Creating Smart Cities: A case study of Energy Hub for effective energy management

Ahmed Fadhil Dulaimi, afdulimi@yahoo.com
Heriot-Watt University
Rachid Hamida, rhamida@enova-me.com
VP - Energy & Technology Performance & Technology Department
Enova by Veolia
Mazin Naser, mazen.nasr@enova-me.com
Manager - Energy Center • Hubgrade Division
Enova by Veolia
Mahmoud Mawed, mahd_mawed@hotmail.com
Heriot-Watt University

Abstract

One of the most critical challenges facing humanity in the twenty-first century is the scarcity of energy. These challenges appear in many different fields, including energy supply, exchange, and consumption. The energy scarcity is due to population expansion, growing worldwide demand for energy, natural resource shortages, and environmental concerns. Furthermore, scarcity of energy requires the growth of renewable energies and energy efficiency; it is considered a top priority for all governments and organisations to resolve.

The energy efficiency of buildings is an important concept when discussed in the context of smart cities. Buildings arethe largest energy consumers since the building sector is responsible for 40% of energy consumption. Recent developments in machine learning within a big data environment have created opportunities for more effective management of energy use in buildings. Managing buildings energy consumption effectively through a real-time measuring process enables the economy to move away from a linear consumption model to a circular model. This will solve the problem of late notification of energy-saving measures failure and allow quick rectification to bring the energy management system back to high performance. The size of the energy hub is unlimited; it can be a single home energy system or a city-wide energy system.

This paper will present a case study on developing a smart energy hub called Hub grade 4 that relies on connected products and artificial intelligence. Hub grade 4 is the name of Enova by Veolia smart energy hub; Enova is MENA regional leader in integrated energy and multi-technical services delivering performance-based energy and facilities management solutions. Hub grade 4 provides an innovative approach to successfully implementing energy efficiency improvement using artificial intelligence and real-time data. The case study will explore how energy management can utilise real-time data to be efficiently used by residential, commercial, and industrial clients. This paper concluded and highlighted lessons learned from the successful implementation of innovative energy management, which relied on a dedicated organisation, effective adoption of digital technologies, and embracing new business models, resulting in power savings of 254 million kW and water savings of around 3 million cubic meters, as well as financial savings of about 138 million AED in 5 years since hub grade 4 started operations its first energy-saving contract in 2017

Keywords
Energy Hub, Smart Cities, sustainability, energy management

1 Introduction

While Cities utilise 78 percent of world energy and generate 60 percent of global greenhouse gas emissions, it occupies only 2% of the earth's geographic area (UN, Cities& Pollution 2018). As urbanisation rises from 55 percent of the world's population to 66 percent by 2050 (UN, world organisation prospects,2018), its environmental impact will increase. Improving resource efficiency at the municipal level would acquire more environmentally sustainable solutions and aid in the transition to a more sustainable future.

One of the most important prerequisites for next-generation smart cities is a reliable, efficient, and low-carbon source of energy (Edward et al., 2019).

The notion of a smart city has gotten a lot of interest in recent years because it uses digital technologies to develop service delivery and energy optimisation. Smart cities use different sensors to capture digitised data and provide information that is then used to manage systems and efficiently optimise assets' performance. Data about equipment, buildings, people and different type of assets are treated and analysed to enable traffic systems, energy supply, water distribution networks, waste collection, law enforcement agencies, information systems, residential communities, shopping malls, commercial buildings, hospitals, airports and other community services to be monitored and managed (Sanguk el. at 2019).

A smart energy city is a city that optimises energy consumption and has a well-planned energy management system, and reports energy-saving achievements properly. (Nielsen et al. 2013) the sustainable smart energy city (SSEC) idea provides comfort, energy-saving and wellbeing to its people through systematic and continuous improvement of energy management systems using new technologies to develop energy consumption. (Sanguk et al. 2019).

This call to build sustainable smart energy infrastructure within the city will allow for continuous enhancement of energy consumption and safe and pleasant living, and a speedy and cost-effective metropolis built on smart infrastructure. (Shahidehpour et al. 2018).

A smart energy city's long-term viability necessitates the intelligent and systematic deployment of technologies, as well as an examination of each of the city's assets. In the energy business, sustainability refers to the effective use of energy in general, but it also refers to the development and deployment of new technologies to enable efficient operations (Park et al. 2016).

2 Literature Review

2.1Energy Hub Concept

The Energy hub concept was first established as a result of the VOFEN project; the research team from ETH Zurich's Power Systems and High Voltage Laboratory proposed the EH concept as part of the project "a vision of future energy networks (VOFEN).Using a greenfield methodology, the project attempts to picture future energy systems in the long term (20–30 years) (Geidl et al., 2007).

It was defined as an interface between consumers, producers, storage devices, and transmission devices in various ways in handling one or more carriers directly or via conversion equipment (Mohammadi et al. 2017).

Traditional energy supply systems (for example, electricity networks) feature a hierarchical structure in which an energy carrier's generation, transmission, scheduling, and administration are primarily the responsibility of a hierarchical structure (Geidl et al., 2007).

As a result, one of the primary advantages of an energy hub is the efficient use of multi-generation (co, tri, or poly-generation) systems to maximise energy efficiency while minimising emissions and costs. (Mohammadi et al. 2017).

Synergies between different types of energy give a huge opportunity for system enhancement. Aside from modern information technology's capabilities, state-of-the-art and new and looming energy technologies, such as fuel cells, are considered.

Energy hub has a good opportunity to reduce energy consumption by optimising and switching between different technologies to match energy usage. also, the energy hub can efficiently use resources, improve efficiency, reduce cost, and minimise carbon emissions. (Mohammadi et al. 2017) Energy hubs can be applied for different sectors; it can be applied for residential, commercial, and also industrial including shopping centres, housing complex, educational complexes, hospitals, hotels, small and large factories, airports and even individual residential or offices buildings, it can be applied for the limited geographical area or an entire city. The size of the energy hub is beyond any limitations; it can be a residential unit or shopping centre, or the whole city.

Energy hubs can be divided into two types, micro hubs and Macro hubs, depending on the type of control, the objective of consumers and consumption pattern; for example, the consumption pattern in residential is during early evening hours while industrial is almost constant. (Mohammadi et.al 2017) The micro hubs are divided sector-wise into residential, commercial, and industrial. The macro hub is a combination of several micro hubs. There is a need to exchange a huge volume of data in the macro hub, where we need smart technologies to process these data.

2.2 Micro Energy Hub

Based on consumption, the micro hub can be in 3 groups of energy hub and will be discussed herein details

2.2,1 - Residential Energy Hub

As per EIA yearly report, US buildings consumed 40 % in 2020, the residential consumed 22% and 18% of the energy consumed by commercial buildings, for several reasons like long transmission network and huge distribution, weak management of consumption. (eia 2020).

For that reason, the energy hub will be a good solution for the residential sector; using PV, heat pumps, led lights, and solar collectors will be a good method to optimise energy usage. Due to rising energy prices, environmental concerns, growing demand for electricity, and network instability. These issues necessitate the most efficient energy generation, storage, and consumption solutions. (Enrico et al 2009)

For all these reasons, the options like energy hub and energy management systems look like good solutions. implementing this model for energy management in real-time for energy consumption, production, storage and conservation benefit both consumer and distribution company; this model was applied on real houses in Ontario, Canada, gives 20% energy saving and on-peak demand of the consumer energy consumption it gives more than 50% reduction. (Isha et al., 2015).

2.2.2- Commercial Energy Hub

Total energy consumption by the residential and commercial sectors includes end-user consumption and electrical system energy losses associated with retail electricity sales to the sectors. When electrical system energy losses are included, the residential and commercial sectors accounted for about 22% and 18%, respectively 40% combined of total US energy consumption in 2020 as per the EIA report (EIA 2020).

