAL, 1990-2025+



Source: Frost & Sullivan

opened in 2019 with the main elements of construction due to be completed in 2024

• The urban development projects in Riyadh, Saudi Arabia, are worth $23 billion and commenced in 2019. These include **King Salman Park, Green Riyadh, Sports Boulevard and Riyadh Art** and are part of the Saudi Vision 2030. In addition, Al Widyan in Riyadh is a future Smart City and integrated lifestyle community. The $8 billion project covers 7 million m2 will include residential units, offices, entertainment and leisure venues and retail outlets to be built over 7 years

• The Government of India had announced $1.36 trillion-worth of infrastructure investment, consisting of more than 6,500 individual projects across sectors which are planned for FY 2019-2025 under the **National Infrastructure Pipeline** of the Department of Economic Affairs. The developments include road and rail transport links as well as the construction of 100 more airports by 2024

• China's top infrastructure projects, which attracted a total estimated investment of $142 billion in 2019, include rail projects in Chongqing, Kunming, Chengdu, Zhengzhou and Xi'an as well as the expansion of the **Xianyang International Airport**. Major developments announced by 13 major cities and provinces are expected to revive the country's economy after the pandemic

Nemetschek (Germany), in second place, is one of the few companies currently capable of integrating BIM and Digital Twin into a smart platform.

Nemetschek is one of the leading companies in Europe to drive digitalisation in the AEC industry. The firm focuses on cross-brand development projects and strategic initiatives across market segments. The group is one of the few vendors which is capable of integrating its BIM and Digital Twin offerings into a smart building platform.

Increasingly, it will be important for market participants to be able to align their solutions with the need to deliver improved building sustainability.

Climate change poses a great challenge to building owners and firms with large portfolios have implemented annual sustainability and energy management targets to comply with local regulations and reduce their environmental footprint.

Many of the leading BIM and Digital Twin providers are committed to helping customers respond to climate-related developments and achieve their green goals.

Providers need to keep sustainability at the top of the agenda while approaching large customers for construction projects. Efforts in this respect in the short term are expected to generate demand for BIM and Digital Twin products in the long term as these solutions are increasingly seen as an integral part of designing and delivering high performance buildings, infrastructure, and cities as part of a low-carbon economy.

Offering their solutions to start-ups which develop clean technologies will also enable BIM and Digital Twin players to grow their brand names and secure a competitive advantage.

To do so, local BIM standards will have to be adopted worldwide in order to allow global customers to work across both countries and vendors.

Local BIM standards are currently deeply rooted in individual countries but the need for global data interoperability is critical for customers working with different BIM vendors in different regions. In the near future, a move to open BIM standards will be crucial to enable collaboration and allow the market to develop on an international basis.

The Industry Foundation Classes (IFC) standard, supported by the buildingSMART initiative, is an example of how the industry is starting to come together to enable the exchange of 3D component-oriented design data between different stakeholders in the AEC industry.

Major BIM brands should continue to contribute towards open BIM standards by allowing their employees to be part of the national and international BIM developer networks.

For first movers, open BIM standards stand to benefit vendors but also to give customers the freedom to bring in new suppliers and avoid getting locked in with one.

BIMO

COMPANY OVERVIEW

Industry Segment:
Digital construction - Information Modelling

Brief Description:
BimO provides high value technological services, driving digital building innovation in the architecture, engineering and construction sector, and helping professionals to implement the building information modelling (BIM) method.

Maturity:
Commercialisation since 2016

Multimedia:
https://www.youtube.com/watch?v=mKYK_hPl2wA

COMPANY STRUCTURE

FOUNDED: **2016**

COUNTRY: **ITALY**

OF EMPLOYEES: **15**

TOTAL FUNDING: **$314K**

REVENUES: **$314K**

PRODUCT OVERVIEW

Technology Focus

- BimO open innovation provides consultancy and processing of BIM procedures within the business, the training of internal figures in the BIM process, as well as the assistance to the management of contracts.
- BimO facility management includes the creation of the information models of buildings and assistance in the running of the facility management.
- The start-up expertise allows the formation of the architectural grid and all the necessary BIM models in terms of architectural, structural, electrical, thermo-mechanical, water, safety, and finally, check model and clash detection.

Main competitive advantage:

BimO offers the experience in BIM design achieved by its team in all the design phases, from the concept to the executive project up to the planning of the works and asset management of the property itself, generating value and certainty in a scenario in rapid evolution.

Value Proposition

- BimO open innovation is a facilitator for all industry operators to enter the future of construction digitalization with the most effective approach.
- It develops BIM-oriented open innovation projects, sharing and circulating its know-how and developing a network of collaborations with the most advanced operators in the supply chain.
- The startup aims to the large landscape of players who need to face the BIM approach at any level: technical offices, architecture, engineering firms, construction companies, and manufacturing companies.

Source: Frost & Sullivan, BIMO

BIMSPOT

COMPANY OVERVIEW

Industry Segment:
Digital construction - Information Modelling

Brief Description:
Bimspot has developed an information modelling software that enables higher-quality model check for more complex projects and better collaboration between stakeholders.

Maturity:
Commercialisation since 2019

Multimedia:
https://www.youtube.com/watch?v=mKYK_hPl2wA

COMPANY STRUCTURE

FOUNDED: **2018**

COUNTRY: **AUSTRIA**

OF EMPLOYEES: **20**

TOTAL FUNDING: **SEED VC**

REVENUES: **$5M**

PRODUCT OVERVIEW

Technology Focus

- The BIM manager solution automates the BIM process like model check, using BIM data as a source of information.
- The platform delivers project management features that align the teamwork, giving access to all building information for making a data-driven decision. Also, a planner solution improves the coordination and communication among members to work efficiently.
- The software enables easy access to all the information needed about the ongoing project and keeps the user updated by sending notifications about new changes.
- The project manager can load a custom set of rules, in the standard model checks which guarantee the overall quality of the model and provide clash detection features.

