Preparing the eco-city of tomorrow

Today, 3.5 billion people live in cities across the globe, growing to 6 billion by 2050. The rapid pace at which urbanisation is occurring brings new challenges to municipalities from water sourcing, transportation and waste handling management to distributed energy generation management. City councils are therefore seeking to address those problems with a pragmatic approach. By switching to a greener economy and producing energy entirely from renewable sources, local authorities could save money while incorporating the environment into their cities' ecosystem.
Designing a sustainable city with the consideration of environmental impact will radically change the way we live, work and play. By partnering with other stakeholders such as power suppliers, utilities services, civil work, electrical engineering solutions providers, and consultant firms, cities can provide a clean and healthy environment without pollution or transport congestion by integrating a digital infrastructure that makes city services instantly and conveniently available anytime, anywhere.
Cities where new urban planning and redevelopments are being done recognise the role of energy management as one of its most critical components. But it also raises concerns. Incorporating distributed renewable energy resources within existing electrical grids can only be accomplished by developing new governance schemes, accepting and implementing new technologies while raising public awareness.

Cities need a new plan to face energy demand and reduce pollution

Globally, there are some 700 cities, each with population exceeding 500,000 people that are growing faster than the average growth rate of cities. This opens up the market for industry players to grow their business in new and emerging smart cities. The World Bank just announced $9 million effort to help 50 city governments in developing countries to advance promising energy efficiency investments, to improve services, develop savings and reduce emissions.

In order to achieve this, new city equipment and public services need to be connected to the smart grid: transport, lighting, infrastructure heating, waste (bio-mass generation plant), water supply and of course the power supply. The demand for electricity increases and intensifies the risk of pollution in the cities. Yet, part of the eco-city projection is to reduce pollution from heating systems and transportation. In many developed countries Industrial and Commercial Buildings consume 40% of all generated electrical power. As more power is needed by cities, CO_2 emissions are increasing too fast with further threats on climate. Cities must reduce their environment footprint.

Facts & figures

The overall smart cities market, valued at $526.3 billion in 2011, is forecasted to grow double fold to $1,023.4 billion by 2016, at a Compound Annual Growth Rate (CAGR) of 14.2% for the period 2011 to 2016.

Among all application segments, the smart energy or energy management market will be the fastest growing market with an impressive CAGR of 28.7%, growing to $80.7 billion by 2016 (source: Markets and Markets report)

Steps to reduce CO_2 emissions

- The integration of renewable energies (geothermal, solar, wind…)
- The transfer from fossil fuelled use (cars, buses…heaters) to electrical (electrical vehicles, tramways… electrical heaters).
- The integration of multiple and decentralised energy production (local clean energy production plants).
- Energy Independence (islanding) and its projected reduced costs for cities.

With the overall determination to move to a carbon free world, utilities, companies and governments around the world are taking actions to lower environmental impact: EU 2020 targets to increase clean energy use are:

- Reduce greenhouse gas emissions by 20% from 1990 levels
- Increase share of renewables in energy mix up to 20%.

The major changes in the city are driven by the energy distribution

Electricity is identified as the best energy vector in urban context – best adapted to city environment. The "Smart city Council" defines a smart city as one that has digital technology embedded across all city functions. Unfortunately, ageing distribution grids that are not infrastructure ready to carry intermittent energies produced by clean power plant such as wind, solar or geothermal. This leads to more constraints on local power grid operators to diffuse electricity. Integrating energy coming entirely from multiple and distributed renewable sources is complex. To do so, power companies need to follow demand and production carefully.

Facts & figures

The infrastructure investment for these cities is forecasted to be $30 trillion to $40 trillion, cumulatively, over the next 20 years.
The market for smart city technologies is growing rapidly, valued today at $8.1 billion and forecasted to grow nearly five times that size by 2018, reaching $39.5 billion (Source ABI Research).

