

Smart City Technologies in Israel

A Review of Cutting-Edge Technologies and Innovation Hubs

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Abstract

This discussion paper was developed by the Inter-American Development Bank's (IDB) Housing and Urban Development (HUD) Division in collaboration with the Knowledge and Learning (KNL) Division. It was financed through KNL's Cutting-Edge Knowledge Fund.

Smart cities reveal the potential of innovative technologies to tackle tough and longstanding problems in cities and dramatically improve the way municipalities operate. Cities in Latin American and Caribbean (LAC) countries have a pressing need for solutions that can challenge existing problems while providing a solid return on investment. In recent years, Israel has developed a unique ecosystem approach toward its smart city technology, with a unique focus on collaboration between research institutes, local governments, and private entrepreneurs. This paper explains how the ecosystem developed and how it can benefit cities and residents. The paper starts by providing background information on the various drivers behind smart city innovation in Israel, including the information industry and government agencies. It then focuses on technologies developed in Israel, providing descriptions and a comprehensive analysis of cutting-edge solutions for smart cities developed by an ecosystem of companies, universities, governments, and startups. Later on, provides an overview of the research and development centers in Israel and the dynamics that fuel creative centers, focusing on the startup ecosystem, academic centers, and established IT companies.

Visita: www.iadb.org/smartcities

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Executive Summary

Over the past few years, the process of urbanization has been facilitated by the creation of smart cities. Smart cities incorporate information and communications technology (ICT) to tackle complex and persistent urban challenges, including mobility, traffic congestion, resilience against natural disasters, and security.

Israel's record of innovation in developing advanced solutions in such fields as homeland security, ICT, transportation, water, clean technologies, and healthcare technologies provide cities and local governments with ideas and products that can drive smart cities. Ideas are not second to products, since in this initial stage of smart cities, the ability to imagine how cities can function is crucial. Smart cities are places where people can live, work, and play using smarter, more efficient, and more economical municipal services.

The objective of this discussion paper is to describe and provide a comprehensive analysis of cutting-edge solutions for smart cities developed or used in the Israeli ecosystem of companies, universities, governments, and startups. The paper starts by providing background information about the various drivers behind smart city innovation in Israel, including the information industry and government agencies.

An overview of the research and development centers in Israel and the dynamics that fuel creative centers focuses on the startup ecosystem, academic centers, and established technology companies.

Then, an overview of smart city solutions in Israel specifically focuses on transportation and intelligent mobility, emergency response, security, early warning systems, housing and smart buildings, citizen participation, water, energy and waste, climate change, and other relevant challenges. In all of these domains, the analysis describes how these technologies can be applied to LAC countries.

The paper describes infrastructure technologies that do not fall into one of the implementation domains enumerated above, including mobile and smartphone applications, big data analysis, and software architectures for smart cities. It describes the organizational and financial aspects of smart city innovation in Israel, as well as their potential for replication in LAC. Finally, the paper includes a list of solutions and solution providers in Israel that can serve as a tool for LAC cities to develop technology-based solutions. The solutions and solution providers are divided by sector.

1. Introduction

Urbanization is one of the most important phenomena of the 21st Century for the entire world and especially for LAC. The LAC region became more urban than rural in the early 1960s, one of the first places on earth to reach that milestone (UN, 2014). Worldwide, this trend continuous to intensify. The number of people living in urban areas globally will increase by over one billion by 2025 (UN-Habitat, 2016).

Technology is becoming a critical force in the development and functionality of cities. With the formulation of smart cities toward the end of the 2000s, cities are pushing the technological envelope forward. A smart city places people at the center of development, incorporates ICT into urban management, and uses these elements as tools to stimulate the design of an effective government that includes collaborative planning and citizen participation. By promoting integrated and sustainable development, smart cities become more innovative, competitive, attractive, and resilient, thus improving the lives of its citizens (IDB, 2016).

Fostering and developing a smart city requires an ecosystem of companies, research hubs, and government agencies. This paper presents the Israeli startup ecosystem, looking at technologies that Israeli companies and research institutes have developed for smart cities and the context that fosters innovation in urban technology.

In the past few years, Israel has become known throughout the world as the center of a vibrant high-tech and startup scene, boasting one of the world's top ecosystems. Israel has hundreds of startup companies and the numbers continue to grow each year (Raviv and Yachin, 2015). Many factors support this ecosystem: the availability of a highly educated workforce and venture capital,

significant investment in research and development (R&D), a culture of entrepreneurship, and the ability to use the Israeli market as a testing ground for new technologies (Yin, 2016).

The technologies presented in this paper have certain characteristics that make them especially relevant to cities in LAC. First, the technologies and the way of thinking about smart cities incorporate bottom-up innovation driven by the products of startup technologies rather than on a large-scale plan. Second, most of the solutions avoid the need to install costly infrastructure and rely on various techniques to support light-weight solutions. This approach makes some of the solutions especially relevant to LAC cities that need easily deployable solutions.

This paper aims to open a window to breakthrough technologies developed in Israel. It reviews technologies related to a wide range of smart city domains, including transportation and smart mobility, emergency response, security, early warning systems, housing and smart buildings, water and waste, climate change, and other domains. It then analyzes how these technologies might be applied in LAC.

1.1. The Israeli Context

In the early 1970s, the origins of Israel's information technology sector focused on enterprise software, communication hardware and software, and automated industrial manufacturing (Yin, 2016). The foundations of the industry were based on a highly educated workforce, with an advanced higher education system and research community, that contributed significantly to Israel's success in high-tech. Skilled human resources have been proven to be a strategic asset in Israel. Compulsory army service allowed many people

to receive experience in leadership and in cutting-edge technology development.

The Israeli startup ecosystem was built gradually in urban areas, close the country's leading academic institutions: The Technion – Israel Institute of Technology at Haifa and Tel Aviv University at Tel Aviv. Companies in this ecosystem are export-oriented, even though the primary market for their products is the United States and Europe. As the IT sector grew, multinational companies seeking innovative technology bought small Israeli startup companies and established local R&D centers (Hakak, Korbet, Feldman, et al., 2016).

Today there are 298 multinational companies in Israel with R&D centers, including Intel, Google, Apple, Cisco, Facebook, and Microsoft. Funding from abroad constitutes a major portion of Israel's total business enterprise R&D contributions. The relationship with the international high-tech community is also evident in investments. Funding from abroad constitutes about 50 percent of Israel's total business enterprise R&D funding, compared to an average 25 percent in other OECD countries (Raviv and Yachin, 2015).

Israel's special circumstances also find their way into the domains in which the technologies are created. Figure 1 reveals that certain domains are especially prominent: water technologies, security, and networks for smart cities. As Israel is a country with limited water and fuel resources, it is not surprising that water and energy solutions were developed. Therefore, it is not surprising that the local startup industry has developed strong skills and knowledge in areas such as water technologies and renewable energy. Another field in which Israeli companies have gained a good reputation is defense technologies. Based on the experience and

knowledge obtained from the development of military technologies for Israel's defense forces, local startups have successfully designed smart city security systems.

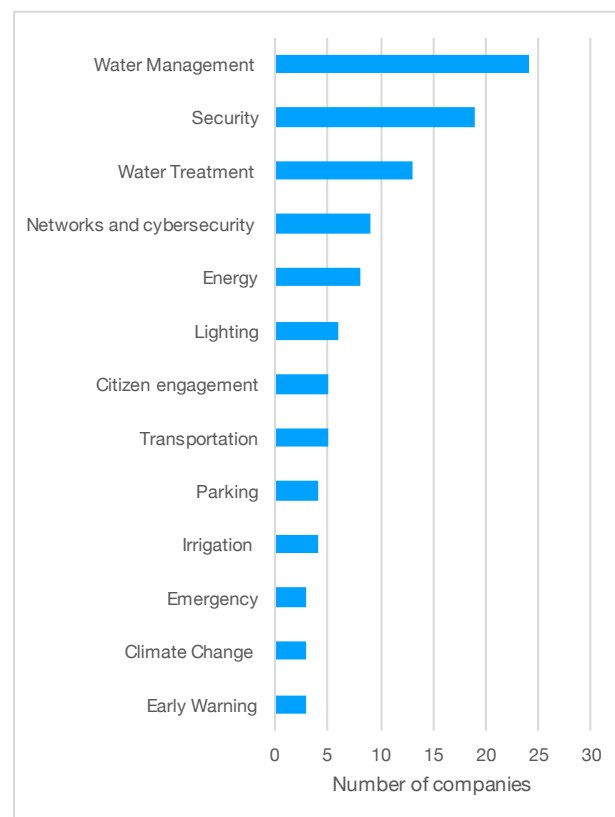


Figure 1: The number of startup companies in different categories of smart city applications, based on the data in the appendix.

1.2. Smart Cities in Israel

Israel serves as the testing ground for many smart city technologies. Smart city projects take a unique path with regard to the technologies chosen for implementation. Several noticeable examples of smart city projects are in Tel Aviv, Jerusalem, and Ashdod.

Tel Aviv is Israel's second most populous city and its main business, technological, and cultural center. While the city itself has some 414,000 inhabitants, it is the focal point of the Tel Aviv metropolitan area, the country's most populated region, home to 3.6 million people, 46 percent of

Israel's population (Israel, 2013). Tel Aviv's main motivation for establishing smart city projects was to improve resident engagement and strengthen trust between residents and the municipal government. Tel Aviv's municipality defines this process as citymaking, meaning transforming a space and a place, where a space is a physical entity, while a real place draws people, has a clear narrative, and is embedded with meaning.

The main driver for Tel Aviv becoming a smart city was to create a more open, transparent, and trusting relationship between the municipality and its citizens. The main project, **Digi-Tel**, began in 2011.