As a result, existing buildings performance is far from optimal, and there is significant room for energy savings in this sector. Business structures are emblems of economic progress, and the construction of high-rise buildings has become a competition between industrialised and emerging countries. (Mawed et al. 2020).

Increased efficiency in commercial buildings is an essential move toward more optimised energy consumption with less impact on the environment. Several factors can influence a building's energy efficiency, and as a result, various strategies can be utilised to increase it.(Mohammadi ,et.al 2018).

In commercial buildings, the integrated energy management system is essential for effective scheduling, successful participation in demand-side management programs, and gaining the benefits of smart grids.

In a study applying energy management system to a commercial building, aiming optimal operation of the building services lowering energy costs, boosting efficiency, and lowering emissions. The findings revealed that by merging several technologies and managing the building's energy systems as a whole, peak demand and energy expenditures were reduced, while carbon emissions were reduced. (Mohammad et al. 2012).

As a result, by controlling information such as weather forecasts, production, and demand patterns, the Building energy management system can determine the best performance of the building's energy systems. This integrated management results in lower costs, fewer peak hours, less environmental effect, and successful involvement in disaster recovery programs. (Mohammad et al. 2012).

Thermal and lighting loads are two important loads in commercial buildings. The main energy consumers in commercial buildings are heat loads, particularly air conditioning systems, heating and cooling systems, which significantly affect peak load (Jesse et al., 2011).

The air conditioning load(HVAC) is greatly influenced by the weather, particularly the ambient temperature. In addition, weather conditions, such as solar radiation, have an impact on the lighting burden. As a result, weather conditions have an impact on the performance of commercial buildings. (Dimitris et al. 2014).

In commercial buildings, the usage of distributed generation units such as cogeneration units like combined heat and power, wind turbines, and fuel cells are on the rise. The integration of distributed generation units, particularly Renewable energy, into commercial buildings poses new issues and/or opportunities for their management, indicating that the energy hub model has excellent potential.

In conclusion, several strategies have been employed to lower the commercial sector's energy expenses and emissions due to increased energy expenditures, environmental concerns, and the need for energy efficiency.

These strategies can be successful when used in conjunction with an integrated management system like building an energy management system. Finally, in the framework of an energy hub model, modelling and achieving building energy management systems in the commercial sector while taking into consideration energy storage systems, multi-generation systems, Renewable energy systems, demand-side management is possible. (Mohammadi et al. 2018)

2.2.3 Industrial Energy Hub

The world's largest energy consumption sector is the industrial sector, and it is considered a major source of greenhouse gas emissions. Energy demand in the industrial sector is steadily increasing as a result of increased industrialisation, the creation of new industrial countries, and rising consumption in developing countries.

According to the IEO2019 reference example, the industrial sector consumed 50 percent of world energy consumption in 2018, and its energy demand will increase by an average of 30 percent per year from 2018 to 2050. (iea 2019).

Aside from CO2, the industrial sector contributes significantly to the emissions of other GHG gases such as carbon monoxide (CO), sulphur dioxide (SO2), and nitrogen oxide (NOx). Therefore, this sector's energy efficiency and emission reductions have a significant impact on climate change mitigation.

Energy audits and waste heat recovery are two of the most basic methods for improving energy efficiency and lowering emissions in the sector. The energy audit will find potential for optimisation and energy savings, the use of technological approaches such as variable frequency drives for motors, heat recovery wheels, cogeneration, energy-saving equipment, and so on are examples of the first instance. (EA Abdelaziz, 2010)

Also, Energy Management System, which determines energy usage when and where it is required. The energy management system aims to reduce energy expenditures and environmental impact without affecting the quality or quantity of delivered services and products (Mawed et al., 2014).

Including Developing energy policies at the governmental level to encourage factories owners to improve energy efficiency, subsidies for the integration of renewable energy sources, rules and deterrent penalties such as carbon taxes, and employee penalties are all examples of government policies to encourage public sector and private sector to improve their energy efficiency; All these can be considered as efficiency enhancement for the industrial energy sector.

It can be said that the need for an integrated energy management system will improve energy efficiency in the industrial sector within an industrial energy management hub. (Nicolás and José 2013).

2.3 Macro Hub

When micro-energy hubs are combined, a concept known as a macro energy hub emerges, in which a group of energy hubs can be operated and managed in a coordinated manner. A residential community, an urban neighbourhood, commercial buildings, an industrial facility, a town, or even a whole city can all be considered a macro energy hub. (Mohammadi et al. 2018).

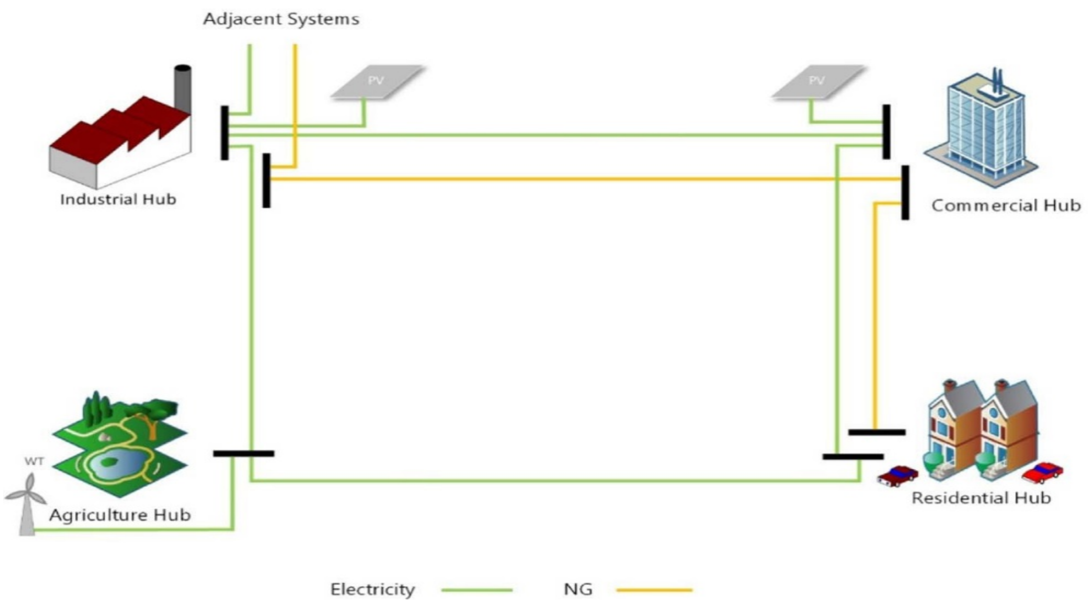


Fig1 Schematic representation of a macro energy hub. (Mohammadi, et. al 2018)

This is only a simplified graph of how electricity and natural gas networks connect four different types of consumers: residential, commercial, industrial, and agricultural (here, we treat farms as part of the industrial sector). Various networks can also connect various consumer sectors.

Increased system efficiency and renewable energy penetration and reduced waste, less environmental impact, and less fossil fuel usage are all benefits of this integration.

The energy hub idea can be used to represent such systems and provide improvement opportunities. The interconnection of infrastructures such as electricity, gas, and district cooling and heating networks is increasing as multi-generation technologies improve; Fig 1 shows the macro energy hub model. the energy hub serves as a link between various energy systems.
This integration can be thought of as a macro-energy hub.