The complexities are:

- Improving urban energy management at the distribution level with ICT (information and communication technologies) to optimise the use of their electrical infrastructures and energy. resources in terms of energy efficiency, electricity consumption and costs.
- Building a smart distribution network to meet higher consumption multiple, integrate renewable and distributed power production, and storage solutions.
- Optimising the existing electrical networks with the integration of renewable energy.
- Building smart homes and buildings.

The Smart Grid: transforming the smart city power grid

A Smart Grid includes new Information and Communication Technology, electronic devices, hardware and software to manage the electrical grids at its maximum efficiency. Utilities can better operate their assets to maximum capacity, maximise energy flow, actively manage demand and enable end-users participation to the market.

At city level, the Smart Grid becomes a Microgrid. Microgrid power systems are small-scale power-generation solutions consisting of local power-generating facilities and individual homes and buildings equipped with wind and solar power systems. In many geographies this type of distributed power generation is already or will be a lower-cost alternative to large-scale fossil systems. The microgrid model places power generation in close proximity to the consumer.

The power is generated by the community for the community, and any excess is fed directly into the power company grid or stored in batteries and reused at times of peak demand. The interaction between the microgrid and the main grid improves sharing of economic and renewable energy, stored capacity and other additional and complementary services.

Micrograds allow power generation and consumption to be managed so that the load is balanced with the supply. Smart power meters allow real-time consumption analysis. This smart approach to managing energy use can result in lower energy costs to the consumer and higher empowerment because it encourages making smarter choices about power use.

The smart city gathers data from smart devices and sensors embedded in its roadways, power grids, homes and buildings, power storage and other assets. Sensors can be positioned for an intelligent lighting system, based on daylight intensity or activating at night when someone is walking down the street. The microgrid infrastructure will connect energy with all the other infrastructures (water, waste, transportation…) while collecting and analysing anonymous information, offering benchmarking, forecasting and decision support to end-users.

Facts & figures

Global installed capacity of microgrid has seen a staggering growth since 2011 and is forecast to grow at a CAGR of over 17% from 2012- 2022 to attain a total installed capacity of over 15GW by 2022 (Research and Markets).

Electricity price is rising and businesses and citizens want to take control over their consumption. Consumers will now have the capability and ability to arbitrage and take decision on how and when they will use energy, about their comfort level and service quality that affects their energy use and carbon footprint. Moreover, the same information will be made available to large city infrastructure facilities that will be able to adjust operational strategies to meet users' expectations, thereby improving overall service quality. Google cites figures from their testing showing that consumers who visually see real-time energy use through the PowerMeter are cutting electricity use 5-15 percent through behavioural changes.

As a consequence, this source of information made available and creating new services to citizens are eventually transforming operators' business model. Those new frameworks will rise up questions around who should pay for the investments, new power rates and prices, and above all, the need for a revision of the regulatory financing model applied to power suppliers.

Characteristics of smart grids vs. traditional power grids

- Consumer (or "prosumer") participation.
- Full generation and storage options: from power plants to Distributed Energy Resources (DER).
- Flexibility to incorporate new energy pricing mechanisms, products and services.
- "Clean", quality power, relatively interruption free.
- Optimal equipment utilisation and efficiency.
- Protection against physical and cyber-attacks.

Alstom's strategy – smartening the city grid

For Alstom, it's more than just a proof-of-concept. Alstom is very active in global and local smart city projects, building up its strong expertise through approximately 23 demonstration projects under implementation worldwide.

On the importance of smart eco-cities and its various impacts on power companies, Alstom Grid innovation is helping to bridge the gap between existing technology and the new digital era with its new capacities in information and telecommunication technologies. Alstom also brings the knowledge and capacity to integrate all kinds of power generation - renewable, thermal and storage and while lowering CO_2 impact – meaning significant environmental, social, technological and economic impacts for the cities.

Facts & Figures

In 2008, the Electric Power Research Institute (EPRI) estimated that smart grid mechanisms could reduce greenhouse gas emissions by 60 to 211 million metric tons annually in 2030.