Digi-Tel aims to create multiple communication channels with residents, personalizing interactions with each resident and visitor to the city. **Digi-Tel**, an umbrella for several infrastructure components, is intended as a platform that allows increased citizen engagement, on top of which other applications can be deployed. The heart of **Digi-Tel** is a resident consumer club through which residents can access personalized, curated information and services relevant to them.

For **Digi-Tel**, Tel Aviv won first prize in the Smart City competition held at the Smart City Expo in Barcelona. The prize recognized Tel Aviv's unique approach to improving the quality of life in the city by leveraging technology. **Digi-Tel** was funded using the regular annual budget, which is funded from city taxes and holdings. The city used in-house software development based on Microsoft's knowledge management and shareware technology.

In Jerusalem, the focus is mainly on security. Jerusalem is Israel's capital and largest city, with a population of 882,652 (Israel, 2013). In recent years, Jerusalem has seen several violent clashes and friction between Arab and Jewish

neighborhoods. The police have been establishing a network of electronic security mechanisms, deploying technologies to automatically detect events, recognize faces, and identify cars. These visual recognition systems are used to automatically identify events that can be handled by forces on the ground. As a result, these technologies allow the security integrated operating control center (IOCC) to be operated by one or two attendants at a time rather than by a large cohort of people.

Israel's port city of Ashdod, the nation's sixth-largest city, with a population of 218,000, is taking a different approach to becoming a smart city based on experimentation and trial and error. Ashdod is setting up a living lab to make the city an international lab for developing and testing advanced transportation systems. The lab is a joint venture with **Mobileye**, the developer of advanced vision and driver assistance systems, Massachusetts Institute of Technology, and several other tech firms, including Microsoft.

The living lab in Ashdod deploys **Mobileye** technology on public vehicles to gain data about accident-prone areas of the city. The project collects data from a number of sources and sets up an open database available to startups, government offices, and academics interested in working on technologies to create smart transportation systems.

2. Research and Development Centers

Smart city technologies arise from several innovation hubs in Israel, providing a backbone for R&D activities. This section describes how these hubs were created and how they can jump-start and support smart city projects.

As with other fields, such as defense and cyber security, the Israeli model is to develop and sustain an ecosystem that can support smart city technology development. The components of the model include R&D institutes, government programs that allow commercialization of research, accelerators and startup hubs, mature companies, and municipalities. Together, this ecosystem can identify, produce, and commercialize technologies in various fields.

2.1. Universities and Academic Institutions

Israeli universities serve as a hub for innovation for smart cities using several mechanisms. In addition to independent research into areas related to smart cities, such as computer science, electrical engineering, and geography, there are research centers dedicated to smart cities.

City Center at Tel Aviv University (TAU): Established in 2016, the TAU Research Center for Cities and Urbanism aims to bring together the many TAU researchers (faculty and PhD and masters students) who are studying cities, technology, and urbanism.¹

Capsula—Smart Mobility @ TAU: Capsula is a partnership between TAU and the Fuel Choices Initiative of the Prime Minister's Office. The center's aim is to reshape global mobility in Israel and abroad. The main program is the Studio, which offers smart mobility startups a three-month residency focused on mentored customer validation.²

Bar Ilan Center for Smart Cities: Established in July 2017 at Bar Ilan University,³ which is co-located near several mid-sized cities, the center experiments with several new technologies, including big data technologies, and applying them to several domains, such as network theories, architecture, and geography. In addition, the center uses the Bar Ilan campus as a living lab for smart city technologies.

Technion civil engineering and urban planning faculties: Though the Technion does not currently have a center dedicated to smart cities, two leading faculties have a significant impact on the field in Israel. The urban and regional planning program, founded in 1969, serves as the largest program in Israel. The Center for Urban and Regional Studies carries out research in spatial databases and urban analysis.⁴

2.2. Startup Companies and Accelerators

Israel is the home base of hundreds of startup companies in various fields related to smart cities. Most companies are funded by independent venture capital and angel investors. The technology provided by Israeli startups is broadly recognized in the international market.

New technologies enabled by mobile devices, the internet of things (IoT), cloud services, big data, and social technologies allow rapid deployment of technologies without expensive physical infrastructure. One of the key characteristics of these technologies is that they blur the lines between industry areas, redefine products

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¹ <https://en-urban.tau.ac.il/>

² <https://www.capsula.studio/>

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³ <https://www.biu-friends.org/smartcity>

⁴ <http://curs.net.technion.ac.il/en/>

versus services, and allow technological solutions to be deployed across country borders. The emergence of these technologies has also made it significantly easier for entrepreneurs to start up new companies. For example, the availability of cloud services provides technology companies with flexible and scalable access to computing resources and reduces the initial investment.

When looking at smart city technologies in particular, many companies rely on cloud and mobile technologies to deploy sophisticated products without getting into large-scale operations that only large companies can carry out. The following are three examples of accelerators and startup incubators that specifically support smart city startups.

Herzeliya Accelerator Center (HAC): A startup accelerator for areas related to urban technologies, funded by private venture capital companies and supported by the municipality of Herzeliya. The city provides datasets that can be used by the startups and the urban space can be used as a testing ground for new technologies developed at the accelerator.

Startups that take part in the accelerator program have access to the workspace and municipal databases, and can interact with the city to run pilot programs.⁵ The accelerator hosts startups in multiple rounds, including a round in 2017 in which startups collaborated with the police to produce security-oriented applications. The round planned for 2018 includes collaboration with an Israeli cellular company regarding IoT applications.

Streets Hub: A non-profit startup accelerator in Rehovot dedicated to startups related to urban

innovation, smart cities, and smart communities.⁶ The accelerator aims to build on its proximity to the Weizmann Institute of Science and support commercialization of ideas that originate in the academic domain. Each cycle in the program includes around five startups that have roughly six months to graduate and promote their idea.

The Library: An urban accelerator run by the municipality of Tel Aviv with funding from Terra Venture Capital and in collaboration with several companies, including Visa, Bosch, and Energias de Portugal (EDP).⁷ The accelerator has completed 16 rounds since 2011. Several startups described in this paper began at The Library, including **BreezoMeter**, a company that developed a location-based mobile app that shows you air pollution levels in real time, and **ZenCity**, which helps municipalities learn about the needs of residents.

2.3. Government Agencies and Incubators

The main government agency related to startup funding is Israel's Innovation Authority (formerly the Chief Scientist Authority) within the Ministry of Economy and Industry. The Innovation Authority is the major policymaking body outside of the university system in all things related to R&D. The Authority includes functional frameworks to fund research and innovation, such as the R&D Fund, the Technological Incubators Program, and the MAGNET (consortia) Program. It includes operative frameworks such as the Israel-Europe R&D Directorate, which manages the Israeli side of the Seventh

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⁵ <https://hac.org.il>

⁶ <https://streets-hub.com/>

⁷ <http://www.thelibrary.co.il/>

Framework Program for R&D Horizon 2020, as well as the Israeli Industry Center for R&D (MATIMOP), which manages all international R&D and bilateral agreements with countries, regions, and international corporations.

The Innovation Authority supports smart city startups mainly through the incubator and MAGNET programs.

Technological Incubators Program: The Innovation Authority initiated this program in 1991 in the wake of the large influx of immigrants from the former USSR, many of whom were scientists and engineers. The intent behind the program was to provide funding to early-stage, high-risk, innovative technological companies that could not raise money from the private sector. A relevant example is the incubator TheTime, which focuses on consumer-facing applications, IoT, and smart cities. This incubator fosters several early-stage companies in this area, such as **Securithings**, a cyber-security solution for IoT device networks; **Books on Map**, which provides location-based content solutions; and **SafeCue**, which identifies traffic events in real time.

The Fuel Choices and Smart Mobility Initiative, Israel's national program for alternative fuels and means of transportation, was launched in 2011 as a joint governmental effort headed by the Prime Minister's Office. The initiative aims to establish Israel as a center of industry and research in alternative fuels and smart mobility. The initiative funds smart mobility research centers to encourage collaboration of academia and industry, supports several pilot demonstrations in the transportation sectors, and funds collaborative research projects.

The Digital Israel Bureau of Israel's national government is responsible for promoting the potential of digital technology and services, with the objective of accelerating economic growth,

reducing socioeconomic gaps, and making government more accessible to citizens. As part of its operations, the bureau develops and operates a unique human capital program—Digital Leaders—for senior executives, invests in promoting and implementing smart and secure solutions, and builds innovative communities, among other projects. The bureau develops and operates programs for municipalities and businesses to finance and develop smart services.

3. Smart Solutions in Action

Some of the diverse challenges facing cities today can be answered with innovation in technology and policy. The solutions developed in Israel have some generalizable characteristics that may be particularly relevant to LAC countries. This section reviews solutions in various domains, including transportation and smart mobility, security, and citizen engagement.

3.1. Transportation and Smart Mobility

As cities become crowded, transportation challenges are becoming crucial to their functionality. Congestion, car accidents, and unanswered demand for parking spaces all hinder the ability of cities to grow their number of residents and their economy, while maintaining the ability of residents and visitors to use existing transportation methods. At the same time, increasing and improving transportation channels by constructing new roads and/or train lines requires a huge investment on behalf of a city. Furthermore, extending the capacity of transportation

channels increases the amount of traffic, leaving the city with even more congestion, overcrowded public transportation, and overflowing parking lots.

On a different note, in developed cities, transportation contributes more than half of the carbon monoxide and nitrogen oxides and almost a quarter of the hydrocarbons emitted into the air. Air pollution carries significant risks to the health of residents, especially in the most populous locations. Transportation accounts for 26 percent of global CO₂ emissions and is one of the few industrial sectors where emissions are still growing, making it one of the largest contributors to climate change processes (Chapman, 2007).

In contrast, most of the smart city transportation solutions developed in Israel aim to enhance the use of existing resources, efficiently using current capacity rather than increasing it. As Israel's transportation was based mostly on cars and buses until recently, it is not surprising that Israeli technologies tended to find solutions that would not require additional investment.