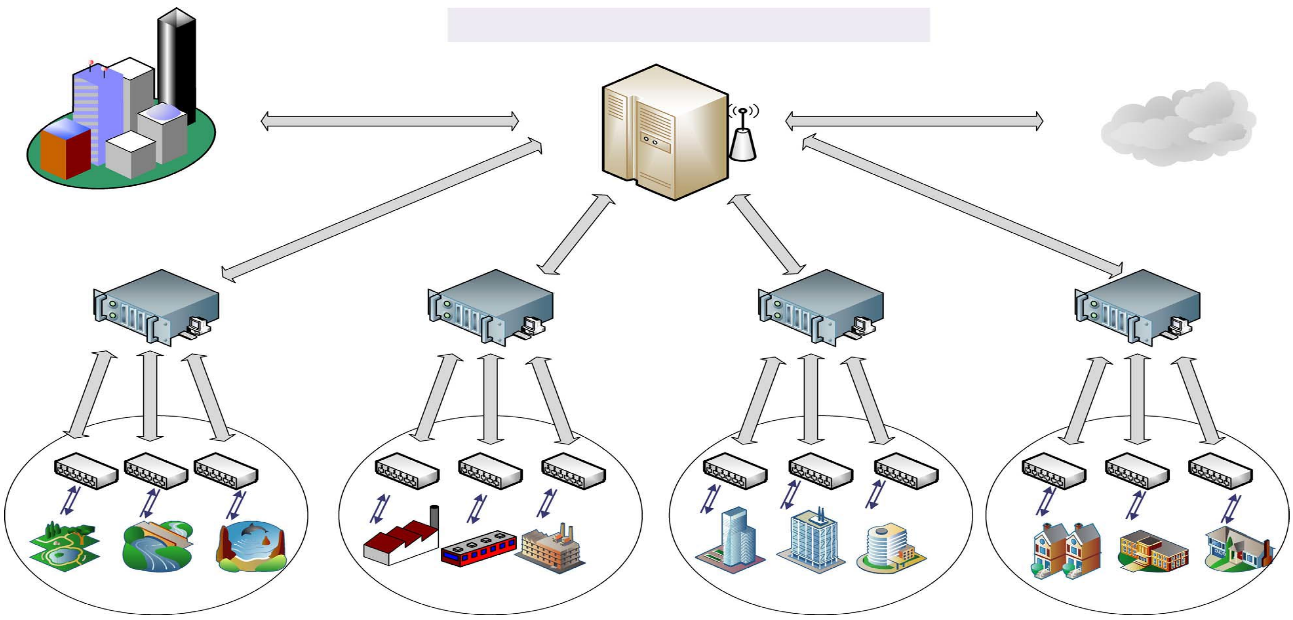


Fig 2 Schematic representation of a centralised macro energy hub management system. (Mohammadi ,et.al 2018)

One common centre is usually used for small-scale systems, but it is incapable of dealing with large-scale systems. Processing and exchanging information becomes more complex as the amount of variables and information to be processed grows, the computing load grows, and achieving the optimal solution in an optimisation problem becomes more difficult. Fig 2 illustrates the centralized hub management system.

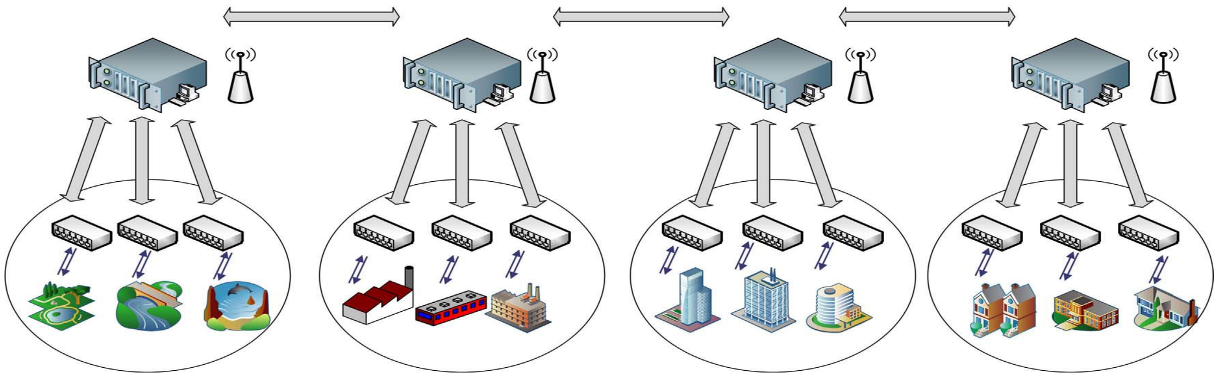


Fig 3: Schematic representation of distributed macro energy hub management system. (Mohammadi ,et.al 2018)

The optimisation issue is broken into multiple subproblems and then addressed in the same way. Compared to a centralised schema, the dispersed method has several advantages. First, the distributed mode is more reliable because, in the event of a failure in the control regions or performance faults, just that area would lose control. At the same time, the remainder of the system would continue to work at its best, Fig 3 showing the connection of several Macro energy Hub.

The main advantage of the macro energy hub is that it allows for the coordinated control of many consumers, each of whom may belong to a distinct group with distinct consumption habits. As a result, coordinating consumer participation in demand response programs can give numerous benefits to the entire system. (Mohammadi et al. 2018)

To summarise, the macro energy hub paradigm improves system resilience while also providing economic and environmental benefits. However, because macro energy hubs have a huge number of data connections that to be processed, smart grid technology can help them work better.

The smart system concept is a generalised version of the smart grid that can manage several energy carriers to satisfy various demands. Smart systems have several advantages, including higher productivity and dependability, lower carbon emissions and energy use, better integration of renewable energy sources, real-time and integrated energy system control, and so on.

2.4 Smart Energy Hub and smart cities

Smart city concepts have gotten a lot of press in recent years because they use information and communication technology developments to improve the quality and efficiency of services and resources. Microgrids have the potential to be extremely useful in the construction of smart cities. (Shahzad et al. 2018)

The goal of the Smart City concept is to make better use of public resources by improving the quality of services provided to people while lowering government operating costs. (Alexandra et al. 2015)

The Energy Hub is a powerful idea of collecting, transforming, and distributing energy resources in the smart city. Power systems are becoming smarter and more automated, and this is referred to as smart grid. In addition to typical network responsibilities such as electricity production, transmission, and distribution, smart grids can store data, communicate, and make choices (Mohammadi et al. 2017).

Smart grids use advanced applications and communication, digital information, and automated monitoring technologies to construct, optimise, and improve the operation of energy network infrastructures. Smart grids result in increased demand-supply efficiency and effective use of existing infrastructure, reducing the need for system development. Smart grid, on the other hand, makes it easier to integrate renewable energy sources on the demand side, particularly in the form of distributed generation. (Maria and Michael 2016).

Increasing resource efficiency at the city level would allow for more environmentally friendly solutions and aid in the transition to a low-carbon economy while also addressing the issues of growing populations in such regions. Several UN, EU, and US projects have recently been launched to develop solutions for such sustainable cities. Among these are the United Nations' GI-REC (Global Initiative for Resource Efficient Cities), the European Union's European Innovation Partnership on Smart Cities and Communities (EIP-SCC), and the United States Smart Cities Initiative. (Edward et al. 2019). However, electricity networks are increasingly shifting toward intelligent systems and automated tasks, prompting the smart grid idea. Unfortunately, despite the extensive use of the term "smart grid" in the literature, no definitive and comprehensive definition of the term exists.

The smart grid is a modern power system that uses autonomous control of information and communication technologies and energy management infrastructures to improve efficiency and reliability. (D. Kolokotsa 2015). The smart grid is on the lookout for a compilation of these technologies to create a self-healing and more dependable network. Smart grid improves supply efficiency by maximising the utilisation of existing infrastructure, reducing the need for system expansion, and allowing the incorporation of renewable energy sources (D. Kolokotsa 2015).