Researchers at Frost & Sullivan surveyed 1,835 executives from more than 40 countries who state that urbanization and smart cities are their key topic for 2014. The top the list technologies and markets to watch for in 2020 are also energy efficiency and smart

The addition bulk load of intermittent renewables onto the grid is making operations much more complex. Energy can be produced by numerous distributed solar, wind, hydro or geothermal plants. **Alstom's Information and communication technologies become the link between users, city infrastructures and grid operators**, via a real-time information system aimed at optimising the integration and usage of intermittent energy. Power companies have to ensure that their installed equipment can safely handle the spikes and drops. Smart Metering is used in homes and office buildings to ensure real-time information on energy need or usage. The data flowing from numerous devices and stakeholders are consequently interconnected with the production and consumption points via a flexible real-time control room. The grid operators can optimally manage the energy across the grid and proactively prepare for its impact on their grids. They can therefore provide energy services continuously and tailored to end-users' requirements with Alstom leading Software solutions making urban infrastructure more efficient and reliable.

Key benefits of the smart city

- Reduced carbon footprint
- Energy efficiency
- Network reliability and stability
- Renewable integration

Alstom's solution for the Smart city

With new stakeholders involved, the need to build a new market at city level can be done by defining new business model combining European, national, regional or even local public and private investments. Alstom Grid is at the heart of the smart city revolution, with solutions combining its key technologies to provide *immediate benefits* to energy producers, utilities, industries and end-users.

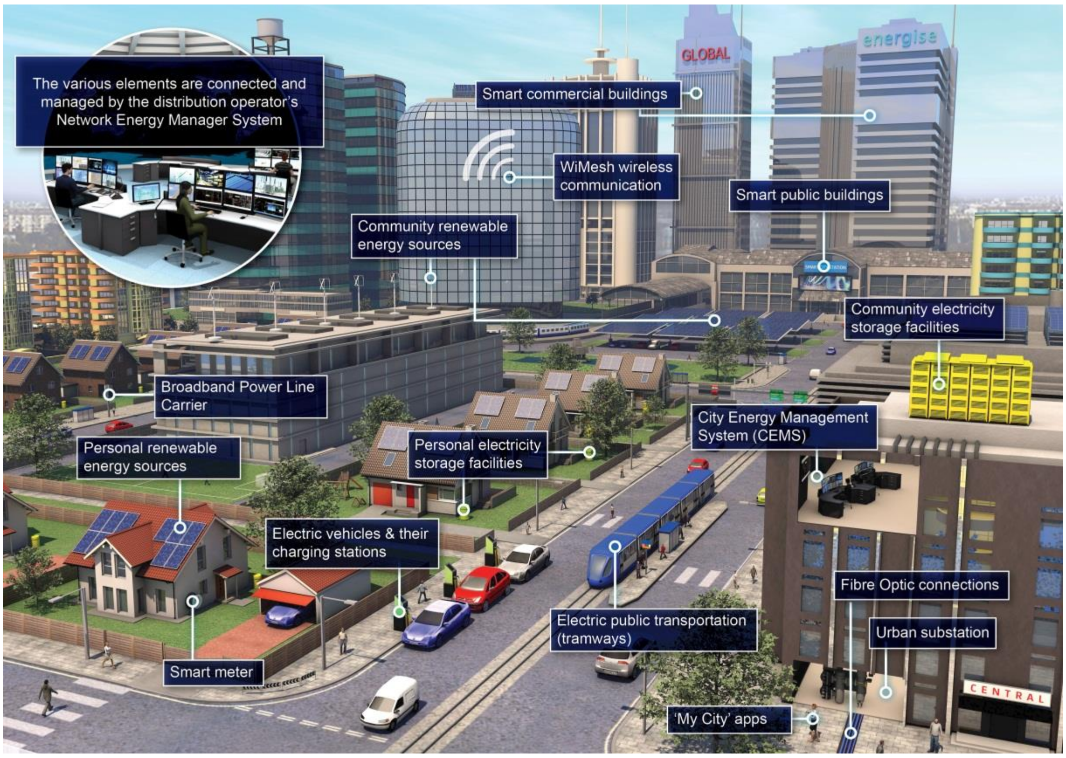
- Intermittent renewable energy integration on the city electrical grid: wind, solar, thermal…
- Distributed generation integration: connecting multiple renewable energy power plants and integrating islanding solutions (becoming autonomous).
- Real-time two-way information technology system
- Energy storage capacity at city level, with integrated dynamic forecasting and communication technologies to store or incorporate renewable energy into the grid and help balance overall demand to production.
- Enabling use of plug-in electric vehicles: providing additional storage services.