Without the availability of ready infrastructure, innovative solutions in Israel have focused on crowdsourcing as a way to make transportation more intelligent. The first well-known technology used crowdsourcing to improve navigation systems with analysis of real-time traffic conditions. The most well-known of these technologies is provided by **Waze** (bought by Google in 2013). **Waze** uses its large installation base to offer customers navigation and traffic conditions through its app. By helping drivers avoid traffic jams, **Waze** provides a way to better use existing road infrastructure, redirecting drivers to smaller roads and streets when the larger ones are jammed; some drivers may delay trips if the roads are clogged.

Increasingly, crowdsourcing technology is also used directly by municipalities. For example, **Waze** offers a product to municipalities sharing aggregated and anonymous traffic condition information. After a pilot project in Tel Aviv, **Waze** is now used to help manage heavy traffic in Rio de Janeiro, Brazil, and many other cities in LAC. Several other startups display similar characteristics that make them attractive to LAC cities, including their reliance on existing data sources without the need to install new sensors or actuators.

A similar crowdsourcing technology is applied to public transportation. **Moovit**, a company based in Israel, can be viewed as the Waze for public transportation. The company's app enables its users to find the fastest and most convenient routes of public transportation, connecting multiple modes of transport (like trains and buses). The app provides real-time data across a city's entire transit system using information from relevant users.

Another aspect of the Israeli approach to smart transportation is relying on information systems and coordination to better manage existing urban vehicle fleets. Rather than relying on developing new forms of transportation, several Israeli solutions are using information systems to better coordinate their operations. Companies such as Uber, Lyft, and the Israeli company **Gett** enable customers to order a taxi with the click of a button, negating the need for a phone call or waiting on the street. Users can track the upcoming cab on an interactive map and gain mile points for using **Gett** services that can then be used to get free rides. The service is currently available in Israel, the United Kingdom, and Russia, and in several cities in the United States.

Another promising solution for urban transportation is Microtransit, a new term that describes a transportation service that caters to

commuters willing to pay more for a ride that is more direct and comfortable than those offered by existing public transportation (Jaffe, 2015). It is based on small vehicles with no fixed routes that serve multiple commuters.

Microtransit solutions build on algorithms and data analysis to create flexible transportation that merges the cost efficiency of public transportation with the agility of taxis. These solutions re-engineer public transit from a system of rigid routes and schedules to a fully dynamic, on-demand network. Passengers request rides through a mobile app and the technology uses sophisticated algorithms to instantly find a vehicle that best matches their route, allowing for quick and efficient shared trips. Such a solution was developed by **Via**, which operates in New York, Washington, Chicago, and other cities.

3.1.1. Mobility

The ability of cities and transportation designers to use big data analysis is another promising domain for technology application. Understanding how driving conditions and transportation systems are used is challenging without installing expensive sensors.

Accidents and hazards on the road can cause major disruptions to traffic. Big data analysis is an emerging solution that fuses data from multiple sources, including datasets from companies such as Waze, to predict traffic hazards and conditions. For example, **Waycare's** technology uses deep learning to predict accidents and hazards on city roads, allowing dynamic real-time traffic flow optimization to mitigate accidents.

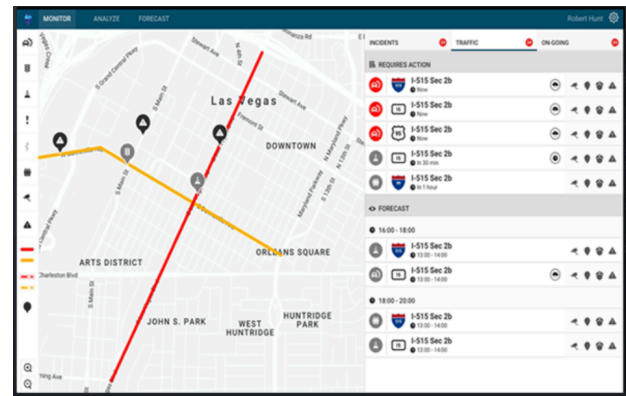


Figure 2: Waycare platform. (Source: Waycare website)

The huge number of smartphone users makes smartphone technology promising for analyzing and optimizing mobility. Municipalities can use information from smartphone users to predict real-time mobility status and location, offering the ability to analyze real-time traffic conditions. Companies such as **Anagog** offer technologies in this market, replacing sensor technology with a system that connects to existing phones. Another solution for analyzing mobility is by connecting to the main switching centers of the mobile networks and tracking all active phones in real time, anonymously and passively, to the exact street they are traveling on, and creating a database that can be used to analyze transportation. This approach has been implemented by the Israeli companies **CitySense** and **Cellint**.

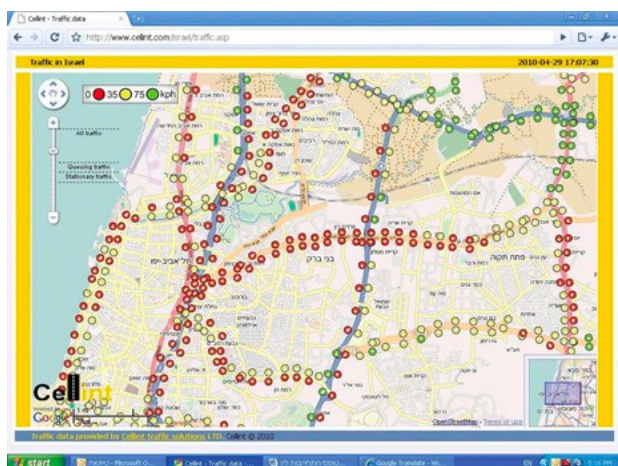


Figure 3: Speed information in Tel Aviv measured by Cellint (Source: Cellint website)

3.1.2. Parking

With the increasing number of cars on the streets, along with the time it takes to park, parking is becoming a major challenge that many cities need to urgently address. Parking is particularly wasteful in urban spaces and it contributes considerably to urban air pollution (Höglund, 2004). Israel's high demand for parking space, especially in Tel Aviv, has encouraged many startups to try to solve parking problems without installing expensive infrastructure. Here too, several innovative solutions aim to achieve the accuracy and performance of sensor-based systems without making any additional large-scale investments.

A general approach to solving parking problems is to better use existing resources by organizing them better and letting customers find and use available spots. Specifically, a study carried out in Israel showed that drivers tend to search for parking spaces in central locations, missing streets that may have more parking (Levy, Render, and Benenson, 2015). Solutions focus on various ways to recognize and direct customers to parking spots. One innovative technology uses video feeds from existing close circuit TV (CCTV) cameras to analyze the availability of parking

spaces. The system is based on existing CCTV cameras, so it does not require installation of costly sensors and displays, making it particularly relevant to LAC cities. **ParKam** uses this technology to offer several products, including an availability map and in-app real-time navigation.

A truly innovative approach is creating new markets for parking based on private parking. The lack of parking spaces in urban centers draws residents to use their own private parking as a profitable resource. However, only a few residents and businesses use their unoccupied parking spots because managing them is difficult. A promising solution is to use brokers to mediate between parking spot owners and seekers. **Eyfo** is an app that allows residents to mark available resources, including parking spots, and to share them with the community.

Another challenge related to parking is the limited ability of cities to create revenue streams out of transportation-related resources. While roads and parking spaces are some of the few resources cities can profit from, their ability to do so is limited by the costs to enforce laws and bill residents and visitors. Parking payment solutions is a growing market in Israel. Allowing easy access to parking payment is another crucial problem. Technologies that facilitate mobile payments rely on mobile applications and other mobile methods. For example, **Pango** is a mobile app that enables its users to pay by phone for their parking spaces. The solution is used in more than 47 large cities around the world, has more than 1,300,000 pay-by-phone transactions per month, and more than 700,000 customers. **Parx** provides parking payment and management solutions for municipalities and parking operators. The company offers a set of payment solutions through mobile applications and smart cards, as well as a backend parking

management systems and business intelligence tools.

Raising revenue through parking is a problem that is also answered by building smart infrastructure parking garages. Solutions include sensor-based systems in which free spaces are recognized, enabling operation of smart parking lots. The data is analyzed and then used for multiple applications, such as directing the driver to an available spot, presenting information about availability through billboards and mobile apps, and better designing parking garages.

Several technologies have been developed to facilitate smart infrastructure for parking lots. **Afcon** and **Tiba** have developed a centralized control system that can operate actuators, displays, and third-party applications through the cloud. One example of this third-party application is **Neopeach**, which uses smart parking systems to direct the driver to a free parking spot. Several Israeli companies, including **NovaSens**, **Spaceek**, and **Parkom**, have developed new parking sensors with the intention of lowering deployment costs. The first two companies rely on flat sensors mounted on the road, and **Spaceek** adds CCTV cameras. **Parkom** uses a cable installed 2 inches below street level to sense free parking spots.

3.1.3. Parking Violations

Identifying parking violations, an important revenue stream, is a serious problem for municipalities. Traditional methods of fining violators, mainly using inspectors, are very costly. Image recognition technologies can revolutionize many aspects of recognizing parking violations and reduce the costs of managing urban parking. Video analysis is being used for several types of applications.

The **Safer Place** platform uses video analysis to identify parking violations (such as occupying spaces for the disabled, blocking the sidewalk, and parking in no-stop zones) as well as traffic violations (such as failure to yield, mobile texting, driving on the shoulder, and crossing a solid line). The analysis can be based on fixed cameras or on mobile cameras mounted on municipal vehicles. In addition to automating ticketing, the system produces legally compliant photo-based evidence that can reduce legal appeals.



Figure 4: A mobile system by Safer Place mounted in a police car. (Source: Safer Place website)

If the car is being towed, residents and visitors may not know how to find it and pay for it. **Tugger** is a multilingual mobile app designed to help drivers locate their towed vehicles in major cities all around the world.