On the consumer side, this means maximising the use of existing infrastructure, reducing the need for system expansion, and making it easier to integrate Renewable energy systems, particularly in the form of Distributed generations.

The use of smart meters and communication technologies is the first to build a smart grid, along with two-way communication and information technologies. These technologies will provide tools to predict different parameters and appropriate management procedures .data collected by these technologies can predict temperature, humidity and solar radiation and allow for two way communication. The two-way communication procedure can provide real-time data and a real-time monitoring system that can correct faults and make real-time adjustments for maximum energy consumption optimization (Konark and Lalit 2015).

2.5 Dashboard of Smart Energy Hub

To create long-term smart energy cities, it is necessary to encourage the development of platforms that give citizens benefits such as convenience, safety, and cost savings.

A smart city uses several sorts of sensors to capture electronic data and provide information that is then used to manage assets and resources efficiently.

Data about citizens, devices, and assets is processed and analysed to enable traffic and transportation systems, power plants, water supply networks, waste management, law enforcement agencies, information systems, schools, libraries, hospitals, and other community services to be monitored and managed (Sanguk et al. 2019).

The efficient management and exchange of energy will be used in the future buildings of sustainable smart energy city through the links between smart energy data analytics, energy prosumer, energy security, and renewable energy.

We are establishing a sustainable smart energy city idea, a platform-driven concept that provides convenience, safety, and cost savings to its residents by merging tailored services and companies into varied environments inside the current urban energy infrastructure.

Smart energy, smart meters, smart homes, buildings, factories, smart grids, and electric cars are all parts of a sustainable smart energy city. These aspects must be strategically linked to actualise the concept of a smart energy city fully. This would make the development of a Sustainable energy city more possible, quick, and cost-effective.

Following the organisation of the energy management strategy, the infrastructure required to operate it is established and designed around the IoT to enable the plan's implementation (Waleed et al., 2018). Smart cities are transformed into Sustainable smart city energy by IoT-focused infrastructure. The key purpose is to evaluate energy data supplied by the IoT and conduct efficient energy management simulations (Sanguk et al 2019).

3 Research Methodology

Choosing Hub Grade 4 as a case study for Energy Hub supports the research argument with in-depth analysis. Both types of hubs are practised in hub grade 4; for micro hub the collection of data from different types of facilities, residential. Commercial and industrial, and these readings collected from electricity sub-meters analysed by energy specialist in hub grade 4, then visualise these data using develops software and combine in macro energy dashboard, the practice of energy hubs and energy management practices is very mature in the UAE .data collected through several visits to Energy Hub of Enova by Veolia meeting energy specialists and discuss data processing and how analytical report and how energy specialist visualise these data on Hub Grade 4 dashboard.

There are missed opportunities to optimise energy consumption due to the lack of success stories of executed case studies. Although there are great opportunities to save energy and optimise energy consumption in existing buildings, these opportunities were missed because of the reluctance of building owners to accept energy-saving plans.

4 Hub Grade 4- a case study of Smart Energy Hub

Many countries are currently merging bespoke services and enterprises inside their energy infrastructure and urban surroundings to establish sustainable smart energy cities worldwide. As a result of these modifications, creating a Smart Energy Hub might be accelerated, providing citizens with benefits such as convenience, safety, and cost savings.

A sustainable city is a city that uses several sorts of sensors to capture electronic data and provide information that is then used to manage assets and resources efficiently. Data about citizens, devices, and assets are processed and analysed to enable traffic and transportation systems, power plants, water supply networks, waste management, law enforcement agencies, information systems, schools, libraries, hospitals, and other community services to be monitored and managed. (Sanguk et al. 2019) Enova by Veolia in 2014 launched Hub grade 4, a new energy hub that monitors and optimises energy, water, and material flows in real-time. Real-time data has been processed in this hub to improve resource use by municipal, commercial, and industrial clients.

Enova by Veolia is a regional leader in integrated energy and multi-technical services, providing clients with a full range of services. It offers customers performance-based Energy & Facilities Management solutions to assist them in meeting their financial, operational, and environmental objectives.

Enova began as a joint venture between Majid Al Futtaim and Veolia in 2002. Majid Al Futtaim is the Middle East's, Africa's, and Asia's largest shopping mall, community, retail, and leisure pioneer. Veolia is one of the well-known world organisations that leads the businesses of preserving the environment; their business is to optimise water consumption, waste management and energy management to help the world become sustainable and green.

The Hub grade 4 dashboard provides real-time data collected from connected sensors and submeters in buildings and services, then the collected data will be compared with benchmark readings and provide analysed feedback to the operation team to do tune-up to running equipment

The studied data is then provided in a reporting dashboard system that displays the most significant and valuable information from digital systems for quick decision-making and performance indicators to operational teams on the ground. Also hub grade 4 provide the customer with online access to reports and information to raise awareness among end-users.

Hub grade 4 incorporate all collected data from EMS, Waste Management Platforms, Water Quality Monitoring and Control Systems, BMS, CMMS, Asset Management software, SCADA systems, Carbon Footprint calculator, Indoor Air Quality monitoring applications. Financial analysis and benchmarking are also included in these systems' capabilities (Antonio and Patrice 2017).

4.1 Micro Hub Grade 4 model

The dashboard shown in Fig 4 shows real-time data for one of the shopping centres collected by installed sensors and submeters for measuring energy consumption (electricity & water).

These data will be examined against the baseline by making the comparison between actual energy consumption readings and the baseline; this will provide a continuous monitoring mechanism, as in case energy consumption is more than the base line energy consumption, the red sign will appear giving alarm to the operator to check the asset performance and bring energy consumption to positive magnitude , below is the legend represent the alarms appeared in monitoring mechanism dash board to ensure proper monitoring of energy optimisation process :

Table 1 – Monitoring Mechanism Dashboard

Facility	Utility	<A	A<B	B<C	C<
Shop.Cent1	electricity	<3.85%	3.85%<7.7%	7.7%<10%	10%<
Shop.Cent1	Water	<2%	2%<7.28%	3%<4%	4%<
Shop.Cent2	electricity	<3.69%	3.69%<7.38%	7.38%<10%	10%<
Shop.Cent2	Water	<3%	3%<4%	4%<5%	5%<
Shop.Cent3	electricity	<3.17%	3.17%<6.34%	6.34% <10%	10%<
Shop.Cent3	Water	<5%	5%<6%	6%<7%	7%<

