



REPUBLIC OF TURKEY
ALTINBAŞ UNIVERSITY
Institute of Graduate Studies
Architecture

**INTEGRATION OF THE SOLAR ENERGY WITH
RESIDENTIAL BUILDINGS WITHIN SMART
CITIES - GULF COUNTRIES: COMPARISON OF
MASDAR AND AL FALAH PROJECTS**

Ghaydaa SHAHEEN

Master's Thesis

Supervisor

Assoc. Dr. Gülay YEDEKCI

Istanbul, 2022

**INTEGRATION OF THE SOLAR ENERGY WITH RESIDENTIAL
BUILDINGS WITHIN SMART CITIES - GULF COUNTRIES:
COMPARISON OF MASDAR AND AL FALAH PROJECTS**

Ghaydaa SHAHEEN

Department of Architecture

Master's Thesis

ALTINBAŞ UNIVERSITY

2022

The thesis titled INTEGRATION OF THE SOLAR ENERGY WITH RESIDENTIAL BUILDINGS WITHIN SMART CITIES - GULF COUNTRIES: COMPARISON OF MASDAR AND AL FALAH PROJECTS, prepared by GHAYDAA SHAHEEN, and submitted on 07/02/2022 has been **accepted unanimously** for the degree of Master of Architecture.

Assoc. Dr. Gülay YEDEKCI

Supervisor

Thesis Defense Committee Members:

Assoc. Dr. Gülay YEDEKCI

Faculty of Engineering and
Architecture,

Altınbaş University

Prof. Dr. Ayse AKNESIL

Faculty of Engineering and
Architecture,

Altınbaş University

Asst. Prof. Dr. Kaya SÖNMEZLER

Faculty of Architecture,

Mimar Sinan Fine Art
University

I hereby declare that this thesis/dissertation meets all format and submission requirements of a Master's thesis.

Accepted by Altınbaş University Institute of Graduate Studies on the following date:

____/____/____

I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Ghaydaa SHAHEEN

Signature

DEDICATION

I am very grateful to my supervisor Dr. Gülay Yedekci, for guiding me to complete my master thesis through difficult times. She always gives me insightful and helpful comments. I received much guidance and advice for keeping in the same performance concentration.

My sincere thank to my parents for their support, strengthening, and encouragement. I would like to thank Abdulrahman and Layan for standing beside me.



ABSTRACT

INTEGRATION OF THE SOLAR ENERGY WITH RESIDENTIAL BUILDINGS WITHIN SMART CITIES - GULF COUNTRIES: COMPARISON OF MASDAR AND AL FALAH PROJECTS

SHAHEEN, Ghaydaa

M.Arch., Architecture, Altınbaş University,

Supervisor: Assoc. Dr. Gülay YEDEKCI

Date: February / 2022

Pages: 163

In most cases, the new ways are evaluated as more harmful to the environment until Solar energy proves otherwise. The internal systems in buildings operate in various forms of power, such as oil, gas, and coal, which cause harm to the Environment. This thesis shows that the luxury in residential homes and solar systems does not conflict with the idea of a perfect ecosystem. This dissertation defines solar power systems applied in Housing inside intelligent cities. The fact that per capita consumption in the Gulf Cooperation Council countries is high compared to the world, solar energy is available most of the year. This thesis aims to identify solar systems compatible with residential buildings in GCC intelligent cities by literature review and case study methodology. There are many types of renewable energy, including wind, fuel cell, Bioenergy, Geothermal, and solar, described in detail with the challenges. In line with the subject of the thesis mentioning all aspects of solar energy and knowing the main ways to generate power. The

Solar power utilization in residential buildings for water heating systems in the passive and active methods, heating and cooling systems, and solar optical Technology. Through the years, solar energy transitions from one form to another in line with the evolution of life. Reaching the top in the next period analyzes the main factors for developing future cities in terms of renewable energy Development, network, and communication technologies sector. The house needs a system that connects technologies with an operating power system, either a hybrid or cogeneration. Housing in intelligent cities is different in design from other buildings causes diversity in building methods and careful selection of materials. Referring to Masdar in Abu Dhabi as a smart city case study applying solar energy's highest buildings standards. Al Falah city is another case study analysis to find solutions and ways to support ordinary residential communities and connect smart residential communities with solar systems. The effective solar residential system in a smart city is sequences steps including the infrastructure, transportation, sensors, internet connection, and security. The integrated smart ecosystem provides residents with high luxury and is environmentally friendly.

Keywords: Development, Technology, Solar Energy, Environment, Residential Buildings.