3.2. Emergency Response

The basic idea in smart cities is to connect citizens to each other and to the city's infrastructure. In this context, smart cities can be crucial in managing and responding to an emergency. Smart cities can reduce the risks of emergencies and the response time. Information systems can help first responders and decision-makers to act more efficiently and with better awareness of what is happening on the ground (Musigdilok, Demeter, Burke, et al., 2017). This section describes several aspects of emergency

response and demonstrates how several technologies can provide a meaningful answer. Israel has dealt with several emergency situations in the recent past and developed several innovative technologies to respond to emergencies. Of these solutions, several are very relevant to challenges faced by LAC cities, including crime, accidents, earthquakes, tornados, hurricanes, and other events.

Due to the tense security and political situation in Israel, emergencies tend to include armed conflicts, such as that between Gaza and Israel in the summer of 2014. Handling such events requires close collaboration between central government, local governments, and private companies. Preparation for emergencies includes mapping different data sets on the government's geographic information system, or GIS, such as people in need of assistance or local control centers. Systems that protect against rockets have been deployed on a large scale following recent clashes with the Hamas government at the Gaza strip. In recent conflicts, an integrated system that is connected to the interception system (the Iron Dome) has been deployed. The government provided an open application programming interface (API) for the alert system, so multiple groups of developers have created applications that send mobile alerts in the event of missile attacks. The same mode of operation can be applied to other countries and other situations, such as natural disasters. Such systems require local and national governments to provide a secure API for major programs, but it allows groups to create innovative applications that enhance government services.

One of the main challenges in areas that are prone to natural disasters is notifying citizens about emergencies. Mass notification technologies aim to provide a solution by enhancing emergency responders' mass notification capabilities through a geo-targeted,

multichannel alert and notification system. For example, **Evigilo** seeks to quickly alert citizens through every possible channel, including phones, smartphone apps, computers and tablets, calls to landlines, television, radio, and even billboards. The system proved to be effective when a magnitude 8.3 earthquake hit the Chilean shore in 2014. **Evigilo's** system provided notifications to hundreds of thousands of people, allowing them to escape tsunami waves.

A pressing challenge for certain LAC cities is recognizing earthquakes as soon as possible. A class of technologies for regional earthquake early warning systems provides early warning based on real-time integration of different sensor types and machine-learning algorithms aimed to improve the ability to accurately foresee an earthquake's magnitude and epicenter. Companies such as Israel's **SeismicAI** have developed products that connect to notification systems and allow about 15 to 30 seconds of advanced warning.

Coordination between first responder teams and between responder teams and residents is a major challenge for cities. An exciting new field of emergency response systems relies on crowdsourcing and direct communication with citizens. Mobile apps allow citizens to tackle security incidents and to communicate, through live video streaming, with the relevant emergency agency and report directly from the scene of the incident. The technology enables command-and-control centers to collect all reports, prioritize them according to their emergency level, and refer the most relevant information and data to the call takers dealing with the report. According to the information received from the scene of the incident, the call takers (emergency teams or citizens near the place of the incident) get a full picture of the

matter and thus can better understand how to manage the event in the field.

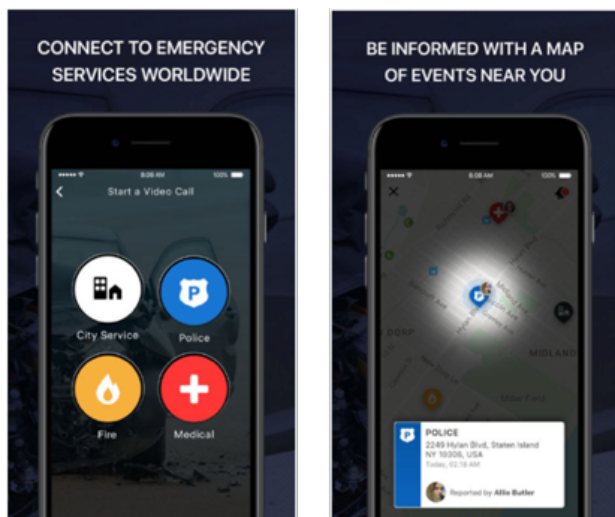


Figure 5: Screenshots of the Reporty app for reporting an incident (left) and receiving information about nearby incident (right). (Source: Reporty website)

Several Israeli companies provide solutions based on mobile app technology. **Reporty**, **NowForce**, **OCTOPUS**, and **Sayvu** offer a command-and-control mobile application for emergency response and security organizations to reduce response times and coordinate multiple first responders and citizens.

3.3. Security

Safety and security of residents is always a top priority for cities. As cities invest increasing resources in CCTV and surveillance infrastructure, the costs of running the security apparatus grow considerably. Therefore, solutions aspire to reach a high level of safety and security while maintaining or reducing costs. Solutions include several approaches. A promising approach is to use computer vision technologies to recognize events, reducing the personnel required to manage security operations. This is a particularly relevant example of how artificial intelligence, or AI, technologies can provide an affordable

alternative to many of the IOCCs in Latin America.

Video analytics technologies rely on machine learning to detect real-time events and for video search and business intelligence applications. For example, event detection technology can recognize if people enter some predefined areas, if an area is becoming crowded, if an object (like a bag) is left alone, or if cars are tailgating or stopping in specific places. **Agent VI** has developed several products based on computer vision algorithms that are deployed in hundreds of sites around the world. In Tel Aviv, it serves IOCC, where a single person is enough to control thousands of cameras.

Image recognition solutions are also applied to various other objectives. **Levitection** has a product that connects to video feed and automatically detects and alerts security personnel to the presence of weapons in large, open spaces. Other vendors of video and sensor analysis software include **Verint** and **NICE**, which provide surveillance, video recording, and intelligent monitoring for law enforcement, municipalities, and private companies. Another company in this field, **Attenti**, was recently acquired by **3M** for \$230 million, and **Visonic** was acquired by Tyco International in 2011 for \$99.4 million.

Accessing and analyzing video feeds is a crucial and costly operation that can require extensive manual labor. Reducing the personnel required to handle surveillance is also the objective of **BriefCam**, which developed an image processing technology that summarizes hours of full-length video and eases the burden of browsing massive quantities of video footage.

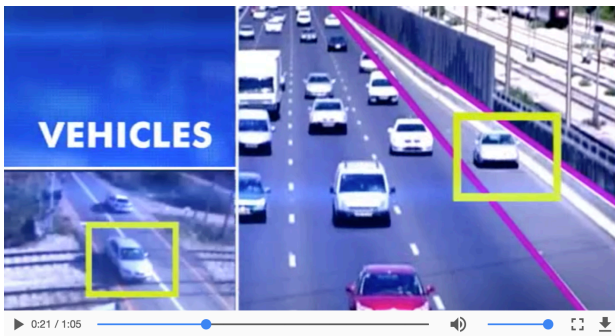


Figure 6: An example of Agent VI event recognition technology. (Source: Agent VI website)

Safe City in a Box (SCIB) developed a kit for city safety. The kit includes high definition cameras and other sensors, a LAN and wireless network, WiFi, mobile, a C41 command-and-control center, and API/SDK software that can be used to build supplemental applications. A novel type of sensor was developed by **SensoGuard**, which provides systemic sensors used to secure sensitive areas.

3.4. Smart Streets and Buildings

Enriching housing, building, and streets with technology serves several objectives. The first and foremost objective is to reduce the cost of electricity and other running expenses. Second, the urban environment can be better navigated and serve residents and visitors. Lastly, cities can expand their revenue streams from the physical infrastructure through digitalization and embedded e-commerce. The solutions to these challenges are mainly based on IoT (internet of things) frameworks that connect and control physical infrastructure. Smart furniture systems provide a sophisticated way to connect the urban environment to smart city systems.



Figure 7: An outdoor anti-vandal 46" digital solar powered sign which provides real-time complete transportation data. (Source: Urban Digital website)

While LED lighting can reduce energy consumption for street lighting by up to 50 percent, installing a lighting control network offers cities an opportunity to deploy a range of cost-saving solutions and improve sustainability. At the basic level, lighting controls provide centralized operation that enables on-off, dimming, and scheduling functions. However, these solutions can be expanded to sophisticated performance optimization, adaptive lighting, etc.

Lighting network solutions are based on a range of networking technologies. Some solutions, deployed mainly in crowded areas, are based on local WiFi networks (with products by companies such as **Metro Control**, **Gaash**, and **Juganu**). These technologies include lighting fixtures (electronic ballasts and LED-connected drivers) connected to WiFi and cloud-based servers that enable intelligent operation of lighting, including programming the times, locations, and parameters in which the network operates.

Large-scale lighting solutions are based on a mixture of networks, including 4G, 5G, WiFi, and peer-to-peer networks. Those networks also connect to a centralized server that can be programmed and optimized for efficiency. Companies that offer cloud-based smart lighting

solutions are **PowerSines**, **Virtual Extension**, and **Menolinx Systems**.



Figure 8: The Apollo lightning luminaire by Metro Control. (Source: Metro Control website)

Connecting street lights together in a network offers a wide range of innovative technologies that can save energy and improve lighting efficiency. However, the lighting network can be the basis for a ubiquitous platform for smart city applications. Large-scale lighting networks are costly, but deploying these networks also offers cities a unique opportunity to create a new IoT infrastructure. This poses a relatively cost-effective way of supporting sensor networks. The streetlight network can serve as a gateway for smart cities and an IoT hub, enabling connections between sensors, cameras, and applications. Startup company **Bright** has developed a network of connected streetlights that optimizes the optical, thermal, and electrical aspects of the lighting configuration.

On the level of large housing projects, challenges arise from lack of communication between residents. **My Tower** provides IoT management tools for more efficient communication and services in connected residential buildings. They develop a neighborhood social network that can update residents about events and conferences and provide a direct connection to local authorities to report and file complaints related to the neighborhood. **Onh** develops systems that

connect municipalities, real estate developers, and residents.