Main competitive advantage:

The centralized issue management model delivers supreme communication, collaboration, compliance and execution of tasks between building and real estate industry professionals. It increases efficiency and reduces building costs, enabling project stakeholders to save time and money and continuously improve quality in construction projects.

Value Proposition

- Spot BIM platform provides instant and easy visualization of models, accessible at all levels, to achieve the same project goal and objectives.
- Through Bimspot project manager solution, it is possible to establish project quality standards to ensure that all relevant building information is constantly updated and accessible to all.
- The start-up brings transparency and ensures quality and efficiency during the planning, construction, and operation of a building.

Source: Frost & Sullivan, BIMSPOT

ARUTILITY

COMPANY OVERVIEW

Industry Segment:
Digital construction - Information Modelling

Brief Description:
ARUtility has designed an augmented reality utility solution that allows users to view underground and above-ground assets.

Maturity:
Commercialisation since 2020

Multimedia:
https://www.youtube.com/watch?v=_XZzkGl6sFU

COMPANY STRUCTURE

FOUNDED: **2018**

COUNTRY: **USA**

OF EMPLOYEES: **5**

TOTAL FUNDING: **$20K**

REVENUES: **$1M**

PRODUCT OVERVIEW

Technology Focus

- ARUtility offers an augmented reality solution to see where utilities are located above and below the ground surface.
- The system can be paired with any external GPS unit to provide more accuracy to augmented reality visualizations.
- ARUtility supports lidar technology, for accurate tracking, occlusion, and visualization solution.
- Remote assistance functionality is built directly into the ARUtility application, with the aim of increasing efficiency, more clearly communicating with field staff, and reducing truck rolls.
- The platform manages an unlimited number of projects and responds to an unlimited number of requests for demanding information from other utilities to view during design and construction, increasing safety and efficiency for the whole workforce.

Main competitive advantage:

The startup's application can be located where the assets are placed in the ground in real-time thanks to its augmented reality utility locating, asset management, and BIM visualization application. These features reduce underground damages, make excavation more cost-effective, aid engineers in identifying conflicts before they happen, and assist utilities with asset management.

Value Proposition

- The solution allows utilities to collaborate and share their asset information.
- ARUtility aims to transform the utility industry by increasing collaboration, increasing safety, and helping utilities visualize their assets in a way never seen before to make more informed decisions.
- Utility partners can easily approve or deny requests for viewing their assets in AR on a project by project basis.

Source: Frost & Sullivan, ARUTILITY

SYNAVISION

COMPANY OVERVIEW

Industry Segment:
Digital construction - Information Modelling

Brief Description:
Synavision uses digital twin technologies to receive detailed and transparent guidelines and assessment of the building performance.

Maturity:
Commercialisation since 2015

Multimedia:

https://www.youtube.com/watch?v=5YFG8W39y6A

COMPANY STRUCTURE

FOUNDED: **2010**

COUNTRY: **GERMANY**

OF EMPLOYEES: 20

TOTAL FUNDING: **LATER STAGE VC**

REVENUES: **$888K**

PRODUCT OVERVIEW

Technology Focus

- By using the "Digital Test Bench" by Synavision, It is possible to create a digital functional description of the control and regulation functions individually for the specific building.
- The technical monitoring starts on the basis of planning documents such as hydraulic or automation schemes in the new building or screenshots of the system diagrams of building control system in the existing building.
- The software automatically checks each individual control function for compliance with the digital target model, based on the operating data of the building technology systems.
- As a consequence, enormous amounts of data can be processed at the push of a button and customers can just see at a glance the optimization potential.

Main competitive advantage:

The platform "Digital Test Bench" creates transparency about the efficiency of technical systems in the building. The development of a digital twin enables to compare it with the planned values. In this way, it can quickly and conveniently name optimization and cost-saving measures that, based on experience, promise a 20-30 % cost reduction.

Value Proposition

- Synavision offers standardized templates for the "digital test bench", which enable comfortable and quick processing with the software.
- The software is certified, which defines the requirements for companies to introduce, implement and improve energy management. In addition to energy savings, this feature can improve climate comfort and avoid operational risks.
- The solution helps investors, builders, project planners, operators to reduce the CO2 emissions of the building stock in the fastest way, thus providing in-house professionals with enormous support in building management.

Source: Frost & Sullivan, SYNAVISION

ROBOTS

Robots are being deployed on many building sites with greater frequency; increasing efficiency and saving time are key drivers but constructors are also focusing on reducing waste and improving safety.

Increasing efficiency

Completing construction projects in the pre-determined time is crucial to avoid incurring unforeseen costs and creating unwarranted disruption. When compared to professional workers using conventional tools, advanced robotic solutions have the potential to increase productivity across construction sites.

Saving time

The key Unique Selling Point (USP) of most robotic solutions is that they are designed to perform specific tasks more quickly than humans. Construction companies are looking to them for time savings with vendors pushing robotic solutions that are said to be able to work up to ten times faster than professionals.

Reducing waste

Human workers tend to make mistakes which leads to the wastage of expensive materials. Robotic solutions for construction applications are intended to handle tools and supplies with precision and in safety. In addition, they can be programmed to only use the amount of resources required to complete a task.

Improving safety

Construction sites are generally cluttered with machines and materials with human workers required to perform tasks in close proximity to equipment and/or at height. The adoption of robots improves safety by reducing the need for operatives to work under dangerous conditions and lowering the risk of accidents.