TABLE OF CONTENTS

	<u>Pages</u>
ABSTRACT.....	vi
TABLE OF CONTENTS	viii
LIST OF TABLES	xii
LIST OF FIGURES	xiii
ABBREVIATIONS.....	xix
1. INTRODUCTION	1
2. SUSTAINABILITY (RENEWABLE ENERGY)	4
2.1. SUSTAINABLE ENERGY IN THE WORLD	4
2.2. THE KEY ROLES FOR RENEWABLE ENERGIES	4
2.3. RENEWABLE ENERGY TYPES	5
2.3.1. Understanding Wind Energy	5
2.3.2. Importance Of Fuel Cells	9
2.3.3. Overview Of Bioenergy.....	12
2.3.4. Geothermal Energy Overview	14
2.3.5. Use Of Solar Energy	16
2.4. SUSTAINABLE ENERGY CHALLENGES.....	19
2.4.1. The Increase In Average Global Temperatures	21
2.4.2. Potential Acid Rain Issues.....	21
2.4.3. Environmental Considerations On Greenhouse Gas Emission	22

3.	SOLAR ENERGY ENABLING TECHNOLOGIES	23
3.1.	SOLAR ENERGY GENERATION SYSTEMS	23
3.1.1.	Solar Photovoltaics (PV)	23
3.1.2.	Concentrating Solar Photovoltaic Systems (CSP).....	25
3.2.	SOLAR ENERGY TECHNOLOGIES FOR BUILDINGS	26
3.2.1.	Stationary State Collectors.....	26
3.2.2.	Methods Of Tracking Concentrating Solar Systems	30
3.2.2.1.	Use of single-axis design.....	31
3.2.2.2.	Use of two axes design.....	33
3.3.	UTILIZATION OF SOLAR POWER IN BUILDINGS	37
3.3.1.	Water Heating System	38
3.3.1.1.	Active systems.....	39
3.3.1.2.	Passive systems	42
3.3.2.	Indoor Solar Power System	43
3.3.3.	Solar Optical Technology	46
3.4.	SOLAR ENERGY TRANSITIONS OVER THE YEARS	48
3.5.	SOLAR ENERGY SECURITY STANDARD.....	51
3.6.	LEVELIZED COST OF SOLAR ENERGY AND INVESTMENT.....	53
3.7.	OVERVIEW OF CONSUMPTION DATA.....	54
3.7.1.	Household Consumption Around The World.....	55
3.7.2.	Household Consumption In The GCC.....	56

4.	SOLAR HOMES IN SMART CITIES.....	58
4.1.	SUSTAINABLE DEVELOPMENT IN SMART CITIES.....	59
4.1.1.	Development Smart City Networks.....	60
4.1.2.	The Future Of Solar Energy	62
4.2.	RESIDENTIAL BUILDINGS IN FUTURE CITIES.....	64
4.2.1.	Communication Technologies	64
4.2.2.	Smart Home Energy Management	66
4.2.3.	Building Compatibility With Photovoltaics - (BIPV)	69
4.2.4.	Element Analysis	72
4.2.4.1.	Analyzing solar energy performance intelligent	73
4.2.4.2.	Ability and efficiency	75
4.2.4.3.	Materials and methods.....	76
4.3.	SOLAR ENERGY CONSUMPTION MEASURING IN BUILDING.....	80
5.	CASE STUDY ANALYZING	82
5.1.	MASDAR CITY IN ABU DHABI, UAE	82
5.1.1.	Project Data Analyzing.....	83
5.1.2.	Solar Energy Levels.....	85
5.1.3.	Buildings Characteristics And Details.....	88
5.1.3.1.	Types of construction	88
5.1.3.2.	Construction materials and proportions	93
5.1.4.	Interaction With High Temperatures	95

5.2.	AI FALAH COMPLEX HOUSING IN ABU DHABI, UAE	97
5.2.1.	Complex Housing Analyzing	97
5.2.2.	Energy Consumption	98
5.2.3.	Residence Sector In Al Falah Complex Housing	99
6.	COMPARISON AND A NEW APPROACH BETWEEN MASDAR AND AL FALAH CITY.....	103
6.1.	RESIDENTIAL ENVIRONMENT DIFFERENTIATIONS	104
6.2.	IMPORTANT CRITERIA FOR CONVERTING HOUSING COMPLEXES.	104
6.2.1.	Housing Complex Planning Management	108
6.2.2.	Housing Environment Improving	109
6.2.3.	Smart City Infrastructure And Services Considerations.....	110
6.3.	METHODS OF TRACKING CONSUMPTION	113
6.4.	ANALYZING HOUSING CONSTRUCTION	115
6.5.	APPARENT HOUSING COMPLEX ISSUES	117
6.6.	MATERIALS STANDARD AND EMISSIONS	119
6.7.	THE USE OF SOLAR SYSTEMS IN HOUSING COMPLEX	120
6.8.	DEALING WITH ENVIRONMENTAL DATA	122
7.	CONCLUSION.....	126
	REFERENCES.....	131

LIST OF TABLES

	<u>Pages</u>
Table 2.1: Stages Produce Fuel Cells	10
Table 2.2: Working Mechanism Phases in Fuel Cells	10
Table 2.3: Numbers of GCC massive projects in 2018	19
Table 3.1: PV Modules	25
Table 3.2: Solar Energy Collectors With a Temperature Range	37
Table 4.1: The Progress of Solar Energy in 2050	63
Table 4.2: Materials and CO2 Emission.....	80
Table 5.1: Masdar city - Buildings Materials.	94
Table 5.2: Annual Percentage of Consumption in Al Falah Complex Housing.....	99
Table 6.1: Comparison Between Masdar City and Al Falah City.	106
Table 6.2: Urban Planning Problems in Al Falah City	110
Table 7.1: Comparison solar technology in Masdar and Falah City	129