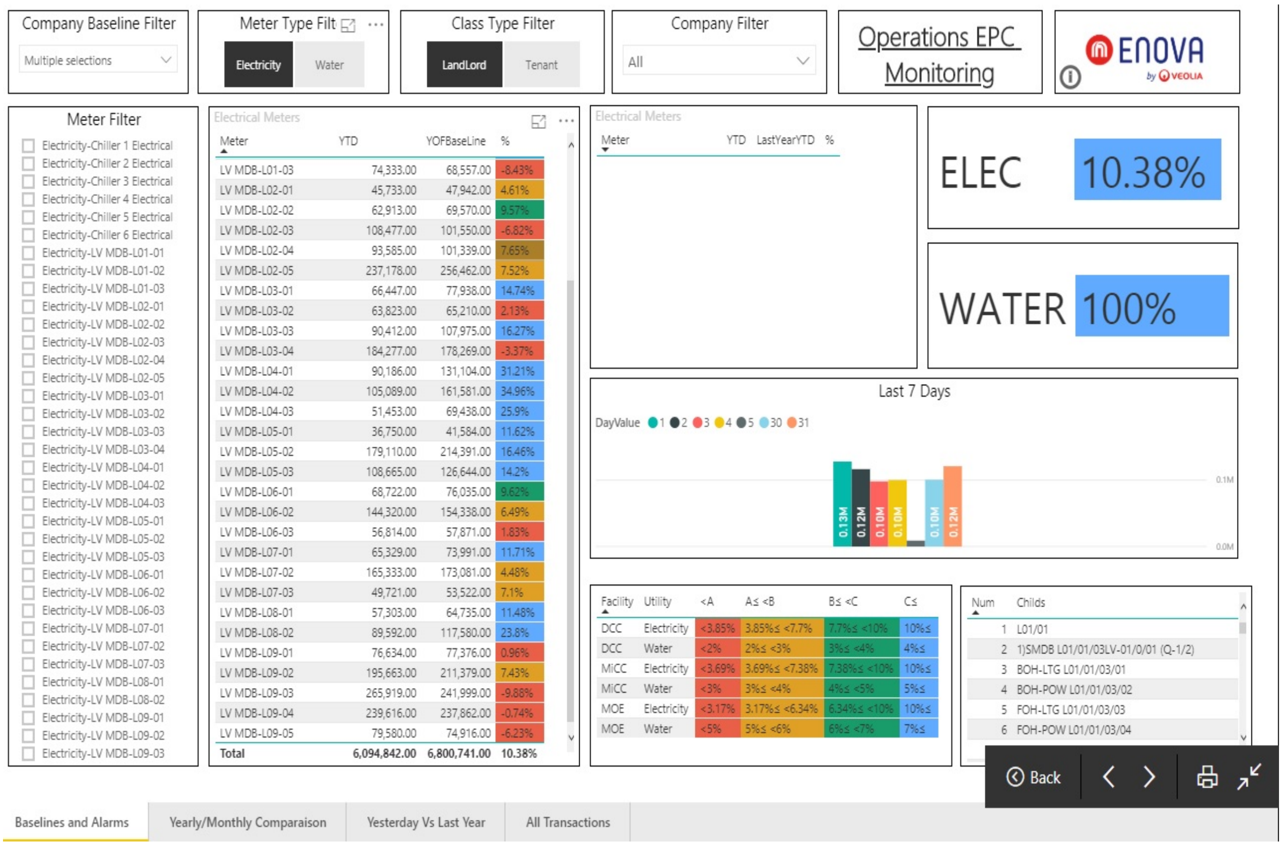


Fig 4 Dashboard showing metering system readings in one of the shopping centres

Then in Hub grade 4, the energy team will analyse collected data and summarised the results as shown in Fig 5 and then use developed software and IoT technology to show total saved electricity in terms of KW, the dashboard showing saving electricity of 1,436,375 KW, which is equivalent to 617,641 AED and saved water 18,251M3 equivalent to 208,794 AED.

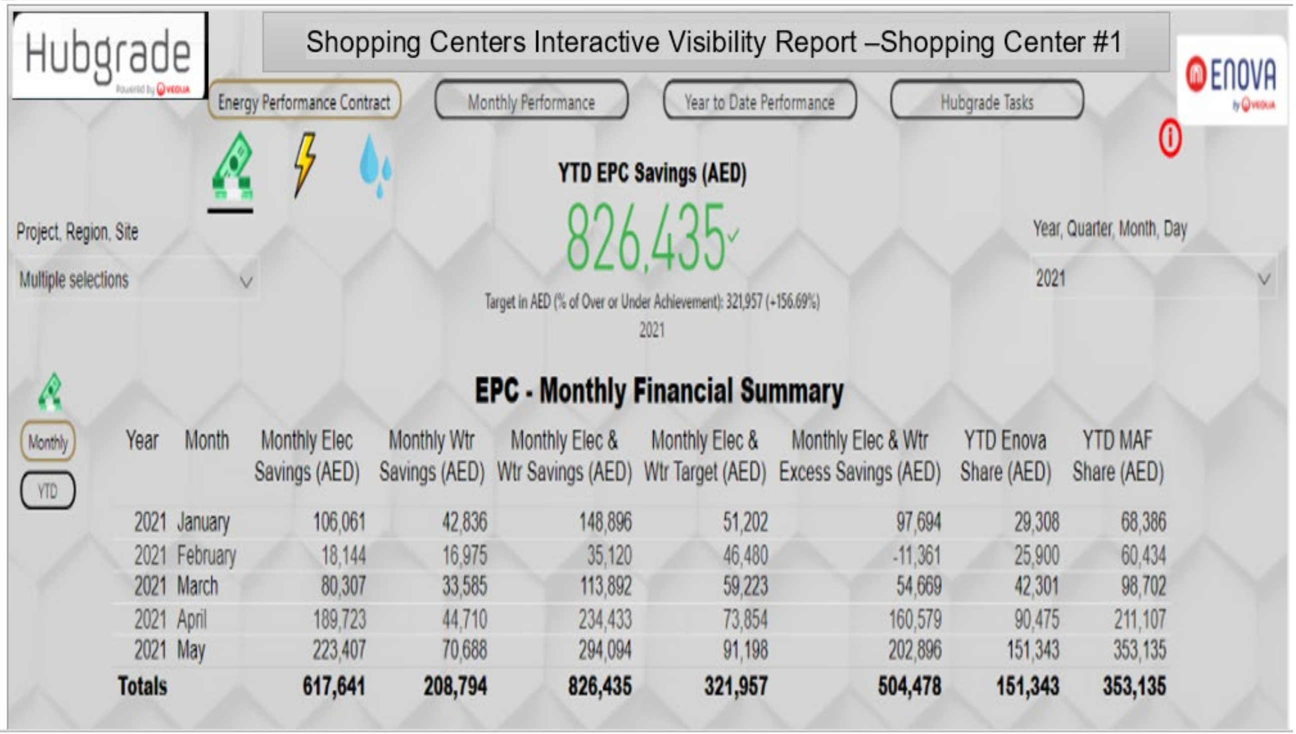


Fig 5: summary of energy consumption results for selected shopping centres

In Fig 6, we may consider the dashboard a micro energy hub dashboard representing energy optimisation for shopping centres at the micro-level where clients and service providers can monitor the progress of building system energy optimisation plans.