Further technology convergence and greater external funding will be needed to take the market to the next stage of growth while implementation costs will need to come down and end-user acceptance improve.

Technology convergence

Most of the robotic solutions currently available in the market are either remotely operated or semi-autonomous. With the advent of emerging technologies such as AI and ML, vendors have struggled to incorporate all the capabilities into a single solution and to develop fully autonomous and advanced robot solutions.

Funding requirement

In general, the robotic industry has witnessed significant funding for R&D purposes. Most of this has, however, been directed toward industrial robots whilst investments into the development of construction solutions has been low. More funding is required to boost technologies and encourage broad adoption.

Implementation costs

Construction robots are typically large and include advanced components such as sensors and software for mapping, localisation and detection along with communications capabilities. This makes both the development and implementation of such solutions expensive whilst maintenance fees are also prohibitively high.

End-user acceptance

One of the key hindrances to the further commercialisation and wide-scale adoption of construction robots is end-users' mind-sets. Whilst the benefits of adoption are increasingly clear, there is a reticence to invest in expensive solutions and scepticism about allowing a robot to complete tasks that humans perform.

Within the construction robots space, the development of drones has become an area of focus. More recently, there has been increase in patent activity with respect to AI-based software for construction drones.

Notable European innovators here include Pix4D (Switzerland).

Source: Frost & Sullivan

Pix4D, Switzerland, develops drones and software solutions for photogrammetry and mapping for documenting and measuring sites from an aerial perspective.

Drones and construction robots more generally are primarily used for unmanned inspection and surveying purposes as well as for autonomously completing specific tasks such as bricklaying or demolition.

Inspection and surveying

Drones are used for visual data collection on sites prior to beginning construction to gather a comprehensive understanding of the landscape for efficient planning. When compared to traditional inspection techniques, small Unmanned Aerial Vehicles (UAVs) are able to perform **inspection** tasks more efficiently and quickly.

Drones equipped with thermal imaging cameras are also increasingly used to determine the state of the structure of existing buildings.

The construction industry has developed autonomous, robotic and remotely operated solutions especially designed for **surveying** and mapping applications. These advanced drones require minimal manpower and can be deployed for data collection in hazardous and remote locations which are typically very difficult-to-access.

Use cases

New England contractor **Windover Construction** (US) uses drones for surveillance to establish 3D models of jobsites which managers import into the company's BIM workflow. Windover is increasingly using UAVs for thermal imaging inspection to track any leakages in piping and other systems under construction.

Bentley Systems, US, the leading BIM vendor, is another company which is investigating the overlap between its home market and robotics with the firm looking to develop solutions for surveying, modeling and mapping construction projects and other activities.

Spain-headquartered **Naska.AI** focuses on designing various types of remotely operated robotic solutions for the construction industry. The company's Husky Unmanned Ground Vehicle (UGV) has the ability to inspect or survey a construction site or building and capture critical information via multiple sensors.

Kespry, US, provides solutions for companies to better manage proposed and active earthwork operations. Without using multiple, cumbersome ground control points, survey-grade field data can be collected for an entire site in as little as thirty minutes.

Bricklaying

Bricklaying robots enable bricks to be laid autonomously and quickly during a building's construction. These solutions construct walls according to a previously uploaded design with one automatic bricklaying robot typically having the ability to cover an area which would generally require the attention of 5 to 6 professional workers.

Use Cases

FBR(Australia), formerly Fasbrick Robotics, focuses on developing advanced technologies for the construction industry. The company's flagship product is called Hadrian X which is a 3D robotic end-to-end bricklaying system based on its patented 3D automated robotic bricklaying solution.

The aim of the company is to get Hadrian X laying up to 1,000 bricks per hour. Currently, the solution has reached 300, and the new model is designed for speeds up to 500 blocks per hour, with blocks weighing up to 45 kg.

Frost & Sullivan believe that FBR's solution has the potential to meaningfully impact the construction industry. Hadrian X has the future ability to complete bricklaying tasks more than 10 times faster than conventional techniques.

Construction Robotics (US) is another emerging participant in the same niche and has designed the semi-automated SAM, a robotic solution which is also intended specifically for laying bricks. Its product is capable of managing 3,000 bricks per day, picking and placing them automatically from a conveyor.

Demolition

Demolition robots are designed for demolition and destruction applications. They are generally unmanned and can be controlled remotely. When compared to manually operated equipment, they are highly efficient but also increase safety by eliminating the need for workers to be physically present in dangerous environments.

Use cases

Brokk (Sweden), founded in 1976, is a key manufacturer of remotely operated demolition solutions. The company, a wholly owned subsidiary of the Lifco Group, caters to the requirements of the mining, construction, nuclear and cement industries.

Brokk also obtained a certificate of acceptance from the Swedish Rail Network for the use of its robots.

The company's product portfolio consists of many demolition robots, rescue machines and descalers. Brokk also provides customised solution according to specific client needs.

Brokk is focused on further developing its robotic solutions. Its products are all available globally with the company's keen collaborate with various key players in the construction industry to increase the overall adoption of its technology.

Frost & Sullivan recognizes Brokk's flagship 900R demolition robot, which boasts a three-arm system powered by a 71 kW electric engine (or 55 kW diesel) , for its modularity, ease of integration and scalability. Its remotely operated solutions are fully protected against explosives which mean that they can operate in the harshest environments.

Window cleaning, welding and material handling

Window cleaning robots are used for tall commercial buildings where maintaining glass facades is time-consuming and labour-intensive. With robots, this task can be significantly automated. Window cleaning robots are increasingly expected to replace humans due to the benefits that they offer in terms of efficiency, safety and accuracy.