LIST OF FIGURES

	<u>Pages</u>
Figure 1.1: Thesis Methodology Steps	3
Figure 2.1: Progressive Levels for Wind Energy.....	7
Figure 2.2: Various Installation Positions for Wind Turbines.....	8
Figure 2.3: Wind Speed and Intensity on Building.....	8
Figure 2.4: Fuel Cells Tanks.....	12
Figure 2.5: Geothermal Energy Installation.....	15
Figure 2.6: Residential Spaces.....	18
Figure 3.1: Solar cell layers.	24
Figure 3.2: (ETC) System.	27
Figure 3.3: (FPC) System	28
Figure 3.4: Solar Air Collectors.....	29
Figure 3.5: Schematic of (CPC)	30
Figure 3.6: Schematic of (CTC).....	31
Figure 3.7: Linear Fresnel Collectors	32
Figure 3.8: Parabolic-Trough Collector	33

Figure 3.9: Parabolic Dish Reflector	35
Figure 3.10: Heliostat Collectors	36
Figure 3.11: Solar Collectors Divisions.....	36
Figure 3.12: Working Stages Air - Water Heating System	41
Figure 3.13: Thermosyphon Solar System.....	42
Figure 3.14: (SAH) System	44
Figure 3.15: Solar Optical Technology.....	46
Figure 3.16: Light Shelves System.	47
Figure 3.17: Solar Energy Progress.	48
Figure 3.18: PV Energy Investment Progress.....	49
Figure 3.19: Levelized Cost Steps for CSP	53
Figure 3.20: Growing Solar Home Systems.	55
Figure 4.1: GCC Smart City Indicators	60
Figure 4.2: Gulf Countries' Networks Investment.	62
Figure 4.3: Job Opportunities Clarification.	64
Figure 4.4: Network Services in House.	65
Figure 4.5: Relation Between Solar Energy and Home Services	67

Figure 4.6: Screen Control Device for Smart Home	67
Figure 4.7: HEMS Sections	68
Figure 4.8: Steps of Connecting Smart Home and Smart City	69
Figure 4.9: Installation PV on Building.....	70
Figure 4.10: Diversity of Building Integrated Photovoltaics Options	71
Figure 4.11: BIPV Pre-installation design.....	72
Figure 4.12: Installation after design	72
Figure 4.13: Hybrid System.....	74
Figure 4.14: A Simple Schematic of Cogeneration Technology System.	75
Figure 4.15: Housing Interaction with Solar Power	75
Figure 4.16:Way of Solar Gain in Housing	77
Figure 4.17: Global construction materials.....	79
Figure 4.18: Increased CO ₂ emissions in the home	79
Figure 4.19: Electricity Consumption in the Year 2016.....	81
Figure 5.1: Plan for Masdar City	83
Figure 5.2: Divisions in Scheme for Masdar City	84
Figure 5.3: Solar Energy in Masdar City	85

Figure 5.4: Masdar City Islamic Housing Design	89
Figure 5.5: Solar Panels Installed	90
Figure 5.6: Wave Facade Design	90
Figure 5.7: Masdar City Contemporary Housing Design	90
Figure 5.8: Interior Design in Masdar City Housing	91
Figure 5.9: Institute’s Library in Masdar City	92
Figure 5.10: Masdar City Headquarters Design	93
Figure 5.11: Wind Tower Components	95
Figure 5.12: Wind Tower Lighting	96
Figure 5.13: Plan for Al Falah Complex Housing	97
Figure 5.14: Al Falah Complex Housing Scheme	98
Figure 5.15: Al Falah Dwelling Types.	100
Figure 5.16: Pre-made Items in Al Falah Complex Housing.....	101
Figure 5.17: Structural System of Al Falah Housing.....	102
Figure 5.18: Al- Falah Complex Housing Plan.	102
Figure 6.1: The Renewable Energy Suitable for The Gulf Countries	103
Figure 6.2: Layers of Successful Smart City	105

Figure 6.3: Master Plans of Masdar and Al Falah City	108
Figure 6.4: Vital Infrastructure in Masdar City	111
Figure 6.5: Infrastructure in Masdar - Capsule cars	112
Figure 6.6: Infrastructure in AL Falah Cites -installing pipes phase.....	112
Figure 6.7: Part of Al-Falah City Plan	113
Figure 6.8: Wind Tower Location in Masdar city	114
Figure 6.9: Town Center Location in Al Falah City	115
Figure 6.10:Main structure in Masdar city	116
Figure 6.11: Shadows in the pedestrian path - masdar city	116
Figure 6.12: Al Falah City Housing	116
Figure 6.13: Structures in the Masdar Headquarters.	118
Figure 6.14: Al-Falah Complex Housing Villages	118
Figure 6.15: Example of glazed cabins.....	119
Figure 6.16: The Construction Phase of Al Falah Complex Housing	120
Figure 6.17: Solar plant in Masdar City	121
Figure 6.18:Linear Fresnel Field Collectors in Masdar.	121
Figure 6.19: Solar Collectors on the Roofs in The Al-Falah city	122

Figure 6.20: Columns Cone-Shaped Interacting	123
Figure 6.21: The Structure Reflects Sunlight and Absorbs Energy.....	123
Figure 6.22: The Center Town in Al-Falah Project	124