3.5. Water, Energy, and Waste

Water and energy are the basic services required for urban settlements. Cities struggle to protect their water and energy supplies, prevent water waste, and expand supply as demand increases.

Surrounded by and populated with deserts, Israel has famously created a green and agricultural area (Shi, Luo, Zhao, et al., 2015) out of its arid landscape. The Israeli water industry is widely acknowledged as a world leader, especially with its entrepreneurial technologies in the areas of desalination and water treatment.

Today, there are more than 500 companies in Israel that work on water and cleantech, operating in various fields related to sustainable water, energy, and environmental technologies. The cleantech sector is dominated by early-stage companies, with a small number of internationally established commercial brands mostly concentrated in the energy and water sectors. The list of companies working on water treatment is very long. This section focuses on companies that work on cutting-edge solutions for large urban populations.

3.5.1. Smart Irrigation

Municipalities are mindful of the significance of improving public areas with vegetation and gardens to signify their commitment to residents and tourists that visit their cities. The main challenge in maintaining those gardens is to reduce the costs, especially of the two major expenses: manual labor and water.



Figure 9: GreenIQ Smart irrigation hub and actuators.
(Source: GreenIQ website)

Cutting-edge technologies in water management systems focus on replacing old irrigation systems with smart solutions that reduce waste and provide new planning capabilities in water management. Intelligent systems leverage weather forecasts and ground data to provide a more efficient approach to irrigation. IoT technologies can solve several important challenges in smart irrigation. Garden hubs connect IoT devices to a platform that controls irrigation scheduling based on current and forecast weather, as well as controlling the garden's lighting, fertilizing, and alerts of leaks and pipe breaks. Intelligent solutions are based on generating irrigation maps and automatically applying the right amount of water to different areas based on the type of soil, type of vegetation, and other parameters. Such solutions serve farmers worldwide. For example, companies such **GreenIQ** and **Cropx** develop sensor and management systems for small and large gardens.

However, the challenge of urban irrigation is not limited only to gardens maintained by the municipality. A growing trend in cities is to maintain community vegetable and herb gardens. Smaller-scale solutions for growers are centered on smart devices for hydroponic growers that aggregate data from thousands of sites around the world and uses algorithms and

machine learning to predict and optimize the growth of food and plants. Devices are placed in the growing environment on the water's surface where its sensors monitor the nutrition content of the water. It connects to a mobile app, sending data and guidance to the grower's phone. By aggregating input from the globally connected network, the program supplies expertise for individuals and smallholder farms. For example, such a device is Eddy, produced by Israeli company **Flux**.

3.5.2. Urban Water Access

Allowing residents and visitors access to fresh water in urban environments is a growing need with the increase in tourism and sport activity. However, drinking facilities are hard to maintain over time and require high maintenance. An emerging solution is to create drinking stations that can generate revenue to maintain them. **Woosh** provides smart water fountains, with a purification system and bottle-cleansing system for reusable bottles. **Watermedia** developed a connected water fountain that shows promotion clips, generating potential new means of revenue for municipalities. The water fountain analyzes the customer's age and gender (based on image analysis) to provide targeted ads.



Figure 10: Watermedia's fountain, analyzing customer's age and gender for personalized ads. (Source: Watermedia website)

3.5.3. Water Management

One of a city's most critical infrastructures is its water system. The growth of cities means that water production should grow as well; however, as water sources are becoming scarce, new and innovative solutions need to make better use of water resources. Smart city solutions aim to build water infrastructure that ensures that water is managed effectively.

A smart water system is designed to gather meaningful data about the flow of the city's water and to act to efficiently optimize operations. Solutions continuously monitor water consumption and learn the water consumption patterns of a home or office to efficiently and accurately manage water resources. Such technologies can provide an indication of water consumption—even on an hourly basis—and alert users about abnormal consumption. Companies such as **Flowless**, **Aqua Rimat**, and **TaKaDu** have developed solutions for smart water management and control for private homes and businesses, helping prevent water damage, unnecessary water waste, and related costs with real-time leak detection and alerts, automatic system

shutdown, continuous monitoring of water consumption, and analytic tools for water providers to allow them to monitor and analyze the performance of the water network.

Recognizing leaks is a particularly hard task. New technologies aim to mainstream this process by finding leaks with acoustic sensors and machine learning. These sensors can be attached, temporarily or permanently, to water pipes above ground, eliminating the need to put sensors underground. **Aquarius-Spectrum** develops technology in this field, extending the sensors with applications such as monitoring, management, and budget-planning systems.



Figure 11: The iQuarius mobile sensor. (Source: Aquarius-Spectrum website)

Another innovative way to discover water leaks is by analyzing satellite imagery from space. Treated water can be recognized by looking for a particular spectral signature typical of drinking water. The user is then presented with a graphic leakage report overlaid on a map with streets and pipes. A company named **Utilis** developed technology that can identify fresh water leaks in urban drinking water supply systems.

Controlling various aspects of the water management system with connected devices is another way cities can reduce water waste and optimize water use. Technologies that manage various components of the system focus either on internal components, such as smart hydraulic

control valves, and end points, such as connected water meters. Several Israeli companies develop technology for smart, remotely accessed meters, including **MTR Wireless Communications**, **Nortex Technologies**, **Mediward**, **Bermad**, and **Mitel Communications**, which develops, manufactures, and sells telemetry radio frequency (RF) solutions. Creating networks for water systems is challenging because it also requires many network routers and antennas. **Telematics Wireless** develops machine-to-machine communication and management systems that can be used for water resource and energy management.

Urban water systems also require filtering. **Amiad** and **Yamit** are two companies that sell new technologies that filter water without using chemicals or polymers.

However, all the sensors in water systems require energy. A very innovative technology uses micro-energy from the water pressure by installing generators within urban water pipelines, allowing cities to manage their smart water networks without having to replace batteries or set up power lines to sensors. **HydroSpin** produces micro generators to be installed inside water pipes.

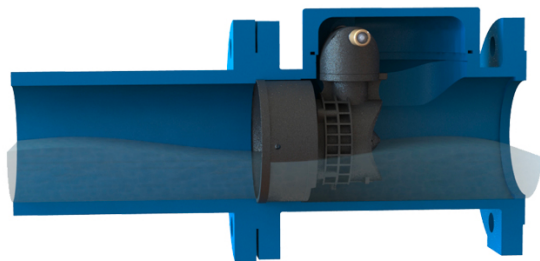


Figure 12: HydroSpin micro generator installed inside a water pipe. (Source: HydroSpin website)

Triple+ detects high-risk events such as gas and water leaks or when people leave buildings unattended.

3.5.4. Wastewater Treatment and Desalination

As urbanization continues, cities must provide healthy water with ever greater sustainability. Two ways to do so is to recycle water or produce fresh water from seawater. For many years, Israel has been a leader in water processing solutions. Roughly 90 percent of wastewater in Israel is reused, making it the nation with the highest recycling levels. Furthermore, several new startups and technology companies are innovating in the field of energy and water management.

Solutions for purifying water include an integrated approach from early-stage evaluation, through design and delivery, to ongoing support and optimization of water assets. Technologies include purifying and cleaning rivers polluted by urban waste (such as **CleaRivers**). Other technologies focus on converting various common water contaminants into nonpolluting compounds using a catalyst that enables a chemical reaction to remove the contaminants (**WellToDo**).

Other technologies to recycle wastewater include some for wastewater treatment systems for industrial and municipal applications. Companies include **Ayala Water & Ecology**, **Plasson**, **ArrowBio**, **AST Clean Water Technologies**, **En Gibton**, **Bluvstein Binot Topaz**, and **Tahal Consulting Engineers**. A particularly interesting technology uses ecological water-disinfection technology based on electrical pulse discharge in water. The method causes a strong shock wave, high light radiation (including UV), high magnetic and electrical fields, ionization and polarization of molecules, cavitation, and very high temperatures at the discharge canal. This technology is offered by **Wadis**.

Desalination is another solution to increase availability of water in cities. **IDE Technologies** specializes in desalination and has built roughly 400 desalination plants around the world. It runs one of the world's largest desalination facilities off Israel's coast in the town of Ashkelon and another at Hadera. **GES**, which designs water and wastewater plants, can also build and operate plants in industrial areas and cities and for agriculture. **HydroP** (Hydrophilic Processes) is working to improve membranes for desalination processes.

3.5.5. Fighting Water Pollution

Water pollution is another urgent urban need that is being tackled by new smart cities technologies. Technologies that recognize and prevent pollution events monitor wastewater quality in real-time, using sensors placed in wastewater manholes to monitor water toxicity levels, detect a pollution event the instant it occurs, and take a sample of the toxic discharge for analysis. The exact composition of the taint is analyzed at the very earliest stage of water contamination to aid in detecting the source of the toxicity. A system by a company called **Kando** can then calculate penalties according to local regulations, producing formal notifications and sending notice of the penalty fee to the polluter. Thus, pollution events can be stopped at the beginning, while allowing cities to generate new revenue.

Other pollution detection solutions aim to provide early warning systems for water supply contamination using a network of luminescent biosensors. **Biomonitech** uses nonpathogenic, luminous marine bacteria as highly sensitive sensors that can rapidly indicate changes in water quality.

3.5.6. Waste Management

Waste collection and management is an essential city service, but in many cities it is an inefficient and ineffective process. Today, most waste collection operations basically empty containers according to predefined schedules. This is inherently inefficient because empty bins get emptied while other bins overflow. The challenge is often lack of coordination and information about waste. Smart city technologies offer particularly promising solutions.