Source: Frost & Sullivan

KITE Robotics, from the Netherlands, offers window cleaning robots which can clean structural windows and facades at any height and at lower costs.

Welding robots are also gaining traction and are used to weld steel and other metals in buildings' construction. They offer precision.

Miller, from the US, markets a robotic system called PerformArc which can be used for welding, cladding and increasingly additive manufacturing purposes.

Material handling robots are being widely deployed in the construction industry. These solutions are specially designed for pick and place tasks, moving objects and resources from one location to another. They have the advantage of decreasing the ergonomical load for workers and increasing the efficiency of material movement on site.

Kewazo, from Germany, focuses on providing robots for transporting materials, parts and, in particular, scaffolding. The company raised a total of $17.75M in capital over the course of 5 funding rounds, with a $10M Series A in January 2023 as last round.

Wearable and exoskeletons

Wearable robotics or exoskeletons are expected to gain ground in the coming years as they reduce the physical burden on workers.

Exoskeletons are robotic suits which enhance the capabilities of manual workers. Exoskeleton robots are aimed to ease the physical burden on humans by bearing or minimising physical loads and reducing the risk of injury.

From an end-user perspective, the manufacturing industry is a first mover in the use of exoskeletons. It is expected to maintain its leadership, growing at 48.8% annually to reach $271.4m in 2025.

Automotive companies such as Ford, Toyota and BMW are also early adopters of industrial exoskeletons. The transport industry is the second-largest segment with adoption in logistics and warehousing a key growth driver.

The construction industry is expected to grow at a CAGR of 44.7% (2020-2025) to reach $30.8m in 2025. Demand here stems from increasing adoption overall but also from powered exoskeletons in niche areas like marine.

In the construction sector, **Eksobionics** (US) provides Ekso EVO, a small and flexible exoskeleton with lower cost, enhanced comfort and completely decoupled left and right shoulder support structures.

German Bionics (DE) has developed Cray X, a water- and dust-proof tool supporting up to 30 kg of lifting compensation, hot swappable battery, and real-time monitoring.

M2D TECHNOLOGIES

COMPANY OVERVIEW

Industry Segment:
Digital construction - Robotics

Brief Description:
M2D develops monitoring and predicted solutions on IoT, Big Data technologies, artificial intelligence, machine vision and machine learning to predict faults in photovoltaic systems.

Maturity:
Commercialisation since 2017

Multimedia:
https://www.youtube.com/watch?v=rTqlqn2UW9Q

COMPANY STRUCTURE

FOUNDED: **2010**

COUNTRY: **ITALY**

OF EMPLOYEES: **10**

TOTAL FUNDING: **$120K**

REVENUES: **$400K**

PRODUCT OVERVIEW

Technology Focus

- M2D platform automates the supervision and maintenance of photovoltaic systems through the use of autonomous robotics systems and intelligent control software.
- M2D algorithm facilitates decision-making through "Nowcasting", a technique that allows to predict the results of what will happen in the immediate future, within the next fifteen minutes.
- Another asset of M2D is its analytical solutions for the preventive detection of plant malfunctions, through the analysis of thermal images.
- The M2D tech's robots move in complete autonomy between the panels of the photovoltaic fields, monitor their status, predict breakdowns and do maintenance.

Main competitive advantage:

By providing information on possible failures that may occur on some system components, it is possible to obtain efficiency recoveries ranging from 10 to 15%. For an average plant these are earnings, in monetary terms, of up to 100 thousand euros a year. Furthermore, data-driven techniques let to know in advance what problems might occur in the plants with the aim of saving companies and preventing maintenance interventions.

Value Proposition

- M2D Technologies since 2010 have been designing products and solutions that aim to optimize the production efficiency of industries and companies.
- The innovative system exploits robotics, automation and artificial intelligence, all the access keys with which the startup supports customers in smart monitoring challenges.
- In addition to robotics, the data generated and its interpretation are crucial for making decisions, especially when it comes to energy production.
- The innovative artificial intelligence platform, made in Sicily, which helps predict faults in photovoltaic systems, is already in use in countries such as Chile, Peru, South Africa and Greece.

Source: Frost & Sullivan, M2D TECHNOLOGIES

DRONE RADIO BEACON

COMPANY OVERVIEW

Industry Segment:
Digital construction - Robotics

Brief Description:
Drone Radio Beacon has developed an innovative system designed to enable safe and reliable automatic drone services through remote management, AI-based reporting and cloud computing.

Maturity:
Commercialisation since 2019

Multimedia:
https://www.youtube.com/watch?v=LyIo5rXLtmw

COMPANY STRUCTURE

FOUNDED: **2016**

COUNTRY: **ITALY**

OF EMPLOYEES: **10**

TOTAL FUNDING: **Incubation**

REVENUES: **$100K**

PRODUCT OVERVIEW

Technology Focus

- Drone Radio Beacon (DRB) uses proprietary AI-based software for providing onboard detection in applications like wind turbine generators or powerlines inspections.
- DRB autonomous drone system exploits a suite of innovative technologies such as battery recharging landing station, a robotic arm for instruments, sensors for visual, infrared, and ultraviolet inspections or NDT, to enhance operations.
- The platform analyses the difference between standard waypoints and reality, increasing precision, reliability, and safety, combining different features with the ground station positioning.
- Thanks to DRB AI engine, the DRB platform rapidly analyzes collected data and pictures taken by the drone thus ensuring full value from a drone inspection.