Alstom can improve urban energy management at the distribution level with ICT (information and communication technologies) and our leading software to optimise the use of electrical infrastructures and energy:

- Smart distribution grid – production, consumption and storage
- Equipment and resources optimising energy efficiency, electricity consumption monitoring and cost-savings
- Common software architecture and open data monitoring and analysis platform
- Multi criteria visualisation (weather forecasts, end-user consumption, local clean energy generation…)
- Collaborative communication based on open standards

Alstom has the expertise in key smart grid technologies to reach the end-consumer or the eco-city, through partnerships with companies like Bouygues (smart buildings), IBM (IT integration), Microsoft (user interface) or Renault-Nissan, (electric vehicles). This strategy positions us across the entire energy value chain - from power generation to end-consumer. Alstom seeks to integrate diverse teams - energy, ICT, efficient and low-energy buildings, and transport into one.

Alstom bring its knowledge and know-how to integrate a **real-time two-way information technology system** including: digital control rooms, network and market management systems, real-time dynamic pricing software, demand response systems (intentional modifications to consumption patterns designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized), aggregation market place software for diffused energy productions (a number of person selling to one buyer via an aggregator), settlement systems (aggregation and pre-dealing) to analyse buy and sell transactions and help with billing, and customers enabling software - leading into a new era of customer's choice and new business models. Alstom offers a **competitive battery storage solution** that includes a power converter and real-time control software to efficiently operate the battery. The Battery energy storage solution (BESS) helps smooth fluctuations caused by renewables by storing surplus energy for back-up, then dispatching the stored energy during peak consumption.



Alstom's demonstrator projects

Alstom's state-of-the-art proven technology is already in place a number of projects. Some example of its know-how and proficiency are show cased across the globe.

A pioneering smart grid demonstration, *Project FENIX* ran in the UK from 2005 to 2009.The objective was to make Distributed Energy Resource (DER) systems a cost efficient, secure and sustainable solution for the European Union's electricity supply system. Alstom Grid provided an advanced system and market interfaces to aggregate and synchronise distributed energy resources in a virtual power plant.

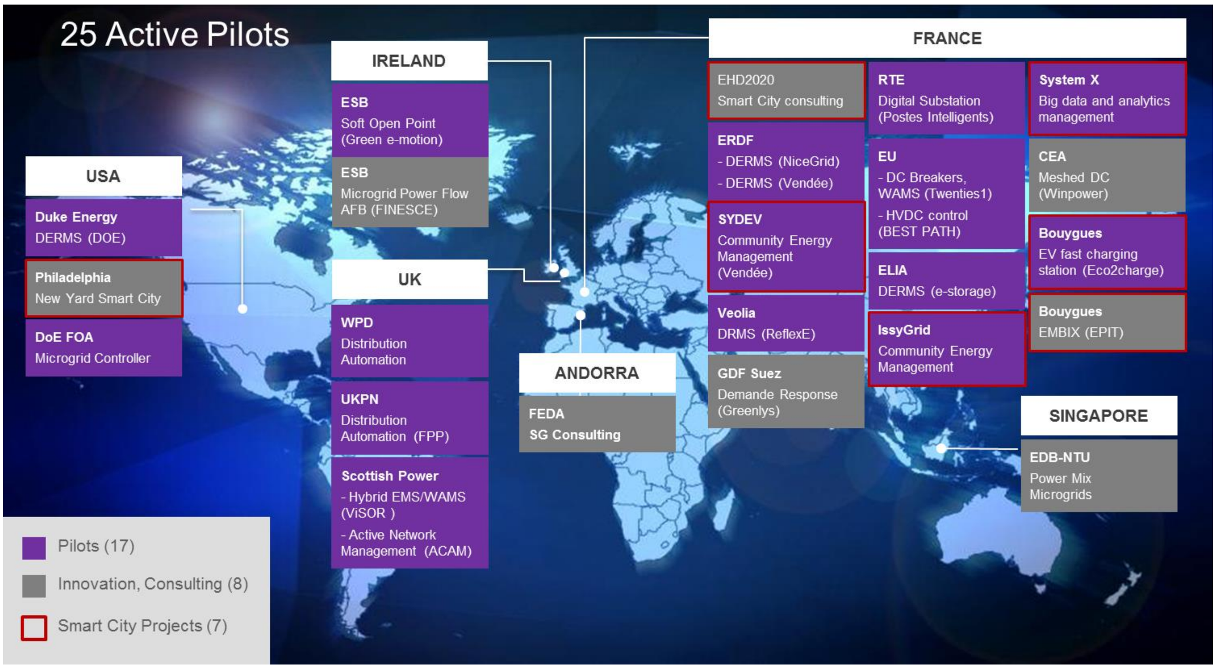
France's first smart grid eco-district, *IssyGrid®*, is a demonstration project aimed at optimising energy usage in the French town of Issy-les-Moulineaux, near Paris.