The first type of technology is to collect real-time information about waste through sensors that measure the volume of garbage cans (such as products by **Genio** and **NovaSense**). The information can then be used to intelligently plan schedules and routes to empty cans. Other solutions include an additional level of dynamics. **GreenQ** offers a connected garbage collection platform for municipalities. The company's technology optimizes garbage collection by showing trash companies their trucks' location history as well as the bin capacity of residents' trash cans.



Figure 13: Genio garbage volume sensor. (Source: Genio website)

3.5.7. Energy

Energy management is one of the most demanding issues in cities because of the complexity of energy systems and because they are crucial for almost every activity in the city.

Furthermore, with electric cars and other developments, it is predicted that energy consumption will only go up. At the same time, climate change and pollution make it very clear that increasing the capacity of energy production is not so simple.

Innovative solutions include managing and generating energy. The ability to better manage the grid in urban areas can be based on technologies that use machine learning to provide predictive analytics for the energy infrastructure. A solution by **Grid2C** analyzes data collected from smart meters alongside customer data, weather data, and pricing information to maximize the efficiency of energy operations and increase customer engagement.

Other solutions focus on managing the redundancy of energy in urban environments. **Brightmerge** develops micro-grids based on sources of renewable energy in an effort to bridge the power gap between the grid and the electricity needs of individual properties.

Producing renewable energy in the city is a growing field. **SolarWat** provides a photovoltaic module for solar energy, making it cost effective and universally applicable to utilities, rooftop solar, sidewalks, and roads. **SolarBead** is developing a smart converter suitable for rooftops and small- or medium-sized power plants. The inverter is based on patented algorithms that improve system performance and enhance energy harvesting, especially in cases of partial shade, degradation of module performance, or rapid alternation of solar radiation.

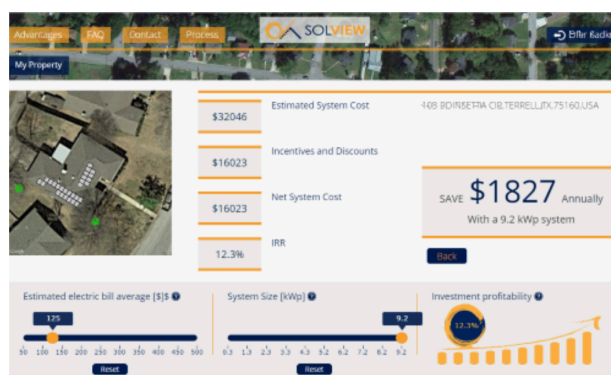


Figure 14: The solar estimator by SolView, showing the predicted annual savings for a home. (Source: SolView website)

Understanding how solar energy can be used in cities has the potential to create cheap energy for households, reducing demand on the grid. An innovative solution is suggested by **SolView**, which developed automated solar-potential assessment and lead-qualification tools to target solar sales. Its platform allows solar professionals to predict the energy savings of every home in urban areas. With this information, sales people can target potential customers, increase conversion rates, and reduce marketing and customer-acquisition costs.

Another form of renewable energy is waste-based electricity generation. **Blue Sphere** is an international independent power producer that transforms agricultural, municipal, and industrial waste into electricity, natural gas, compost, and other byproducts.

Storing and making the energy available is a major part of renewable energy. **Gencell** designs and manufactures fuel cell power generators that can provide backup power to essential urban resources, such as communication towers. Solar energy is one of the most readily available sources of alternative energy to date, but it is entirely dependent on strong daytime sunlight. **Brenmiller** has developed a thermal energy storage device that can absorb energy from a

variety of sources: wind energy, solar panels, an electrical grid, water, etc. The device stores the energy and supplies electricity by generating steam.

3.6. Climate Change

Climate change poses an imminent threat to cities. Excessive heat and air pollution increase mortality and morbidity in cities on six continents (Harlan and Ruddell, 2011). In Israel, the most looming challenge are forest fires, which have become widespread in the past decade (Lelieveld, Hadjinicolaou, Kostopoulou, et al., 2012). On the other hand, cities are also one of the largest contributors to climate change gasses. Therefore, reducing carbon emissions and solving environmental challenges cannot only improve the quality of life within the city but also have a significant positive impact on the whole planet. In addition to climate change threats, energy consumption and production in cities also creates pollution that hurts the urban population.

Fighting climate change requires cities to engage diverse stakeholders and create incentive systems to challenge existing markets of energy toward a more sustainable urban environment. Smart cities can provide municipalities and residents with tools to understand and fight pollution and carbon gas emissions.

An interesting technological solution to carbon gas emissions is based on hyper-spectral imaging technology and systems that monitor, detect, and track particulate matter and biochemical agents. The technology can be operated from various aircrafts and satellites (**GreenVision** uses light aircrafts) and can be deployed several times a year. Other solutions use air pollution sensors that can be installed on

public or private housing (developed by **Argolan**). Another solution is based on mobile phone applications, crowdsourcing weather and pollution sampling. **BreezoMeter** has developed an API and a mobile app that allows users, including organizations, to receive accurate air pollution data.

In the Eastern Mediterranean, hot, dry weather is one of the most dangerous effects of climate change, increasing the risk for wildfires. After a devastating fire in 2010, the research department of the Ministry of Public Security, together with researchers in meteorology and forest fire behavior, developed an operational technology to predict the spread of fires called **Matash**. The system consists of collected meteorological data, such as temperature, relative humidity, precipitation, and wind direction and speed, as well as infrastructure data, such as topographical conditions, a map of flammable materials, and the moisture level of vegetation. The system then uses the data to predict the fire's spread, providing the information to firefighters and other municipal teams.

3.7. Citizen Engagement

Municipalities are governance bodies that need to provide quality services to their citizens, communicate routinely with residents, and get elected. Therefore, establishing open, transparent, and trusting relationships between the municipality and its citizens is a crucial challenge for municipalities. Another concern is maintaining branding as a technologically innovative and meaningful place to live.

An example for an approach that tackles this complicated challenge, is Tel Aviv's core smart city project **Digi-Tel**, a platform that provides personalized access to services and information

via email, text messages, a tailored website, and a tailored mobile application. The information provided is uniquely relevant to citizens, taking into account their location, interests, needs, and other personal attributes. **Digi-Tel** creates a connection between the city and its residents by alerting them to neighborhood road work, showing them the nearest bike-sharing station, or offering discounts to cultural events. It also promotes active participation, as residents can report on anything from activities and events to city obstacles or hazards.

A pressing need for municipalities is to receive feedback from their citizens and to communicate effectively. Several solutions aim to provide local governments with better information regarding their residents. Analyzing social networks and other communication channels for people's sentiments and issues with the municipality is an innovative field. **Zencity** is a dashboard for local governments that provides real-time insights based on citizen feedback. **Zencity's** algorithm analyzes interactions across many platforms, such as social media, municipal hotlines, etc., and finds out the trends, topics, and sentiment in citizens' discussions about the city.

Using social media in smart cities is also the approach of **P-Pulse**, which processes transactions from live, anonymized geospatial data collected from individuals, social media channels, live-streaming sites, open government data, and non-governmental organizations. The system presents the information using a visual-mapping interface integrated with a built-in time machine for smart decision support.



Figure 15: P-Pulse user interface to present city events. (Source: P-Pulse website)

Neighbor is a system for managing resident relations in housing towers. It incorporates an automatic payment system, a social network and communication mechanism for the residents, and other services.

Many of the engagement challenges cannot, and perhaps should not, be answered by government but by citizens themselves. **Playkers** is a social network for athletes, helping residents find courts and resources and to organize.

4. Infrastructure Technologies

Technology is empowering cities to respond quickly to various challenges. However, smarter applications and services require a robust and agile infrastructure that can support and them. Different types of smart city services require different types of infrastructure. For example, citizen engagement systems such as **Digi-Tel** require big data infrastructure that can support complex queries on a resident data warehouse. Video streaming, the basis for many security and traffic control services, requires fast networks, which are also necessity for security applications. All of these applications require a secure network that can protect the applications

and IoT devices from hackers and to communicate directly with users. This section looks at four areas of infrastructure technology: big data, mobile and smartphone technology, software architecture, and networks and cyber security.

4.1. Big Data in Smart Cities

Big data is becoming an essential tool in managing and making decisions in cities. The smart city intelligence and data analysis market continues its transformation as big data technologies allow massive datasets to be stored and analyzed. A big data technology stack includes an infrastructure layer consisting of servers and network devices, and a data organization and management layer that processes structured and unstructured data for analysis. As populations in cities grow, the efficient use of limited resources becomes more important. A key factor in smart cities is the analysis of large quantities of data to better manage resources on the micro level.

Several companies offer solutions for big data analysis based on both video and geospatial data. **Qognify's** system provides insights that correlate structured and unstructured data from multiple sensors and channels, detecting irregular patterns and recognizing trends. **Verint's** suite of video surveillance solutions meshes data from geo-tagged sources to provide security intelligence and insights to improve security responsiveness.

In parking, **ParKam** provides business intelligence tools to analyze and design parking resources. For example, a heat map to better design any smart city parking lot, a business intelligence tool for parking lot management, and an enforcement tool that provides the controller real-time indication of any parking

violation within the visible area (such as double parking or parking in a restricted area). As the system is based on existing standard cameras, it does not require installation of costly sensors and displays, making it particularly relevant to LAC.

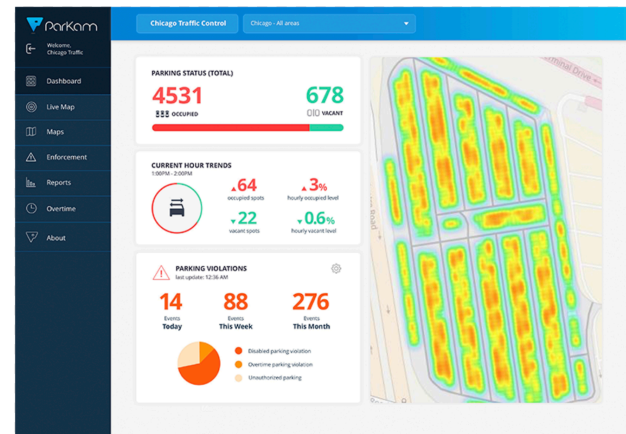


Figure 16: A screenshot of ParKam's heat map of a car park (Source: ParKam's website)

Another example is the startup **Waycare**, which uses big data to predict accidents and hazards based on multiple data sources, including inductive loop traffic detectors, microwave vehicle detectors, weather data, events (such as concerts and sporting events), camera feeds, and navigational apps.