ABBREVIATIONS

DNI	:	Direct Normal Insolation
OECD	:	Organization for Economic Co-operation and Development
TFEC	:	The Foundation for Enhancing Communities
IsDB	:	Islamic Development Bank
UNFCC	:	United Nations Framework Convention on Climate Change
IPCC	:	Intergovernmental Panel on Climate Change
VAWT	:	Vertical Axis Wind Turbine
HAWT	:	Horizontal Axis Wind Turbine
IRENA	:	International Renewable Energy Agency
IEA	:	International Energy Agency
CPV	:	Concentrator photovoltaics
EGS	:	Enhanced Geothermal
HDR	:	Hot dry rock
CSP	:	Concentrating solar photovoltaic systems
PV	:	Photovoltaics
TRNSYS	:	Transient systems simulation
FLHS	:	Full load hours of storage
ETC	:	Evacuated tube collector
BIPV	:	Building - integrated photovoltaic

GNSS	:	Global Navigation Satellite Systems
GPS	:	Global Positioning System
BMS	:	Building Management System
NEEAP	:	National Energy Efficiency Action Plan
HEMS	:	Home Energy Management System
TES	:	Thermal Energy Store
ETFE	:	Tetrafluoroethylene
PFA	:	Pulverized Fly Ash
GGBS	:	Ground Granulated Blast furnace Slag
NREA	:	New and Renewable Energy Authority
PCM	:	Phase Change Material
BAPV	:	Building Applied Photovoltaics
BIWE	:	Building Integrated Wind Energy
MBR	:	Mohammed bin Rashid
UPC	:	Urban Planning Council
SAC	:	Solar air collector
FPC	:	Flat Plate collector
CPC	:	Compound Parabolic Collector
CdTe	:	Cadmium telluride
CIGS	:	Copper indium-gallium diselenide
CIS	:	Copper indium selenide

a-Si	:	Amorphous silicon
SO ₂	:	Sulfur oxide
UAE	:	United Arab Emirates
GCC	:	Gulf Cooperation Council
PTC	:	Parabolic-trough collector
HFC	:	Heliostat field collectors
ICS	:	Integral Collector Storage
HVAC	:	Heating, ventilation, and air conditioning
SAH	:	Solar air heating
BAPCO	:	Bahrain Petroleum Company

1. INTRODUCTION

The surrounding world depends on several revolutions that are the basis for the formation of society. In the 18th century (1784) textiles and machinery industry specialized in fabrics dominated for that century. Electric power, telephone connection, and car manufacturers were the first stage of the 20th century (1844). The second stage of the 20th century (1969) was computers and the internet. In the 21st century, the fourth revolution started in 2010 and continues until 2022 and beyond. The fourth revolution relied on technology and enabled it to activate the services until it became the center of attention and development. Around 20 years ago the civilization and development began to appear in all domains (Al Shugairi , A, 2020). Architecture and construction are use technology inside the building to provide comfort and modernity. There are many intelligent systems inside the buildings, depending on the gas, electricity, and endless energy. The technology growth in artificial intelligence buildings counts on a vast part of energy consumption. At the same time, there are many new characteristics added remains energy and technology are the recent trends in architectural development. 55% is the annual rate that clarifies consumption energy by buildings worldwide (UN Environment Programmem, 2020, 4).

The high level of luxury in buildings is increasing, but the rising cost and the resulting environmental damage remain. The existence of intelligent cities depending on technology is allowing competition in the field of modern technologies. In the building sector, there is the ability to find solutions that are environmentally friendly and, at the same time, suitable for a high level of luxury. The use of solar energy inside buildings systems raises investment and keeps pace with the aspiration towards the future. Adopting solar energy for water heating or heating and cooling the spaces is meets the consumer's desire for efficiency and high quality. The development of solar energy in terms of multiple options, capacity, efficiency, safe performance, flexible performance, and lightweight enables it to operate building systems. The integrating development is the presence of technologies, internet networks, strong infrastructure, and low-emissions materials that support the completion of the project. The simulation outputs include knowledge about the existing smart city, understanding the

communication technologies, and linking the developed home with solar energy. It is choosing the right solar energy system, being familiar with the number of services needed inside the house, and matching data systems. This thesis aims to provide the best strategies and equipment for solar energy in a residential building that meets the future vision and agrees with intelligent city criteria. The research problem raises questions about housing trends of new cities in the twenty-first century without considering the environmental threat, which is a problem for humans, animals, and plants. Environmental pollution results from burning raw materials to produce electrical for running home systems. The lack of sufficient information and knowledge of the possibilities of solar energy causes a limitation of its combination in many fields. This thesis is essential to clarifying the abilities of solar energy systems and matching them with well-being residential buildings to meet the population's needs in the gulf country. The following part introduces the relationship of intelligent solar homes with the surrounding environment. This research balances the advanced city, high technology, and the population's comfort with analyzing solar generating system performance methods to preserve the ecosystem. Many intelligent cities worldwide won awards for their effectiveness. Smart cities projects are the solution to problems of climate change, increased carbon dioxide, and acid rain coming from ordinary projects. Recently, solar energy residential projects are presented quality life and superior performance. Many intelligent cities worldwide won awards for their effectiveness. Masdar City in Abu Dhabi has proved the concept of an advanced solar smart city with appropriate standards. The case study compares Masdar City with Al Falah City and attempts to develop the idea of sustainable cities into sustainable developed cities. The thesis was adopted a quantitative method to collect information and note the proportions. The dissertation methodology is contained seven chapters, including a literature review and case study. The first chapter is the thesis introduction, including the objective, methodological approach, and research problem. The second chapter talks about the types of renewable energies in general. The end of the second chapter explains the reasons for choosing solar energy in GCC and the effects of using fossil fuels. The third chapter describes the types of solar energy generators and the most important collectors used in dwellings. In addition, it illustrates the most significant home systems HVAC, water heating, lighting, and