Situated on the French Riviera in Carros near Nice, *NICEGRID* aims at designing and testing in real scale a massive Photovoltaic integration, Islanding the grid in extreme situations and including a Demand Response solution designed to induce lower electricity use at times of high wholesale market prices or when system reliability is being jeopardized. Alstom Grid delivered the Network Energy Manager solution operated by the ERDF the French power distribution operator to manage the distributed energy resources and an electricity storage solution.

In North Carolina project led by the US Department of Energy is designed to integrate distributed energy resources into the electrical grid efficiently in order to help the operator reach its smart grid targets for 2030, including a 40% improvement in system efficiency. Alstom Grid supplied its Integrated Distribution Management System (IDMS), capable of integrating multiple types of energy distributed production resources.

In France, Alstom and its partner Veolia are building the *Réflexe* project consisting of a Virtual Power Plant (distributed renewable energy generation and integration) combined with solutions in aggregation and decision-making software for distributed energy resource management that also include energy storage.

The *Green eMotion* project is taking place in Ireland and Spain. This project is built on intelligent control of PEV charging, with the installation of Direct Current fast-charging station capable of charging three electric cars simultaneously.



Looking ahead

This energy transition in the city can only happen if there is a strong customer engagement and understanding of the energy supply and distribution market to take control of their services and costs. Installing smart meters and sensors is a prerequisite for a real-time forecasting and planning and this needs to be socially acceptable in the age of big data (Cyber security and data protection). There is an inadequate existing energy distribution business model; the changes are outstretched by unlocking citizens' potential which drives new services and the need to rethink the power distribution business model.

Facts & Figures

Building smart homes and buildings as the expenditure needed to provide software interfaces between Smart Grid and Smart Buildings over the next 20 years will amount to $34 billion, an average of $1.7 billion per year with the majority of this being spent on existing Smart Building installations

Alstom is driving innovation through its Smart solutions and addresses the four pillars that set the technologic bases of the smart city: electricity generation management, transmission, distribution and demand. Real-time control systems, generation delivery optimization, delivery of real-time information and near instantaneous balance of supply and demand at the device level, storage solutions…these are key to interconnecting all urban energy resources into a single smart city portal, providing the means to improve urban energy efficiency and reduce carbon footprint. Alstom's leadership in power generation, transport, transmission & distribution provides technology and solutions to the energy sector to energise a smarter world.