In the field of energy, **Grid4C** uses big data with machine-learning capabilities to provide predictive analytics to energy value chain participants. The company's solutions analyze data collected from millions of smart meters alongside customer data, weather data, and pricing information to maximize the efficiency of energy operations and increase customer engagement.

4.2. Mobile and Smartphone Technology

Mobile apps and devices are becoming increasingly important to gathering data and

interacting with residents in smart cities. Smart city services notify residents about traffic congestion, public transportation, and a host of other useful information (Meyerson, 2013). For example, through mobile apps, **BreezoMeter** provides air quality data and **Reporty** allows users to be notified about emergencies.

Mobile technology is also used to analyze the behavior of residents and visitors to a city. For example, several companies use mobile signal data to learn about people's mobility and to design transportation infrastructure. **Trendit** uses call detail records, which are generated by mobile carriers, as an anonymized mobility dataset to determine how many people are in a place and how they got there. **Anagog** offers technology that analyzes multiple smartphone sensor signals to capture, analyze, and understand the real-time mobility status and location information of smartphone users. The company's technology makes it easy for businesses to identify consumer behavior and competitive trends.

4.3. Software Architecture

Smart city activities require large-scale software infrastructure systems that integrate data, services, and processes. While most smart city services start by building IT services in a specific domain, the following information highlights some general trends.

ContextShield provides a platform to manage citizen data for smart city applications while protecting privacy and complying with privacy regulations, such as the General Data Protection Regulation, a regulation by which the European Parliament, the Council of the European Union, and the European Commission unify data protection for all individuals within the European Union.

One major challenge is to create networks of connected devices. **RealiteQ** is a virtual IT network based on supervisory control and data acquisition (SCADA) used for real-time remote control, monitoring, and crisis management, especially with water-control and energy systems in smart cities.

4.4. Networks and Cyber Security

Creating scalable and agile communication networks is essential to developing new smart city technologies. **Ayyeka** develops end-to-end remote monitoring solutions that can bring field data to management systems and SCADA systems. The company's solutions are designed for dispersed-asset networks, such as smart water network, smart grid, oil and gas, built environment, environmental, and smart-city applications. A similar need for the world of video is answered by **Surf Solutions**, which has developed a technology to gather and consolidate video from multiple sources in real time.

Waterfall Solutions provides network security products that secure networks for sensor and SCADA-based networks. The company's products provide stronger-than-firewall protection for industrial control networks. Companies such as **IPgallery** and **WaveIP** have developed IoT-based solutions, creating new IoT networks and mobile edge computing networks. **Mobilicom** designs and develops spontaneous mobile wireless communication solutions based on fourth-generation (4G) mobile wireless technologies and ad hoc broadband mesh networks.

5. Partnerships and Processes

Smart cities are built through processes that include many stakeholders, including cities, technology providers, research organizations, and residents. This section points out two distinct processes that demonstrate how smart city technologies can grow and evolve: financing and developing smart city projects, and collaboration between academia and industry.

5.1. Financing and Development

Considering the Israeli case study, there are several distinct paths to finance smart city projects. It is important to note that many of the solutions do not require large investments in infrastructure. For example, **Waze** offers large-scale information about traffic conditions at a fraction of the cost necessary to deploy physical infrastructure. Similarly, companies such as **Agent VI** can reduce the costs of running an IOCC from 25 routine workers to just one or two.

Several companies, such as **Safer Place**, offer a pay-as-you-go model that allows municipalities to minimize costs while creating new cash flow streams. **Fluence** provides financing packages to finance water and wastewater treatment plants using a build-operate-transfer model or through operating and financing leases.

Blue Sphere partners with various investors, banks, and other institutions to fund projects. The company's main business model is build-own-operate, whereby long-term energy agreements are executed with national governments or electricity companies in advance of the projects.

5.2. Academia and Industry Collaboration

In some areas, Israel has consistently been a global leader in R&D development, including expenditures on R&D as a percentage of GDP and percentage of engineers among residents. Several relevant programs can serve as a model of incorporating R&D into practical technology.

Many of the technologies mentioned in this paper are the fruit of long years of academic research in Israel. For instance, **WellToDo's** technology was developed at the Technion and was quickly funded after it was proven at pilot sites in contaminated wells in Israel.

The Tel Aviv-Yafo municipal government aims to retain and attract talent in the international competition for high-tech innovation. On several fronts, the municipality of Tel Aviv has actively encouraged foreign startups and entrepreneurs to participate in its local startup ecosystem. As part of this initiative, the city develops programs for international students to stay in Tel Aviv and build technology, supports international networking events and conferences, and provides discounts on city taxes for technology companies.

Another attractive model is the new Advanced Technologies Park recently established in the city of Be'er Sheva. The objective is to encourage high-tech companies to locate in the city. Companies can benefit from close proximity to the Ben-Gurion University, the Soroka Medical Center, the new Israel Defense Forces technology campus, and Israel's national cyber headquarters. Companies are also entitled to city and state incentives, including investment grants, reduced tax rates, a property tax discount, and participation in expenses and employment grants.

Technology and innovation hubs are currently also being promoted in smaller urban and rural areas that are offering financial advantages and tax benefits. Other hubs of startups in Israel are located in cities such as Herzliya, Netanya, Petah Tikva, Ra'anana, and Yokneam.

Hackathons are used throughout Israel as a way to inspire smart city innovation, to identify talent, and to explore possible venues for development and collaboration. Smart city hackathons have been carried out in Tel Aviv, Ramat Gan, Jerusalem, and in many other cities. The cities provide the space, some funding, and, many times, access to urban data repositories.

The processes described here point to several paths to create and use smart city technologies. Thus innovative technology is a combined effort between academia, government agencies, and private companies. Moreover, as Israel's smart city technologies rely increasingly on data analysis and light-weight sensing (such as video analytics), smart city projects are becoming more cost effective and the ability to fund them is becoming more flexible.

6. Conclusions

This section summarizes the technologies and processes described in this paper and points out several directions in which smart cities can move forward.

As smart cities continue to evolve, more and more domains are becoming part of the "smart" framework. While early projects have focused on municipal information systems and mechanized infrastructure, many of the startups covered in this paper provide solutions that make cities smarter by allowing new types of interactions between its governing bodies and its residents. This smart type of institutional approach to

Smart Cities is one that can and should be adapted and replicated in LAC.

Analyzing the technologies covered in this paper reveals several principles that can be applied to many domains. Many are based on light-weight sensors, connected by a flexible network, based on mesh networks or 5G cellular networks. As a result, the technologies do not require extensive installation. Many technologies are based on data fusion, which reduces the need for a large staff to monitor ongoing activities and make decisions. Another trait is the use of mobile technology to communicate directly with residents, rather than installing expensive public displays. For example, companies such as **Reporty**, **Breezometer**, and **Digi-Tel** use existing smartphones to interact with citizens. In LAC, where the penetration of cell-phones is big, investing in initiatives that benefit from the existing hardware infrastructure can generate great impact with reduced costs.

The organizational processes described in this paper point to how smart city technologies can be created, developed, and deployed. Many are developed through private sector participation based on scientific innovation, such as several water purification products. Also, several technologies have been created by developing military technology and applying it to the civilian market. Examples include video analytics and security applications. Recent smart city technologies covered in this paper rely on big data analysis, such as **ZenCity** and **P-Pulse**, two companies that analyze streams of social media information to identify information about municipal events.

Technological innovation plays a key role in the smart city scene. Multiple Israel-based companies are developing a host of innovative solutions that use emerging technologies—such as the cloud, mobile, big data, social networks,

IoT, and intelligent systems—to facilitate smart city solutions.

Even though some of the examples mentioned in this paper feed from the particular context of Israel, an important lesson that can be drawn for the cities in the LAC region is that promoting innovation that generates impact relates to the creation of meaningful synergies between the public and private sectors, academia, and citizens. This is the starting point of a virtuous cycle that must feed from results generated in previous iterations of products and best practices to create new and even more innovative solutions with the data and knowledge in hand. This way, the Israeli experience, with its set of cutting-edge solutions, can serve as a tool for LAC cities to develop technology-based solutions that will make smart cities in the region run smoothly.

The Appendix classifies all the companies covered in this paper.

Appendix: Companies in Various Domains

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Citizen Engagement

Company	Website	Description
Neighbor	http://neighbor.co.il/	Manages communication, payments, and administration in large housing towers.
Playkers	http://playkers.com/	An app that allows residents to establish sports teams and find and rent sport fields.
P-Pulse	http://www.p-pulse.org	Processes events from geospatial data collected from social media, open government data, and other sources.
Zencity	http://zencity.io/	Provides a dashboard for local governments to provide insights based on citizen feedback.

Climate Change

Company	Website	Description
BreezoMeter	http://www.BreezoMeter.com	Provides air quality data through a mobile app.
GreenVision Systems	http://www.greenvs.com/	Provide hyper-spectral imaging solutions for environmental monitoring.
Kando	http://www.kando.co.il	Measures data analytics to prevent pollution events.

Early Warning

Company	Website	Description
Evigilo	http://www.evigilo.net	Provides alerts and disseminates notifications.
SeismicAI	https://www.seismicai.com/	Offers a regional earthquake early warning system using a network of sensors.
SensoGuard	http://www.sensoguard.com/	Provides systemic sensors to secure sensitive areas.