Main competitive advantage:

Drone Radio Beacon is a patented solution for driving drones with very high accuracy (10s of centimeters) and outstanding reliability. This solution is able to precisely and quickly drive the drone inside the plant via pre-determined safe flight paths, close to the relevant buildings, autonomously and safely. Bridges, dams, viaducts can be inspected automatically with high precise localization for point references and 3D reconstruction even without GPS signal.

Value Proposition

- DRB can be also used as a stand-alone or a redundant safety device in mission-critical applications as it does not need any GPS signal or video processing technique to operate.
- Safe, precise and automated flight is assured by DRB ground station able to drive a compliant drone according to a predetermined path.
- The solution can establish no-fly zones, let the drone follow predetermined flight corridors, or land it precisely onto the ground station itself.

OKIBO

COMPANY OVERVIEW

Industry Segment:
Digital construction - Robotics

Brief Description:
Okibo has developed a battery-operated robotic platform that moves freely around indoor construction sites performing wall and ceiling finishing tasks such as joint taping, plastering, sanding and painting.

Maturity:
Product under development, commercialization expected since 2024.

Multimedia:
https://www.youtube.com/watch?v=hm9ZSN37jVM

COMPANY STRUCTURE

FOUNDED: **2018**

COUNTRY: **ISRAEL**

OF EMPLOYEES: **15**

TOTAL FUNDING: **Accelerator**

REVENUES: **$1M**

PRODUCT OVERVIEW

Technology Focus

- Okibo's advance technology allows its robot to autonomously traverse the rough terrain of construction sites with high precision while maintaining human and equipment safety.
- The platform uses advanced computer vision, laser detectors, geo-positioning, and inertial motion sensors to assimilate into any construction site.
- Using a novel 3D scanning method, the robot is capable of 3D mapping its environment, enabling progress monitoring, BIM comparison, and reliable understanding of the plastering requirements.

Main competitive advantage:

The startup automates multiple types of on-site construction jobs avoiding the exposure of human workers to potential risks, such as working at heights and working with toxic materials. Furthermore, equipped with a suite of advanced sensors and AI algorithms, the robot requires minimal human intervention and, with a natural user interface, it is easy to set user instructions and letting the robot do its job, freeing your staff for other tasks. It enables constructors to lower costs and simplify the process of handling wall isolation.

Value Proposition

- Okibo has demonstrated that its robot can paint a full room composed by 4 walls, fully autonomously, continuously, with no human intervention, no prior programming, and no prior data provided to the robot about the job.
- The robot performs top-quality plastering jobs in a fraction of the time spent in conventional plastering methods, utilizing the maturity and robustness of the industrial robotic arms.
- The precise 3D scanning of its environment, combined with the accuracy of an industrial robotic arm, enable to reach supreme finish quality, consuming only electricity.

Source: Frost & Sullivan, OKIBO

BUILT ROBOTICS

COMPANY OVERVIEW

Industry Segment:
Digital construction - Robotics

Brief Description:
Built Robotics has created an autonomous vehicle and software designed to transform heavy equipment into autonomous robots, aiming to accelerate construction projects.

Maturity:
Commercialisation since 2017

Multimedia:
https://www.youtube.com/watch?v=7KuUnYj5XGQ

COMPANY STRUCTURE

FOUNDED: **2016**

COUNTRY: **USA**

OF EMPLOYEES: **35**

TOTAL FUNDING: **$50M**

REVENUES: **$4M**

PRODUCT OVERVIEW

Technology Focus

- Built Robotics develops AI software able to transform the existing construction equipment, including excavators, bulldozers, and skid steers, into fully autonomous robots.
- The AI guidance systems can be installed on existing equipment from any manufacturer, while still maintaining complete manual operation capabilities.
- Heavy equipment that is outfitted with Built's software uses GPS and LIDAR systems to dig trenches between pre-determined GPS points on a construction site.
- Onboard cameras and the LIDAR systems will also notify the autonomous machinery of nearby workers or other vehicles. Machine operators will be able to establish a "geo-fence" that the robot is unable to operate outside of.
- By upgrading off-the-shelf heavy equipment with AI guidance systems, Built's technology enables machines to operate fully autonomously.

Main competitive advantage:

The proprietary software enables the upgrade of excavating equipment allowing all types of machinery to operate autonomously or be piloted remotely, making it the first of its kind to be offered commercially in the U.S. The solution drastically reduces the construction timeline, so the project manager can knock out work overnight so that it's ready for the human workers in the morning to speed them along.

Value Proposition

- The solution enables clients to operate machines fully autonomously, indeed, it is used to build critical infrastructures such as wind farms, gas pipelines, and new housing developments.
- The autonomous fleet can be managed via a web-based platform, which allows remote equipment operators to supervise the robots, preventing workers from injuries.
- Moreover, the startup is rolling out a training program that emphasizes the increasing added value that an operator is expected to provide now that the robot does all the monotonous work.

Source: Frost & Sullivan, BUILT ROBOTICS

MANAGEMENT SOLUTIONS

Management solutions are large, cross-platform content systems designed to manage construction projects' financials, quality, safety and productivity

Typically, they focus on one or more functionalities on a modular basis:

- **Financials,** accounting systems designed to keep project budgets under control and accessible by project stakeholders
- **Quality and Safety**, monitoring systems designed to mitigate risk and document quality and safety processes
- **Productivity,** tracking systems designed to log labour hours and production quantities and measure against goals
- **Project Management,** management systems designed to facilitate collaboration among project stakeholders

Continued increases in the volume of information available and the growing need for collaboration between multiple stakeholders are driving demand.

Capital projects in the infrastructure space span years or sometimes decades. The scale and complexity of these undertakings makes the management of construction documents and information, secure collaboration between stakeholders, effective risk management and compliance and efficient project governance critical.