SPOTLIGHT ON MICROGRIDS

Today, energy autonomous systems that can operate independently, called Microgrids, have been gaining more and more attention. A Microgrid is an electrical system that includes one or multiple loads as well as one or several distributed energy sources that can be operated in parallel or disconnected from the electrical utility grid. Microgrids can address energy access or energy distribution challenges, where power network development can be both economically and technically challenging such as in developing countries. Likewise, in developed countries, a Microgrid allows greater independence from the larger electricity grid which can lead to a more resilient energy infrastructure for the end-users during disturbances.

1. The context

According to the International Energy Agency (IEA, 2014), the global demand for electricity is set to expand by over 70% between 2010 and 2035, or 2.2% per year on average. Over 80% of this growth is expected to take place in non-OECD countries. The question is: how to deliver this electricity to all these consumers? And how can developing countries' economies grow with such a challenge ahead of them? Globally, over 1 billion people still live without access to electricity today, putting them at a major developmental disadvantage. It is a known fact that communities with power enable children to study during the night hours with electrical lights, people can charge cell phones to stimulate their business activities and appliances can complete the household comfort.

Furthermore, with an overall determination to move to a carbon free world – power network operators, cities and governments around the world are taking steps for lower environmental impact. To achieve this, the integration of intermittent renewable energy sources unto the existing grid has become vital. Connecting clean local energy sources such as wind and solar plants reduces the need to rely on other distant polluting source of generation. Shifting to a carbon free distributed energy generation will also give way to an increased use of electrical transport - the shorter the distance from generation to consumption, the more efficient, economical and green it becomes.

2. Microgrids meet these challenges

Microgrids connect together infrastructures (houses, commercial buildings, public lighting, public transport, etc.) within a district or a city or on an island. Microgrids systems can be used to optimise the dispatch of electricity subject on demand. They can also apply for a better use of local resources (such as small-scale photovoltaic panels or wind mills). They enable a better and combined optimisation on a territory, and aggregate local flexibilities such as demand response or storage.

3. How are Microgrids built?

To build a Microgrid, essential constituents are needed:

The first component needed in any Microgrid system is the power source. Renewable energies such as solar or wind power have grown progressively successful due to their reduced carbon footprint. They also provide energy access to rural areas or to peripheries of transmission grids, which can represent a structural handicap for electricity supply when transmission lines are disrupted.

The second one is the power management system that operates the transfer of electrical power from the power source to the electricity consuming devices. The power management system controls and balances with specific software systems the supply and demand within the Microgrid. The Microgrid energy manager can therefore monitor and operate the Microgrid depending on conditions affecting network operations—such as sun or wind forecasts, consumption patterns, and/or technical issues on the network —in an efficient and reliable manner.

Batteries Storage systems are also essential to any Microgrid. They allow balancing the electrical power across the Microgrid. Electricity is then made accessible when it is required by the user. The Microgrid operator charges or drains these batteries based on electricity demand. Batteries, installed with a power converter and software which controls the storage facilities, can react quickly to weather conditions and consumer demand. Power supply is consequently automatically balanced across the Microgrid while ensuring safe, efficient load management. The system also considerably improves capacity to integrate intermittent renewable energy sources. Battery storage within a Microgrid may participate also to the main grid system services by supplying voltage and frequency regulation services. As such, Many Microgrids in developed countries have an integrated connection to the larger electrical network. This connection enables the Microgrid to exchange power system services with the larger utility network.

4. Benefits

In some geography, this type of distributed power generation is already a lower-cost alternative to large-scale fossil systems. The Microgrid model places power generation in close proximity to the consumer. The power is generated by the community for the community, and any excess is fed directly into the power company grid or stored in batteries and reused at times of peak demand. The interaction between the Microgrid and the main grid improves sharing of economic and renewable energy, stored capacity and other additional and complementary services.

5. Alstom's solution for Microgrids

Alstom brings the knowledge and capacity to integrate all kinds of power generation - renewable, thermal and storage and while lowering CO_2 impact – meaning significant environmental, social, technological and economic impacts.