the effectiveness of solar energy in operating. The fourth chapter talks about smart cities and the basic needs for using solar-powered homes. It explains the connection between Infrastructure and control of home services. The fifth chapter is two case studies detailing an intelligent project named Masdar city and a sustainable project called Falah Complex Housing. This chapter analyzes the location, services, and details of dwellings in addition to the consumption of solar energy. The sixth chapter is divided into two parts a comparison between the case study in both projects and the second part giving suggestions for development. This chapter includes some criteria that develop ordinary housing into intelligent housing. There are ways mentioned in this section to develop Al-Falah city by raising the level of housing to be high standard. Also, analyzing competent solar home performance within advanced surroundings helps perform better. The final chapter evaluates the thesis in general and mentions details that support advanced city projects in the GCC.

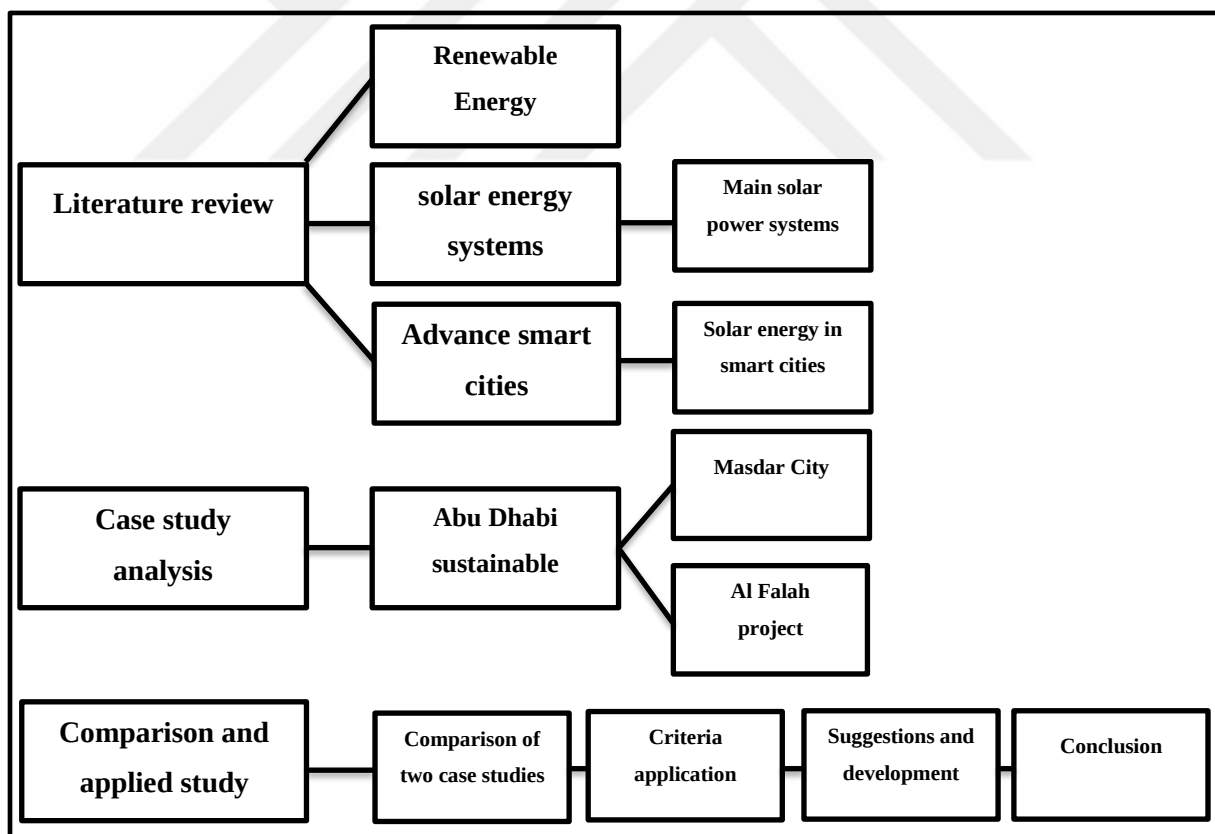


Figure 1.1: Thesis Methodology Steps

2. SUSTAINABILITY (RENEWABLE ENERGY)

Sustainable energy is the falls under renewable energy to serve and preserve it for the most time possible both are complementary to each other. Since renewable energy re-produces energy continuously and without fixed quantities, Sustainable energy conserves this generated energy for a while and rationalizes use (J.M.K.C. Donev et, 2020).

2.1. SUSTAINABLE ENERGY IN THE WORLD

Sustainability is the continuity and development of the economy while preserving the source from damage or low efficiency. Energy imbalance leads to problems and chaos in the economy of countries. The Brundtland report States in 1987 that development is a response to the needs of the present time and has confidence that the next generation will create new ways of sustainability keeping parallel with recipient needs and requirements. In 1992, the first global agreement stipulated biological diversity, where using sustainable materials was one term of this agreement. The world officially recognized sustainability expression as a productive item from that time. According to human consumption, the demand for sustainable energies increases every period (Russell, I, 2008, 121,126).