The accessibility and ease-of-use of intuitive consumer file-sharing platforms have made such solutions hugely popular, especially amongst millennials. When similar options for collaboration are not available in the enterprise segment, employees often turn to the likes of Dropbox and Google Drive. However, the lack of authentication, rights management and security lead to the undue exposure of branded enterprise Intellectual Property (IP) which is an issue for enterprise IT departments.

Dedicated Construction Management Systems (CMSs) that enable owners, General Contractors (GCs) and Specialty Contractors (SCs) to efficiently manage their business processes and information handling help reduce wastage, costs and the need for repeat work thereby accelerating time to project completion.

In addition, a progressively mobile and dispersed workforce expects to be able to benefit from smart solutions that are similar to those it sees elsewhere.

The proliferation of smartphones, tablets and other personal mobile devices and their use by construction employees for official purposes has forced enterprise IT decision makers to open up to Bring Your Own Device (BYOD).

Most companies now report that they would be at a competitive disadvantage if they did not embrace the BYOD trend. Today, 70% of US enterprises support BYOD and Frost & Sullivan expects this percentage to grow.

BYOD also helps construction firms save on device and plan costs by no longer having to invest in official devices for their employees.

Today's workforce is overall younger, more connected and more dispersed than ever before. Providing workers with the necessary tools to manage construction information in a secure, reliable and seamless way while collaborating with the various stakeholder groups involved in a project is top-of-mind for management.

Project environments use multiple solutions and software for areas such as design and ideation, pre-construction planning, contract management, supply chain supervision and resource allocation. One of the biggest drawbacks of home-grown solutions is the challenge for in-house departments of integrating them.

CMS vendors facilitate the seamless integration of ERP, CAD, and accounting software with their own platform and, increasingly, employees' devices to create workflows that maximises efficiencies and eliminates redundancies.

Nonetheless, resistance to change amongst buyers remains a barrier to growth.

Construction companies have, more or less successfully, used paper- and spreadsheet-based processes for decades so potential customers often need education and

direction on the benefits that CMS solutions can bring and how to evaluate them.

About fifteen years ago, many large contractors experimented with using technology for project scheduling with tools such as Microsoft Project. These systems were slow and not without limitations, Later, they integrated document management tools, ERP modules and collaboration platforms. Many owners and contractors still do business without a purpose-built project management solution, often using proprietary systems.

Enterprises' openness to technological change is dependent on a number of factors, including but not limited to their organisational culture, vertical and regional industry dynamics, regulatory environments and the makeup of their workforce.

While some companies have readily embraced CMSs, recognising the host of efficiencies that they bring, others have followed a much steeper adoption curve.

With changing employee profiles, increasing use of mobile devices, growing complexity of projects and greater regulatory scrutiny, Frost & Sullivan expects the use of CMSs to become the norm in the long term as GCs and SCs eventually all look to procure them.

Frost & Sullivan expects sales of CMSs will continue the positive trend with the space reaching $5.9 billion by 2024.

From a functionality point of view, demand is growing most rapidly for project management solutions, followed by construction financials.

End-users across the industry increasingly require and appreciate robust CMS solutions with features for document management, budget and cost analyses, inspection libraries and daily logs. These are becoming ever more vital as stakeholders in the construction sector try to use digital solutions to streamline operations, break down data silos and reduce ambiguity and time-wasting manual processes.

Integration is also key, particularly with project management and financial management solutions, while mobile compatibility is vital for field productivity and quality/safety platforms in order to take document and labour tracking capabilities from the office to the field.

GCs and SCs benefit from this latter functionality because it allows them to spend more time on site while at the same time ensuring that the correct processes are well executed.

Oracle and Trimble (both US) each sell multiple solutions to different segments which yields competitive worldwide shares of 25.0% and 16.5% respectively.

Understanding what is needed to thrive in this space whilst also enabling customers to consistently sustain their own competitive edge is critical to maintaining leadership.

The CMS market is crowded with numerous small and large vendors competing for clients and share. Among the most important sources of differentiation are the depth of vendors' product line strategies and their ability (or otherwise) to address the needs of a variety of stakeholder groups involved in construction projects from start to finish.

The majority of suppliers provide point solutions which address project management, cost control, quality or field productivity tasks and focus on single or select user personas.

Few vendors have been able to provide end-to-end platforms that integrate successfully with the existing software that is widely used by their customers let alone develop services that cover the entire ecosystem.

Other critical competitive factors include a company's vision, its focus on the needs of and challenges faced by specific customers, its commitment to innovation and its relative brand strengths and recognition.

Below this, the market is crowded with smaller players providing "point" products that are aimed at addressing single issues such as field productivity.

The market leaders compete with integrators which bring together a range of the point solutions. Other vendors, such as Procore (US), offer end-to-end platforms; while they will sell individual components, their solution is intended to be comprehensive.

Source: Frost & Sullivan

Below the top three vendors, another fifty vendors make up a long and fragmented tail. With only approximately 20% of all owners, GCs and SCs using dedicated CMSs, there is significant room for growth.

In the future, further consolidation is expected with a view to suppliers delivering end-to-end solutions and addressing current interoperability issues.

The potential of the CMS market is significant.

Currently, the industry has barely scratched the surface of the opportunity. Over the coming years, Frost & Sullivan expected that thousands of new customers will switch from pen and paper CMS solutions and many will switch between vendors.

Owners, GCs and SCs increasingly understand that CMSs are a "must-have" to stay competitive in a market that is rapidly digitising.

The CMS market is currently very fragmented with only a handful of vendors providing true end-to-end solutions while the majority sells point solutions. A wave of continued consolidation is likely as stakeholders look to combine their offerings.