Emergency Response

Company	Website	Description
NewForce	http://www.nowforce.com/	Provides a mobile application for command and control in emergency response.
Sayvu	http://sayvu.com/	Offers a mobile application for emergency response.

Energy

Company	Website	Description
Brenmiller Energy	http://www.bren-energy.com/	Developing energy storage through steam-based solutions.
Brightmerge Israel	http://www.brightmerge.com	Developing micro-grids based on sources of renewable energy.
Gencell	http://www.gencellenergy.com/	Provides alkaline fuel cells for backup energy.
Grid4C	http://www.grid4c.com/	Uses machine-learning capabilities to provide predictive analytics for energy infrastructure.
PowerSines	http://www.powersines.com/	Developing a management solution that allows users to visualize their energy consumption.
SolarBead	http://www.solarbead.com/	Provides microinverter suitable for rooftops and small

		or medium-sized power plants
SolarWat	http://www.solarwat.co.il	Provides a photovoltaic module for solar energy.
SolView	http://www.solview.com/	Developing automated solar-potential assessment and lead-qualification tools to target solar sales.

Irrigation

Company	Website	Description
Arad	http://arad.co.il/he/	Developing remote water meter-reading solutions for walk-by, drive-by, and fixed network systems.
Cropx	https://cropx.com/	Develops sensor-based systems for irrigation to save water and energy.
Flux	http://www.fluxiot.com	Developing solutions for hydroponics growers to predict and optimize the growth of food and plants.
GreenIQ	http://greeniq.co	Develops sensor and management systems for landscape irrigation.

Lighting

Company	Website	Description
Bright	http://www.bright-led.net/	Developing infrastructure for sensor networks based on streetlights.
Eltam	http://www.eltam-eh.com/	Developing electronic LED-connected drivers.
Gaash	http://www.gaash.com/	Provides WiFi-based lighting and centralized management solutions.
Juganu	http://juganu.com/	Developing WiFi-based lighting and centralized management solutions.
Menolinx Systems	http://www.menolinx.com/	Developing cloud-based lighting management systems.
MetroControl	https://www.metrocontrol.com/	Provides a complete WiFi-based lighting solution.

Networks

Company	Website	Description
Ayyeka	http://www.ayyeka.com/	Develops remote monitoring for SCADA systems.
IPgallery	http://www.ipgallery.com	Develops network and data analysis for smart cities.
Mobilicom	http://www.mobilicom.com/	Develops spontaneous mobile wireless communication solutions.
NeoPeach	http://www.neopeach.com	Developed a system for smart parking.
Reali Technologies	http://www.realiteq.com/	Provides a virtual IT network for real-time remote control and to monitor water and energy systems.
Tiba	http://www.tibaparking.com/	Develops smart parking lots using dedicated sensors.
Virtual Extension	http://www.virtual-extension.com	Provides wireless mesh technology that can address sensors and IoT devices.
Waterfall Security Solutions	http://www.waterfall-security.com	Provides network security products that enable IT integration for critical infrastructure.
WaveIP	http://www.waveip.com/	Developing point-to-point and point-to-multipoint broadband wireless solutions.

Parking

Company	Website	Description
Afcon	http://www.afcon.co.il/	Develops sensor-based systems in which free spaces are recognized, enabling operation of smart parking lots.
Eyfo	http://eyfoapp.com	Allows residents to mark and share urban resources and items.
ParKam	http://parkam-ip.com/	Provides a parking solution that includes availability map, in-app real-time navigation, enforcement, and business intelligence tools to manage parking lots.

Parkom	http://www.parkomint.com/	Provides a management solution for parking lot systems.
PARX	http://www.parxglobal.com/	Provides parking payment and management solutions for municipalities and parking operators.
Spaceek	http://spaceek.com/	Helps manage parking lots and guides drivers to available spots.

Security

Company	Website	Description
Agent Video Intelligence	https://www.agentvi.com/	Develops computer vision algorithms that identify real-time events.
ContextSpace	http://www.contextspace.com/	Provides secure platform to build smart cities with secure and private digital civic engagement.
Levitection	http://www.levitection.com	Provides video storage and analysis systems to secure public places.
Magos	http://magosystems.com/	Develops radars to secure facilities.
My Tower	http://www.mytowerapp.com	Provides IoT management tools for communication and services in connected residential buildings.
Octopus	http://www.octopus-app.com/	Helps modern cities manage growing city infrastructure, assets, resources, and ICT systems, and engage with residents.
Qognify	http://www.Qognify.com/	Helps organizations capture, analyze, and leverage big data to manage security risks.
Reporty	http://www.reporty.com/	Developing a mobile app to allow people to call for help and others to provide help.
Safe City in a Box	http://safecityinabox.com	Provides an end-to-end security system for public security, including video and sensors.
Surf Solutions	http://www.surfsolutions.com/ / surfsight/	Provides a video surveillance management solution that gathers and consolidates video from multiple sources.

Transportation

Company	Website	Description
Anagog	http://www.anagog.com	Analyzes multiple smartphone sensor signals to analyze real-time mobility status.
Axilion	http://axilion.com	Specializes in software solutions for intelligent transportation systems, including traffic signal network coordination and traffic control.
Cellint	http://www.cellint.com/	Creates solutions that monitor movements and behavior patterns of inhabitants and visitors for all transportation modes.
Safer Place	http://www.saferplace.com	Provides a video-based solution that automatically detects moving violations and illegal parking situations.
Via	https://ridewithvia.com/	Allows customers to book a ride through algorithm-based vehicle path matching.
Tugger	http://www.tugger.info	Provides a mobile app designed to help drivers locate their towed vehicles.
Waycare Technologies	http://waycaretech.com/	Develops in-vehicle and internal city data to establish two-way communication between the city and the vehicle.

Waste Management

Company	Website	Description
Blue Sphere	http://www.bluespherecorporate.com/	Transforms agricultural, municipal, and industrial waste into electricity.
Genio	http://genio.co.il/	Provides solutions to plan, monitor, and manage waste collection.
GreenQ	http://greenq.gq/	Offers a connected garbage collection platform for

		municipalities.
NovaSense	https://www.nova-sens.com/	Provides a garbage sensor.
Triple+	http://tripleplus.io	Identifies gas and water leaks in residential and commercial environments.
Woosh Water Systems	http://www.wooshwater.com	Provides connected water fountains.

Water Management

Company	Website	Description
Aqua Rimat	http://www.aquarimat.com	Develops solutions for water management and control for private homes and businesses.
Aquarius-Spectrum	http://www.aquarius-spectrum.com/	Develops technology for online leak detection in water pipes.
Arad Group	http://arad.co.il/	Develops connected water meters.
Bermad	http://www.bermad.com/	Provides connected water meters and water management hardware.
Flowless	http://aquarimat.com/	Provides solutions that monitor water consumption in a home or office to manage water resources.
HydroSpin	http://www.h-spin.com/	Provides a technology that produces micro-energy from generators within urban water pipelines.
Madey Vered	http://www.mv-technology.com/	Provides connected water meters and water management hardware.
Miltel Communications	http://miltelcom.com	Manufactures telemetry RF solutions for smart meters.
Miya	http://www.miya-water.com/	Provides solutions to manage and fix urban water supply systems.
MTR Wireless Communications	http://mtr-wireless.com/	Offers network-based metering solutions for water, gas, and electricity consumption.
Nortex Technologies	http://www.nortex-tech.com/	Provides remotely accessed water meters.
Plasson	http://www.plasson.com/	Provides wastewater purification systems.
Tahal Consulting Engineers	http://tahal.com/	Specializes in water resource management.
TaKaDu	http://www.takadu.com	Builds management solutions for the water sector, providing an analytics tool that allows the performance of the water network to be monitored and analyzed.
Telematics Wireless	http://www.telematics-wireless.com/	Provides remotely accessed water and lighting controls.
Utilis	http://www.utiliscorp.com/	Identifies fresh water leaks in urban drinking water supply systems.

Water Treatment

Amiad Filtration Systems	http://www.amiad.com/	Specializes in drinking water filtration.
AST Clean Water Technologies	http://www.ast-water.com/	Develops water treatment solutions for water purification, wastewater, and industrial-stream treatment.
Ayala Water & Ecology	http://www.ayala-aqua.com/	Provides a sustainable natural technology to treat sewage and waste streams.
Bluvstein Binot Topaz	http://www.binot-topaz.co.il/	Provides water and wastewater treatment systems for industrial and municipal applications.
CleaRivers	http://www.clearivers.com	Offers complex microbial solutions and systems designed to purify water.
En Gibton	http://www.engibton.com	Provides water and wastewater treatment systems for industrial and municipal applications.
Fluence	https://www.fluencecorp.com/	Provides water and wastewater treatment solutions.
HydroP	http://www.hydrom.com	Improves the performance of membranes for

		desalination processes.
IDE Technologies	http://www.ide-tech.com/	Specializes in developing and operating desalination facilities, industrial water treatment, and water reuse plants.
Wadis	http://www.wadis-co.com/	Offers water-disinfection technology based on electrical pulse discharge in water.
WellToDo	http://welltodo.co.il/	Uses a process to convert various common water contaminants into nonpolluting compounds.
Yamit	http://www.yamit-f.com/	Creates purification systems for the industrial and municipal markets.

Various

Company	Domain	Website	Description
Watermedia	Water Access	http://watermedia.com/	Provides connected water fountains that include advertisements.
Onh	Smart Housing	http://www.onh.city	Develops systems that connect municipalities, real estate developers, and residents.
Urban Digital	Smart Streets	https://urban-digital.co.il/	Provides digital furniture for urban spaces with online connections to IT systems.
Argolan	Pollution	http://www.agrolan.co.il/index.asp	Develops air pollution meters.

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