2.2.THE KEY ROLES FOR RENEWABLE ENERGIES

When the indicators of the available energy decreased in 2019 and realized the benefits that come from renewable energies accrue to the citizen and environment, the demand for sustainable renewable energy in the globe increased by 183 GW. Thirty-seven countries are participating in (OECD) organization responsible for development in all aspects and providing well-being and the growth of the standard of living. In 1960, this organization started with only 18 countries, aspirations for future development and prosperity. The project succeeds in including 37 countries. In 2017 and ten years before, the energy demand increased by 42%.

Due to this, the focus has become on extracting renewable energy and transforming the mechanism of operation on it. (OECD) organizations found a new stock of renewable energies up to 44%, which means the available wealth is more than the consumer. Some countries do not exist in the (OECD) agreement with large renewable energies sector projects. Their investments development has increased over the last ten years of 25% (REN21, 2020, 24).

2.3. RENEWABLE ENERGY TYPES

Renewable energy serves all sectors, such as residential, industrial, agricultural, transportation, commercial, etc. On the world level, some countries have marks in this field, and they also gained green certificates showing the progress of the sustainable energy field. Norway and Sweden are two countries that have proven they have robust renewable energy systems that serve most sectors. In sustainable energy, there are several types of power, and each type has compatible with a specific nature and a specific service sector. Until this time, research is still focused on discovering new uses for sustainable energy. Five main types of energy used in the sustainable field turn orientation to renewable energy: solar energy, wind energy, fuel cells, bioenergy, and geothermal energy (REN21, 2020, 24).

2.3.1. Understanding Wind Energy

Wind energy is sustainable energy that powers devices and systems and replaces petroleum energy. There are difficulties facing wind energy, and it requires a sizeable economic amount that may affect the budget allocated to the energies. It depends on the geographical area, wind speed, and location of installed wind turbines. Can install turbines on tall buildings or farms dedicated to wind energy, then pumped and distributed to other facilities. It is also installed on tall concrete buildings not to feel the vibration. Lastly, the sound coming out of the turbine's rotation leads to an aura of noise. Wind energy is found in abundance in the southwestern region of the United States, unlike the Middle Eastern cities, where the future vision of wind

energy constitutes around the world 20% of the total renewable energies (Noori, M, Kucukvar, M, & Tatari, 2015, 940-941).

Several sizes and types of wind turbines are commensurate with the location and energy required. (HAWT) and (VAWT) are basic types of wind energy production and several factions fall under each division. In 2013, it showed that 74% were using type (HAWT), and 18% were using (VAWT). Small wind turbines have many advantages that can apply in many world regions. The small turbines can produce very high energy and increase social and economic benefits (ANDERSEN, A, 2017, 14-15).

a) Wind energy management

Wind energy passes through three stages to reach operating energy, kinetic energy, and mechanical energy after that electrical energy. Mechanical energy is environmentally friendly energy. It depends on movement, doesn't emit gases and fumes harmful to nature. Providing a high amount of money available to invest is a condition for developing the project. The height of buildings has several dimensions, reflected in the turbine installation and quantities of energy created. If the turbines are installed on high towers, the performance will be better, and the cost and maintenance will be higher. The opposite thing will happen if installed on low towers. The surrounding environment for wind turbines has the most impact on performance and outgoing energy. The density of trees, different building heights, and infrastructure create inaccuracy in calculating wind energy. Investing in wind energy is considered very costly due to the ongoing expenses on the project. A profit of around 86% is an investment that is suitable for large institutions or countries (ANDERSEN, A, 2017, 14-15).

b) Financial considerations in wind energy

Wind energy is growing incoming energy until it occupies a place in onshore and offshore spaces. In 2019, the Expanding area investments in onshore was 54 Gigawatts and offshore 9 Gigawatts, which is a high number for wind energy, around 19%. From 2015 to 2018, there

was a sharp decline in wind energy produced, but in 2019 was compensated nine times more than previous years. The 2019 increase is classified as the second-largest growth in the world. It was 651 gigawatts, shown in figure 2.1. China, Europe, and the United States have the most significant increase rates in wind energy. Between 2018 and 2021, the countries that came to the fore were the Middle East, Southeast Asia, and Latin America. The end of 2018 and the beginning of 2019 was the rebirth, where 102 countries were activating wind energy (REN21, 2020, 131).