- Intermittent renewable energy integration on the electrical grid: wind, solar, ...
- Distributed generation integration: connecting multiple renewable energy power plants and integrating islanding solutions (becoming autonomous).
- Real-time two-way information technology system
- Energy storage capacity at city level, with integrated dynamic forecasting and communication technologies to store or incorporate renewable energy into the grid and help balance overall demand to production.
- Enabling use of plug-in electric vehicles: providing additional storage services.

SPOTLIGHT ON GRID-CONNECTED STORAGE

Thanks to grid-connected energy storage solutions, utilities can better take advantage of sun- and wind-generated energy with much more confidence in managing supply and demand.

1. The context

Consumers and business are using more and more electricity every year. According to a 2012 report from the International Energy Agency (IEA), global energy demand is expected to increase by 89% between 2010 and 2035.

New sources of energy, such as wind and solar, are helping meet these sharply rising demands. But wind and sunshine are not always available, and not always predictable: the sun only shines for certain hours of the day at best, and wind can only be forecast a few days ahead.

This makes it difficult for grid operators to balance energy supply and demand. When there is not enough energy from renewable sources like sun and wind, there are greater risks of blackouts, brownouts and other grid instabilities. There is also a risk of overwhelming the grid with a sudden surge in renewable energy generation.

To properly benefit from the full potential of intermittent renewable energy, a solution must be found to ensure that there will always be the right amount of electricity readily available.

2. Grid-connected battery storage systems provide the solution

Energy storage is a promising answer to these challenges. Battery energy storage systems enable grid operators to 'save' electricity for when they need it. When there is a surplus of renewable energy, they can store it, and then distribute this stored energy in seconds to cities, towns, factories and homes when there is high demand. Battery storage makes it possible for generators and utilities to better manage energy supply and demand.

3. How does it work?

Grid-connected battery energy storage systems consist of a battery, a two-way power converter that connects the direct current (DC) battery to the alternating current (AC) grid, and real-time control software to balance the frequency and power flows while optimising the efficiency and service life of the system. These systems are housed into a 20 feet container.

4. Business benefits

Energy storage technologies can be installed at all levels of the grid: generation, transmission and distribution.

Grid-connected storage offers a back-up solution for times when electricity resources are in high demand, such as evening hours. Even better, the back-up plan does not drain the earth's precious resources; instead it captures energy that will be naturally replenished.

Storing energy makes the network more flexible so that operators may choose to store large amounts of energy when they do not have demand for it, and avoid overloads on the lines during rush hours.

It also helps everyday consumers to better manage and buy energy when it is better priced. Consumers can even become part of the network by installing their own solar panels to store energy, and then sell it back to the operator or eventually charge their electrical vehicles.

The energy storage market has made significant strides. It has already doubled in worldwide storage capacity from 370 MW in 2011 to 734 MW in 2013.[1]

A 2012 report from Pike Research predicts that by 2020, almost 70% of the energy storage market will be driven by the integration of renewables into energy grids. The report expects the total capacity of battery energy storage on the grid to reach 10,000 MW by 2020.

5. Alstom's solution for grid-connected storage

Alstom MaxSine™ eStorage is an integrated energy storage solution compatible with any types of battery technologies (NaS, Li-ion, and others). The eStorage Management System, based on adaptive algorithms is an integral part of this solution. When coupled to an intermittent source, it builds and adjusts in real-time a production plan according to weather forecasts, increasing energy efficiency while extending the lifetime of the system. Alstom Grid is the market leader in Energy Management Systems (EMS), critical to demand response and distributed resource management. Derived from EMS, eStorage Management System allows operators to accurately forecast, dispatch and satisfy energy needs, and participate in energy trading.

Alstom offers a turnkey solution for MaxSine™ eStorage: from network analysis to civil works, from installation to maintenance, Alstom offers a global approach that provides the best energy storage solution for each customer's specific needs.

Alstom MaxSine™ eStorage is currently live and fully integrated into "NiceGrid", the smart solar-energy pilot project being conducted in the French municipality of Carros near the French Riviera.

For more information, visit the Alstom Grid website at www.alstom.com/grid

[1] Source: Presentation DOE (US Department of Energy) – European Utility Week 2013 in Amsterdam