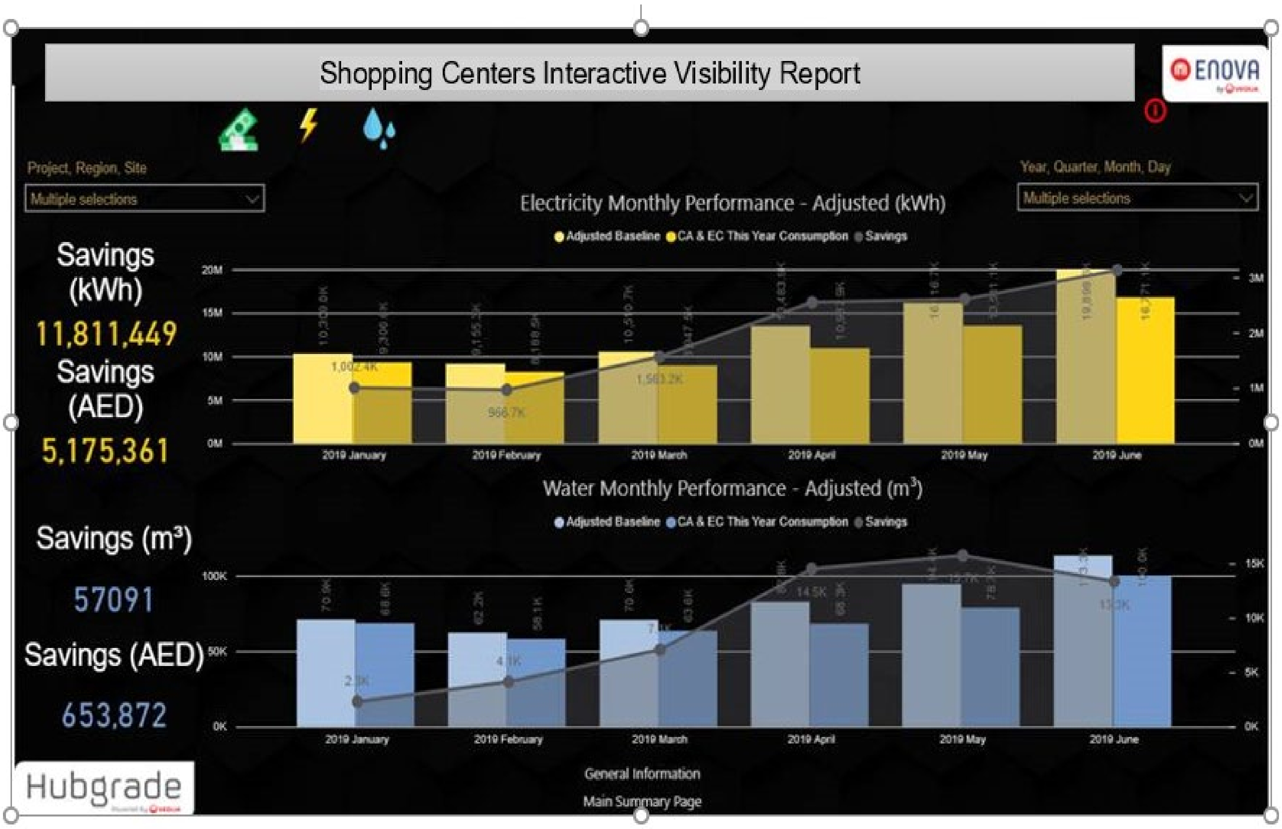
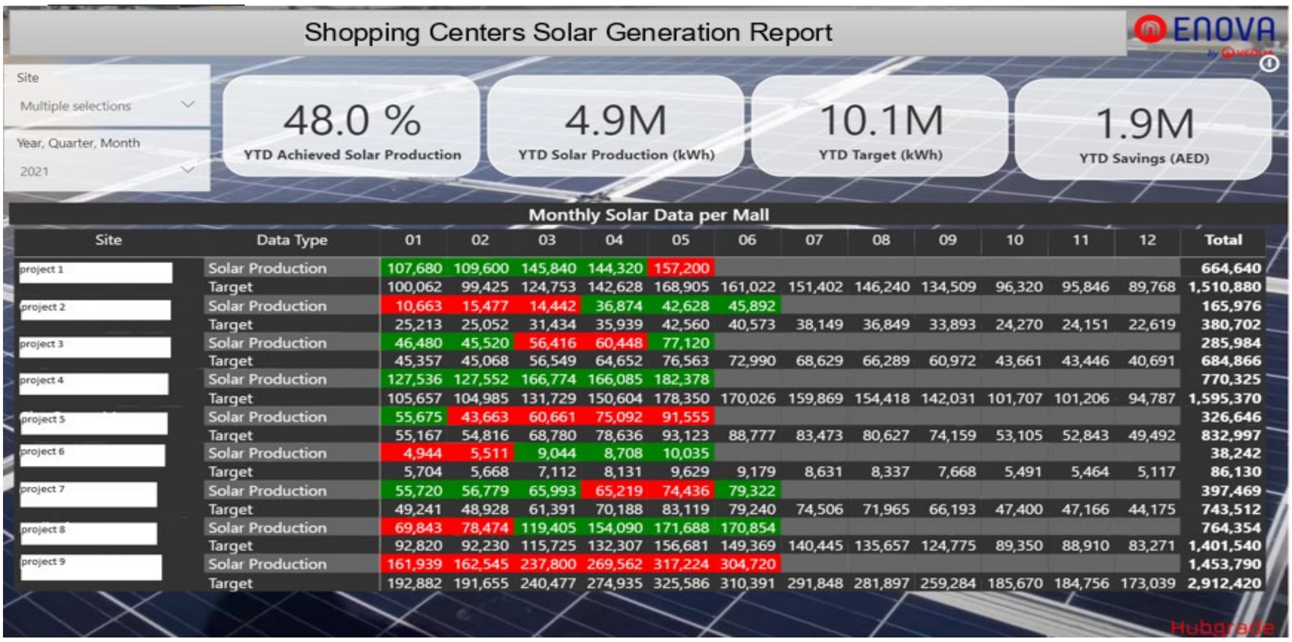


Fig 6 :Dash board for energy optimisation results for shopping centers as model for Micro energy Hub

4.2 Micro Hub Grade 4 model for renewable energy

The integration of renewable energy in hub grade 4, as shown in Fig 7, will help the implementation of microgrids and will develop the implementation of sustainable smart energy cities and support the increasing demand for power and reduce carbon footprint. The dashboard for a solar system for all shopping centres connected to solar system submeters sends energy generated readings in real time to Hub grade 4, compared with targeted values set by the energy team to monitor solar system performance. The solar dashboard reports 4.9Mil KW generated from solar grid installed in shopping centres from Jan 2021 till June 2021, achieving 48% from the yearly target.



Site	Data Type	01	02	03	04	05	06	07	08	09	10	11	12	Total
project 1	Solar Production	107,680	109,600	145,840	144,320	157,200								664,640
	Target	100,062	99,425	124,753	142,628	168,905	161,022	151,402	146,240	134,509	96,320	95,846	89,768	1,510,880
project 2	Solar Production	10,663	15,477	14,442	36,874	42,628	45,892							165,976
	Target	25,213	25,052	31,434	35,939	42,560	40,573	38,149	36,849	33,893	24,270	24,151	22,619	380,702
project 3	Solar Production	46,480	45,520	56,416	60,448	77,120								285,984
	Target	45,357	45,068	56,549	64,652	76,563	72,990	68,629	66,289	60,972	43,661	43,446	40,691	684,866
project 4	Solar Production	127,536	127,552	166,774	166,085	182,378								770,325
	Target	105,657	104,985	131,729	150,604	178,350	170,026	159,869	154,418	142,031	101,707	101,206	94,787	1,595,370
project 5	Solar Production	55,675	43,663	60,661	75,092	91,555								326,646
	Target	55,167	54,816	68,780	78,636	93,123	88,777	83,473	80,627	74,159	53,105	52,843	49,492	832,997
project 6	Solar Production	4,944	5,511	9,044	8,708	10,035								38,242
	Target	5,704	5,668	7,112	8,131	9,629	9,179	8,631	8,337	7,668	5,491	5,464	5,117	86,130
project 7	Solar Production	55,720	56,779	65,993	65,219	74,436	79,322							397,469
	Target	49,241	48,928	61,391	70,188	83,119	79,240	74,506	71,965	66,193	47,400	47,166	44,175	743,512
project 8	Solar Production	69,843	78,474	119,405	154,090	171,688	170,854							764,354
	Target	92,820	92,230	115,725	132,307	156,681	149,369	140,445	135,657	124,775	89,350	88,910	83,271	1,401,540
project 9	Solar Production	161,939	162,545	237,800	269,562	317,224	304,720							1,453,790
	Target	192,882	191,655	240,477	274,935	325,586	310,391	291,848	281,897	259,284	185,670	184,756	173,039	2,912,420

Fig 7: Solar energy generation Dashboard for shopping centers

4.1 Macro Hub Grade 4 model

The sustainability report shown in Fig 8 represents a summary report for all energy optimisation activities monitored by Hub grade 4; it acts as a Macro energy hub dashboard for all projects controlled by hub grade.

It represents the integration of several micro hubs like residential buildings, hotels, shopping centres..etc. under the control of Macro energy hub, which gives financial, economic and technical benefits and increases the contribution of preserving the environment protect the environment.