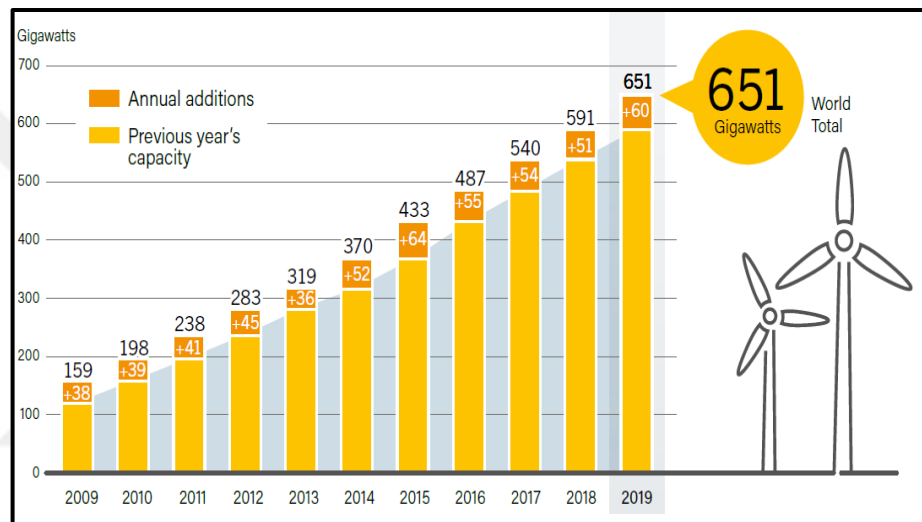


Figure 2.1: Progressive levels for wind energy (REN21, 2020, 131)

c) The use of wind energy in dwellings

Wind energy in residential buildings plays an influential role, where many sustainable and non-sustainable housing systems use it. The integration of wind energy and its use in the operation of home services is still in the beginning. It has proven its efficiency in some regions, but it still needs development and overcoming the existing obstacles. Wind energy has recently become an interest of developers and architects until it has been named (BIWE). The (BIWE) will continue to improve and make tests through experiments and the development of installation and design methods. Wind turbine designs and installation locations vary in line with housing type, figure 2.2 shows (Poerschke, U, Woollen, M, Srebric, J, Stewart, S, Murtha, T, 2011, 15).

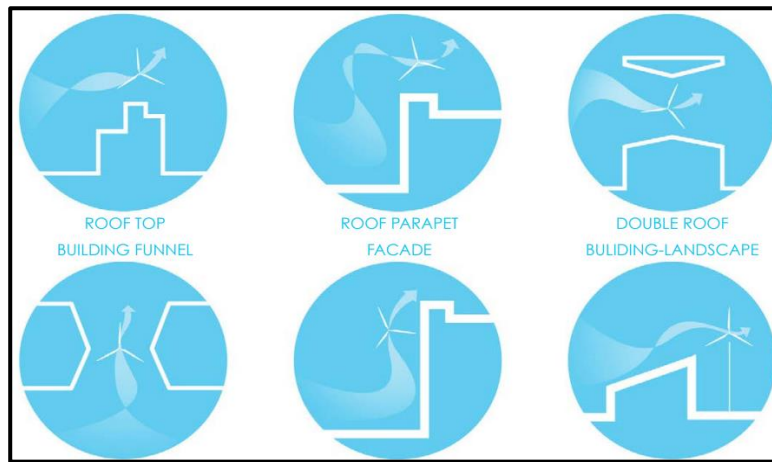


Figure 2.2: Various installation positions for wind turbines (Poerschke, U, et al, 2011, 11)

Site determination is a challenge facing this type of renewable energy due to other factors affecting productivity. Wind speed and intensity scale are the primary factors for wind turbines working, so there must be accurate and masterful devices to give the correct numbers shown in fig 2.3 (ANDERSEN, A, 2017, 14-15). Wind turbines affect when installed on buildings because the turbines rotate and lead to vibration of the structure. The weight and heaviness that get on the building affect the infrastructure (Poerschke, U et al., 2011, 8). Wind energy has gained credibility in some housing projects as an alternative to power dependent on fuel. The dwelling must be located near turbine areas with constant winds or in neighborhoods with regulations that allow installing a turbine on the house's roof. With these conditions, not all cities can be familiar with all conditions and activate this type of energy inside homes, including Gulf cities (Cortés, C, 2021).

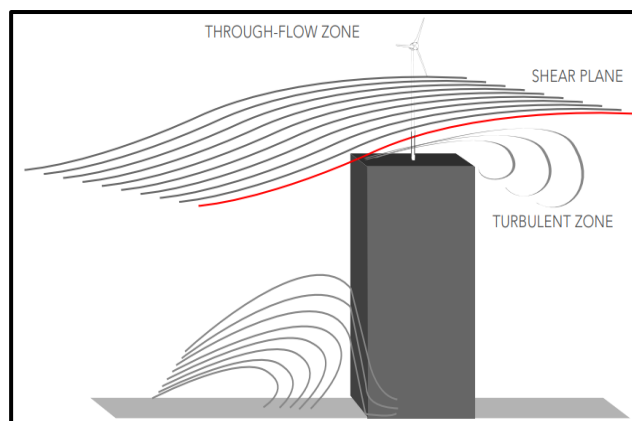


Figure 2.3: Wind speed and intensity on building (Poerschke, U, et al, 2011, 27)

2.3.2. Importance Of Fuel Cells

There is a possibility to conserve fuel energy in tanks. Fuel cells are most common in recent years, and the vision to introduce in all sectors. It is a mixture of oxygen and hydrogen in specific proportions to produce a reaction and generate energy. There are several types of fuel cell energy, such as the fuel cell based on methane (CH_4) or hydrogen (H), or other elements. These elements combustion doesn't negatively affect the environment. Fuel cells are interpreted as power generating like batteries that can operate various airplanes and trains. Hydrogen filling stations became widespread in some countries such as Japan, Germany, and the US (Sealing technology, 2020).