Few CMS vendors are building their end-to-end solutions organically.

Until the space develops and matures around a few major vendors, customers will continue to experience interoperability issues which will drive owners, GCs and SCs to seek to acquire multiple solutions to address all of their CMS needs.

MELA WORKS

COMPANY OVERVIEW

Industry Segment:
Digital construction - Management solutions

Brief Description:
Mela Works has developed a work management application designed to manage and organize fieldwork, exchange information in the field and monitor construction site costs in real-time.

Maturity:
Commercialisation since 2018

Multimedia:
https://www.youtube.com/watch?v=q_fPb_3fprc

COMPANY STRUCTURE

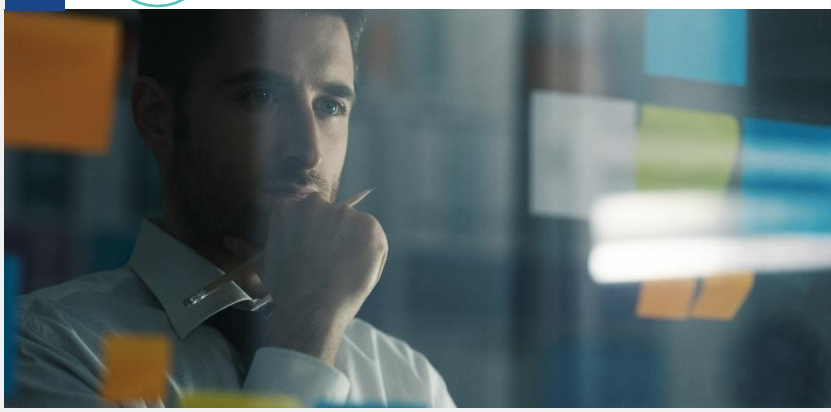
FOUNDED: **2017**

COUNTRY: **ITALY**

OF EMPLOYEES: **10**

TOTAL FUNDING: **$1.77M**

REVENUES: **$130K**



PRODUCT OVERVIEW

Technology Focus

- Mela Works allows project managers to monitor the construction progress, material consumption, and man-hours in an easy and intuitive way.
- The system works by tracking team locations, assets used, sends out work information to all the managers, workers, and contractors, and also automatically processes and analyses operational data. It is also possible to export the work journal, intervention reports, minutes, etc., and customize reports based on the information needed.
- The chat features, like a historical book of the activities, stores the document construction sites and maintenance operations. Even remotely it is possible to collect images and voice notes in the field, share information in real-time with whoever you want, on-site or in the office, eliminating paper documents.

Main competitive advantage:

With Mela information and data to organize fieldwork is recorded and verifiable in real-time. As a consequence, the margin of error due to incorrect transmission or wrong interpretation of the data is considerably reduced, with considerable savings in time, resources and money. The risk of disputes or late payments is also significantly reduced thanks to the traceability of the digital recording of every single site event, and lastly it increases productivity during fieldwork

Value Proposition

- Mela Work solution enables the creation of reports quickly from the construction site or from the office, monitor materials, labour, and vehicles used in individual construction sites.
- The reports and the work journal, created automatically with Mela Works, have legal value and follow current legislation.
- The cloud service offered by Mela allows users to access the information everywhere they are, enabling to store, organize and export data in several formats, avoiding spending more time downloading and organizing data in hand-drawn reports.
- In addition to accounting, it establishes the use of IT platforms also for the accounting, technical and administrative aspects of the construction site.

Source: Frost & Sullivan, MELA WORKS

BUILDOTS

COMPANY OVERVIEW

Industry Segment:
Digital construction - Management solutions

Brief Description:
Buildots has developed data-driven construction management platform intended to turn construction sites into fully digitized environments helping to collect, analyse and leverage data useful for making the best decision in a short time.

Maturity:
Commercialisation since 2020

Multimedia:
https://www.youtube.com/watch?v=1u1hhrMVBvw

COMPANY STRUCTURE

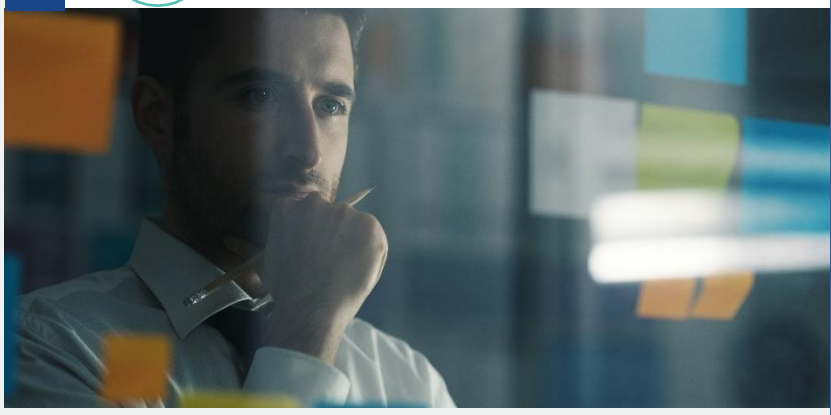
FOUNDED: **2018**

COUNTRY: **ISRAEL**

OF EMPLOYEES: **60**

TOTAL FUNDING: **$16M**

REVENUES: **$4M**



PRODUCT OVERVIEW

Technology Focus

- Buildots' technology automatically analyses and maps all files, producing a detailed digital construction program, which will be tracked by the system.
- Buildots AI leverages the capacity of a simple hardhat mounted camera and state-of-the-art computer vision algorithms to track all activities on-site and to provide all the information required.
- The proprietary algorithms automatically analyse the video data captured on-site to determine the exact status of each construction activity.
- The technology package offers multiple insights such as on-demand project status and gaps both detailed and aggregated, per-trade throughput and progress analysis, visual documentation for collaboration as-built and handover, objective evidence to resolve potential disputes.
- Through online dashboards, emails, and SMS, teams receive detailed reports and insights regarding different aspects of all construction processes.