To summarise the results of energy optimisation in all projects as visualised in the sustainability report, hub grade 4 was able to save 254 million kW power and around 3million cubic meters of water and give a financial saving of about 138 million AED.

These results are encouraging results to motivate public and private sectors to adopt energy-saving and energy management to benefit from efficient usage of energy and push authorities to adopt solid policies to move the community to more efficient power consumption as Jaffi and stain argue that Each kilowatt of energy of plant capacity reduced to save the city more than the individual who decides to save energy (Jaffi and Stain 1994).

Applying the hub grade 4 concept on the city level that adopts efficient energy consumption and promotes a developed energy management system that can link different kinds of micro energy hubs using smart digital technologies will create a sustainable smart energy city.

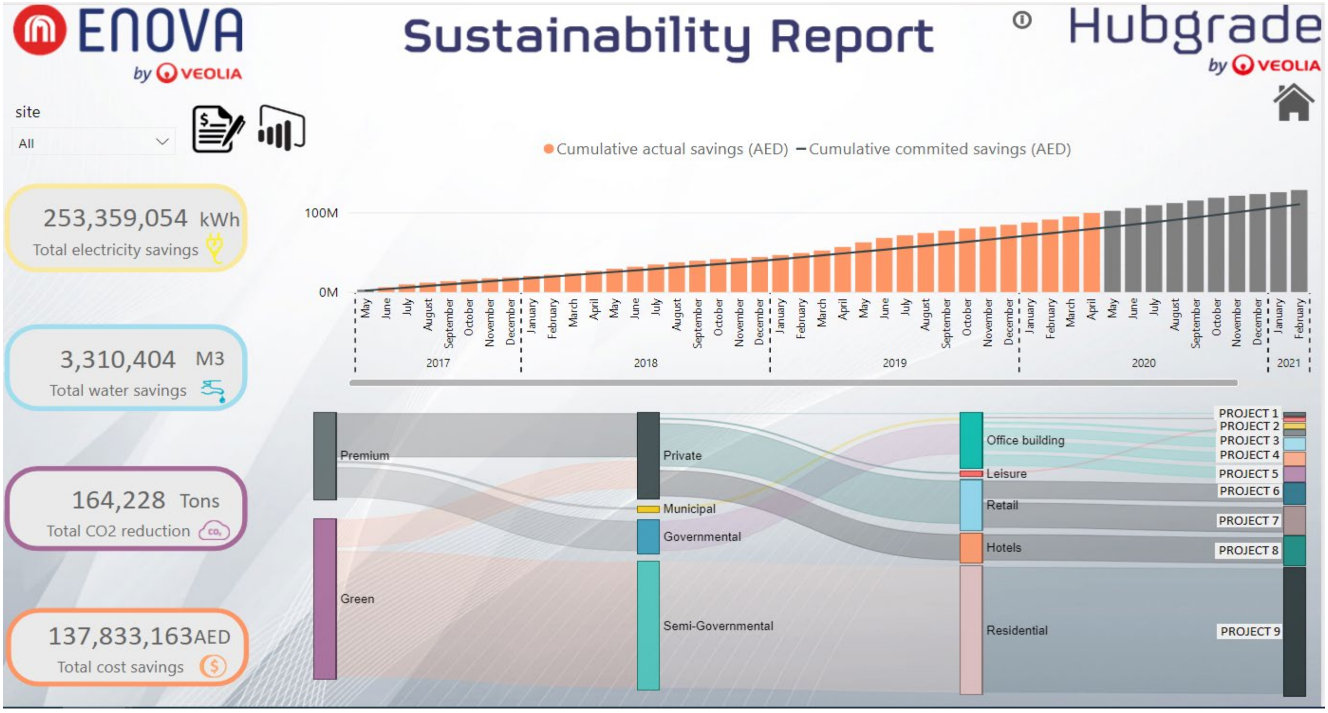


Fig 8:Comprehansive Macro Dashboard for a different types of buildings, residential, commercial and industrial

5 Findings and Discussion

The research and case study reveal that the impact of the increased population on earth require huge efforts to customise the consumption of natural resources; the optimal use of these resources requires a centralised monitoring system and integrated energy management.

Introducing Energy hub as a concept provides a powerful tool to manage energy flow and monitor energy consumption in real-time utilising new technologies and IoT, providing required data to the energy hub dashboard to visualise the results of optimising energy consumption and minimise carbon footprint.

Applying the concept of energy hub on city level introduces two types of energy hub. First, one micro hub and 2nd is macro hub depending on the type of facilities and consumer and consumption pattern; the micro-energy hub can be residential, or commercial or industrial, while macro hub can integrate several types of micro hubs, moving toward smart energy system with developed new technologies evolving energy management to be smarter and smarter towered machine learning and digital twin to reach to optimal use of energy resources.

Hub grade 4case study shows the benefits of employing energy hub on micro level and macro level leverage the huge amount of data and visualising the results on smart dashboards allowing operator and the client to take the right decision. It is a good model for creating a sustainable smart city that optimises its recourses.

6 Conclusions and Further Research

To create a sustainable smart energy city, it is essential to combine and customise several services and businesses within the structure of energy systems and city infrastructure.

A healthy society that uses smart technologies to manage a collection of smart city infrastructures that support sociotechnical and socioeconomic initiatives and celebrate cultural and ethnic diversity, for example, could play a key role in organising the global response to challenges posed by rapid urbanisation (Shahidehpour 2018).

Since an energy hub has the ability to integrate several services for different types of facilities, an energy hub is an excellent solution to optimise energy consumption as an integrated energy management system; the micro-energy hub can be a great solution to remodelling of energy consumption of residential, commercial and industrial facilities while Macro energy hub can integrate several micro hubs giving the advantages of technical, economic and environments benefits. However, due to the large volume of data and connectivity with a large number of sensors, the use of IoT and smart technologies became essential to explore the results of energy system optimisation moving these facilities to be smarter and smarter.

The case study shows considerable energy savings and proof that optimising energy consumption in micro and macro levels utilising smart technologies and IoT, presenting these results through the smart dashboard is the first step towards a sustainable smart energy city.

Below in Fig 9 is a model of a future sustainable smart energy city where centralised macro energy hubs adopt different services introducing new IoT and digital technologies will bring considerable energy savings besides minimising future plans for new power plants.