Main competitive advantage:

The proprietary AI and computer vision algorithms easily detect, track and manage partially completed activities. The platform lets to have consolidated project view with "percent complete" and identification of the most urgent issues and integrates into existing management workflows, enabling clients to get the necessary information to make the best decisions about the construction project.

Value Proposition

- Buildots platform is designed to enable maximum control of construction processes at minimal effort. Furthermore, the system ensures easy integration, fast access, and user-friendly interface.
- The online process management system solves problems such as a missing tap, apartments late on electrical works, or a recurring delay for a specific activity by measuring the data captured through the automated video analysis.

Source: Frost & Sullivan, BUILDOTS

SAMSON LOGIC

COMPANY OVERVIEW

Industry Segment:
Digital construction - Management solutions

Brief Description:
Samson Logic has developed equipment management software intended to provide a new way to handle construction materials in all stages, starting at the ordering of the materials, through their packing at the factories, their transportation, and consumption.

Maturity:
Commercialisation since 2020

Multimedia:

https://www.youtube.com/watch?v=0A6tfnY_3jY

COMPANY STRUCTURE

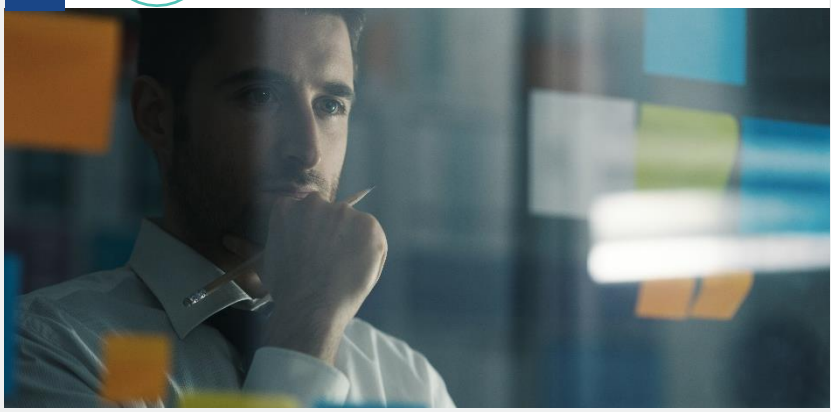
FOUNDED: **2019**

COUNTRY: **ISRAEL**

OF EMPLOYEES: **10**

TOTAL FUNDING: **$40K**

REVENUES: **$1M**



PRODUCT OVERVIEW

Technology Focus

- Samson Logic provides a comprehensive system that manages construction material logistics from production to on-site storage.
- It provides proprietary smart containers with IoT sensors to ensure safe transport of raw building materials, as well as a software system that fully manages the entire process of the building materials.
- The software sends manufacturers precise instructions for packing the products so that they arrive set in according to the work stages, the lifting capacity of the crane, and in accordance with transportation regulations.
- The packages themselves are adapted for transportation, lifting with a crane and stack mounting.
- All the information is collected, analyzed, and managed by raw material inventory

Main competitive advantage:

By keeping an active inventory of materials on a given site, the software empowers somewhat traditional construction sites with a new more modern solution. This is an easily implemented solution that aims to bring increased on-site safety, prevent accidents, cut costs by saving crane time, workers' time, and storage area while reducing materials waste, and in the end, create efficient order of the sometimes chaotic and logistically challenged work sites.

Value Proposition

- Samson Logic promotes the safety and efficiency of the construction industry. The IoT sensors at the back of each package allow tracking of the materials at each stage of its lifecycle, by collecting vital information and creating real-time safety alerts.
- The startup aims to turn construction sites and factories into organized, efficient and safe places, for quality logistic management of the storage area and materials consumption, monitoring and controlling the delivery process.

Source: Frost & Sullivan, SAMSON LOGIC

ABOUT INTESA SANPAOLO INNOVATION CENTER:

Intesa Sanpaolo Innovation Center is the company of Intesa Sanpaolo Group dedicated to innovation: it explores and learns new business and research models and acts as a stimulus and engine for the new economy in Italy. The company invests in applied research projects and high potential start-ups, to foster the competitiveness of the Group and its customers and accelerate the development of the circular economy in Italy.

Based in the Turin skyscraper designed by Renzo Piano, with its national and international network of hubs and laboratories, the Innovation Center is an enabler of relations with other stakeholders of the innovation ecosystem - such as tech companies, start-ups, incubators, research centres and universities - and a promoter of new forms of entrepreneurship in accessing venture capital. Intesa Sanpaolo Innovation Center focuses mainly on circular economy, development of the most promising start-ups, venture capital investments of the management company Neva SGR and applied research

For further detail on Intesa Sanpaolo Innovation Center products and services, please contact

businessdevelopment@intesasanpaoloinnovationcenter.com

ABOUT FROST & SULLIVAN:

For over five decades, Frost & Sullivan has become world-renowned for its role in helping investors, corporate leaders and governments navigate economic changes and identify disruptive technologies, Mega Trends, new business models and companies to action, resulting in a continuous flow of growth opportunities to drive future success.

For further details on Frost & Sullivan's coverage and services, please contact

LIVIO VANINETTI
Director of Frost & Sullivan's Italian operations;
livio.vaninetti@frost.com

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