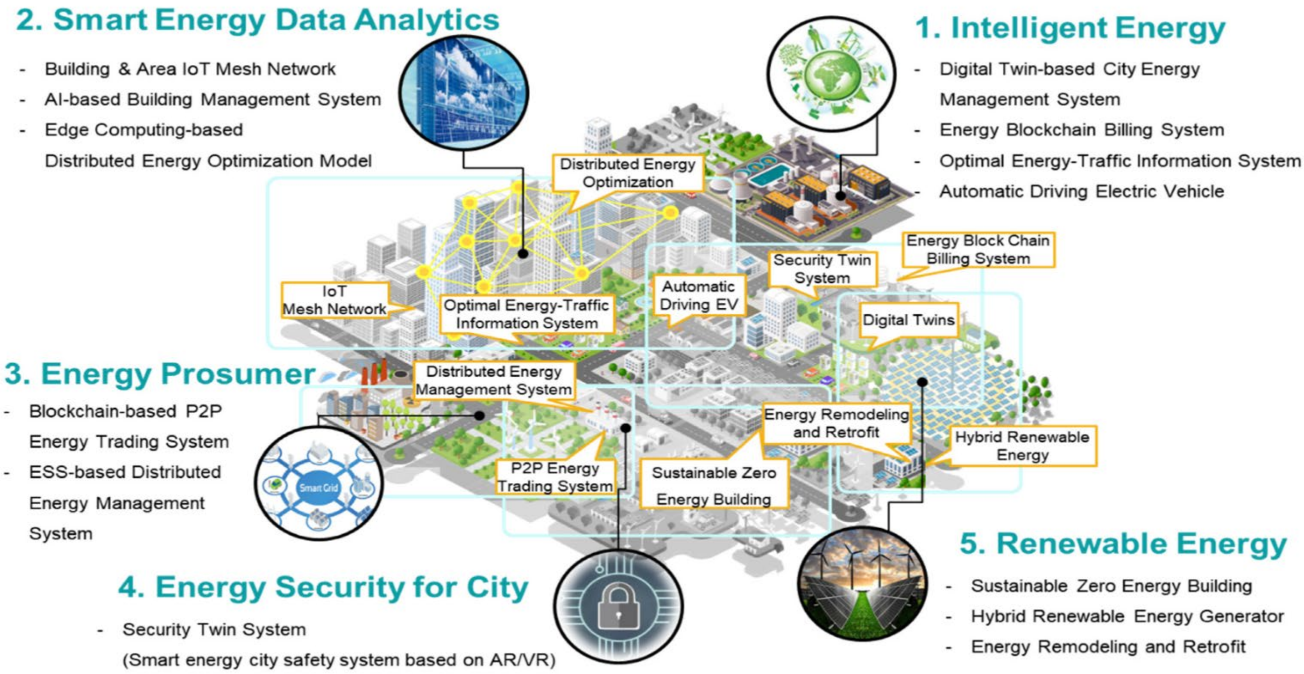


Fig 9: Future model for sustainable smart energy city (Sanguk et al. 2019)

Future plans require the intervene of governments to play a significant role to form new policies, new regulations to incentivise and promote sustainable smart energy cities and smart energy hubs to encourage communities and building owners, businesses to adopt building micro hubs as part of city infrastructure and connect these micro hubs to centralised macro hubs (Kablan, 2004).

Also, future studies should concentrate on the connectivity of all services using smart technologies creating digital twin model and building comprehensive smart energy hub controlled by city municipal as an urban twin model which deals with several services electricity, water supply, renewable energy, waste management, traffic, electric cars and city security system.

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References

Alexandr Krylovskiy∗, Marco Jahn∗, Edoardo Patti(2015) Designing a Smart City Internet of Things Platform with Microservice Architecture.

Antonio Neves Da Silva and Patrice Novo(2017) Hub grade 4 Smart Monitoring Centers: Measuring Resource Consumption and Moving towards a Circular Economy.

D. Kolokotsa (2015): The role of Smart Grids in the Building Sector.

Dimitris Lazos n, AlistairB.Sproul, MerlindeKay (2014) Optimisation of energy management in commercial buildings with weather forecasting inputs: A review.

EA Abdelaziz a, R. Saidur a, S. Mekhilef b (2010) A review on energy saving strategies in industrial sector.

Edward O'Dwyera, Indranil Panb,c,∗, Salvador Achaa, Nilay Shaha(2019) Smart energy systems for sustainable smart cities: Current developments, trends and future directions.

EIA (2020) US Energy information administration independent statistics and analysis https://www.eia.gov/tools/faqs/faq.php?id=86&t=1 accessed on 1st of July 2020.

Enrico Fabrizio a, Vincenzo Corrado b , Marco Filippi b(2009) A model to design and optimize multi-energy systems in buildings at the design concept stage.

Geidl M, Koeppel G, Favre-Perrod P, Klockl B, Andersson G, Frohlich K. Energy hubs for the future. IEEE Power Energy Mag(2007).

Isha Sharma, Claudio Ca˜nizares,, and Kankar , Bhattacharya,. (2015) Residential Micro-Hub Load Model Using Neural Network.

International Energy Outlook (2019) https://www.eia.gov/outlooks/ieo/pdf/ieo2019.pdf accessed on 6th of July 2021.

Jaffe, A.B.,Stavins,R.N.,(1994).The energy efficiency gap : what does it mean ? Energy Policy, Volume 22, Issue 10, October (1994), Pages 804-810.

Jesse Steinfeld∗, Anna Bruce, Muriel Watt,(2011) Peak load characteristics of Sydney office buildings and policy recommendations for peak load reduction.

Konark Sharma n , Lalit Mohan Saini(2015) Performance analysis of smart metering for smart grid: An overview.

Maria LorenaTuballa a,n, MichaelLochinvarAbundo(2016) A review of the development of Smart Grid technologies.

Mawed, M.; Al-Hajj, A.; Alshemery, A.A., The impacts of sustainable practices on UAE mosques' life cycle cost. In Proceedings of the Smart, Sustainable and Healthy Cities: 1st International Conference of the CIB Middle East and North Africa Research Network, Abu Dhabi, UAE, 14–16 Dec. 2014; pp. 307–324.

Mawed, M.; Tilani, V.; Hamani, K. The role of facilities management in green retrofit of existing buildings in the United Arab Emirates. J. Facil. Manag. 2020, 18, 36–52.

Mohammad Chehreghani Bozchalui, Ratnesh Sharma, (2012) Optimal Operation of Commercial Building Microgrids using Multi-objective Optimisation to Achieve Emissions and Efficiency Targets.
Mohammad Mohammadia, Younes Noorollahia,⁎, Behnam Mohammadi-ivatloob, Hossein Yousefia Energy hub: From a model to a concept – A review http://dx.doi.org/10.1016/j.rser.2017.07.030 ,Received 8 November 2016; Received in revised form 29 December 2016; Accepted 9 July (2017)
Mohammad Mohammadia, Younes Noorollahia,⁎, Behnam Mohammadi-ivatloob,Mehdi Hosseinzadehc, Hossein Yousefia, Sasan Tribade Khorasanid Optimal management of energy hubs and smart energy hubs – A review ,27 February (2018) Corresponding author. E-mail address: Noorollahi@ut.ac.ir (Y. Noorollahi).

Nicolás Pardo*, José Antonio Moya (2013) Prospective scenarios on energy efficiency and CO2 emissions in the European Iron & Steel industry.

Nielsen, P.S.; Amer, S.B.; Halsnæs, K. Definition of Smart Energy City and State of the Art of 6 Transform Cities Using Key Performance Indicators;(2013).

Park, S.; Park, S.; Byun, J.; Park, S. Design of a mass-customisation-based cost-effective Internet of Things sensor system in smart building spaces. Int. J. Distrib. Sens. Netw.(**2016)** , 12, 1550147716660895.

Shahidehpour, M.; Li, Z.; Ganji, M. Smart Cities for a Sustainable Urbanisation: Illuminating the Need for Establishing Smart Urban Infrastructures. IEEE Electrif. Mag. (**2018**), 6, 16–33.

Shahzad Khan*, Devashish Paul¥, Parham Momtahan¥, Moayad Aloqaily (2018) Artificial Intelligence Framework for Smart City Microgrids: State of the art, Challenges, and Opportunities

Sanguk Park, Sanghoon Lee, Sangmin Park and Sehyun Park(2019) AI-Based Physical and Virtual Platform with5-Layered Architecture for Sustainable Smart EnergyCity Development
UN-Habitat, UNEP, the World Bank and Cities Alliance, https://www.un.org/en/climatechange/climate-solutions/cities-pollution accessed on 6th of July 2021

Waleed Ejaz, Muhammad Naeem, Adnan Shahid, Alagan Anpalagan, and Minho Jo(2018) Efficient Energy Management for the Internet of Things in Smart Cities.

World Urbanization Prospects The 2018 Revision,
https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf accessed on 6th july 2021
Yan Su. (2019) Smart energy for smart built environment: A review for combined objectives of affordable sustainable green.

Kablan, M.M(2004); Decision support for energy conservation promotion: an analytic hierarchy process approach; Elsevier Science; Energy Policy 32 (2004) 1151–1158.