Based on its importance, Japan created the most significant housing complex whose homes run on hydrogen fuel energy. Some countries depend on using this type of renewable energy. For example, 60% of household energy consumption in Japan is from fuel cells (Cristi, 2009).

a) Fuel cells operation process

Several chemical compounds are qualified to produce renewable energy fuel cells after passing through stages. The Methane compound is one of the essential sources for making hydrogen flow. Three main steps, Anode, Electrolyte, and Cathode, are responsible for methane reaction. The movement direction changes depending on compound charges, whether negative or positive see table 2.1 (Besenic, T, 2016, 2). Fuel cells are applied in daily life, such as transportation, houses, intelligent devices, and power plants for different sectors. Fuel cells operate on a continuous power similar to engines that don't store energy like batteries. In table 2.2, there are schematic representations of four parts of the cell that explain the working mechanism of the fuel cell (ACHARYA, P, 2004, 2-5). The characteristic of fuel cells is simplicity in equipment and systems that allow operating in energy scope. It depends on long-term and straightforward interactions that don't require complicated use (Besenic, T, 2016, 4).

Table 2.1: Stages produce fuel cells (Besenic, T, 2016, 2)

phases of energy cells	Steps names	Description
	Anode	Hydrogen cells oxidize the fuel and convert cells to (+) charged where the electron atoms are canceled out.
	Electrolyte	It is space working as a conductor of electricity through breaking bonds in a short period then filters the anode and carries the electrons to the other section.
	Cathode	The cathode is a stage that combines reactions and divisions to make the space ready for the next charge. The two atoms are combined (+) charge coming from hydrogen and (-) charge from oxygen to be water.

Table 2.2: Working mechanism phases in fuel cells (ACHARYA, P,2004, 2-5).

Fuel cells components	Steps names	Description
	Fuel processor (reformer)	This section stimulates hydrogen, increases concentration, and prepares it for reaction inside the fuel cell. The fuel reformer takes care of the materials inside the cell to be free of impurities.
	Fuel cell stack	Stack is the basis for the entire system. A long continuous line carries individual fuel cells to work regularly to increase output current flow.
	Power conditioner	The power conditioner regulates its operation by controlling the current. It is a linking point between what the cell exits (stack) and Internal cell interactions.
	Thermal management	It is a system that prevents the heat of cell parts from decreasing or increasing by controlling their temperature. It also cleanses the impurities and produces a stream net running ready to use.

b) The prominence of fuel cells

After experimenting with the fuel cells in different fields, their efficacy has been proven effective as alternative energy. The efficiency is more prominent than typical combustion engines at a higher temperature, and the transformation of energy from chemical to thermal occurs very quickly. This kind of energy is versatile in use in terms of power and capacity. Scalability is a factor that helps activate the fuel cells if the operating devices are small doesn't affect versatility in use in terms of energy and ability. The research is always ongoing, but there is no way to save the environment from pollution 100 %. Using fuel cells is the best compared to other internal combustion engines because environmental emissions are very low (Besenic, T, 2016, 4).

c) The use of fuel cells in dwellings

The consumption of fossil fuels in 2016 reached 127,000,000 metric tons, and renewable energies got 48 000,000 metric tons. The use of fossil fuels may reduce in the coming years when renewable energies are activated in several fields, including houses (Najmi, H, 2018, 25-26). The most important way to deliver fuel energy to housing is the presence of a tank inside a network system extending to a house through underground pipes. Fuel cells are not installed inside the house, such as solar panels or wind turbines, but outside. The energy is stored inside tanks that look like large refrigerators, established in the ground, not movable figure 2.4 shows. Fuel cells do not store hot water, and it depends on a boiler inside the tank works when needed. The initial cost of using in homes is low, and the reliability is high (Dodds, E, Hawkes, A, 2014, 14-17).

In recent times, the activation of energy by hydrogen elements has become effective many times more than fuel. From 60% to 80%, the alternative energy efficiency ratio to perform the functions is according to the type of energy-producing cell. Many dwelling projects apply the fuel cell concept worldwide, and for the Gulf countries, this type of energy has not been activated in a straightforward way (Najmi, H, 2018, 25-26).



Figure 2.4: Fuel cells tanks (Dodds, E, Hawkes, A, 2014,14-17)

2.3.3. Overview Of Bioenergy

Bioenergy is a kind of energy that comes from a whole BioSource, composed of substances mixed with gases and liquids, micro-organisms, and degradable residues of plants, humans, and animals. In ancient times, bioenergy was one of the first types of energies that have been identified to the production of heat for serving society. In the current era, the vision has become more advanced. Besides heat production, the agricultural sector and crop production have received more interest. Bioenergy has a positive impact on the safety and health of the environment from harmful gases plus gathering of carbon dioxide in the air, contributing to the exploitation of dilapidated areas providing land for cultivation (Ferreira, S., Moreira, N, & Monteiro, E, 2009, 1568-1569). The divided percentages of materials consumed to produce bioenergy are 15.9% for the food, 3.3% for the animals, and the rest of the elements around 47.6%. With regards to wood, switchgrass, agricultural and forest are represented 19.6% (Ferrari, G, Pezzuolo, A, Nizami, A ,Marinello, F, 2020, 2-7).

a) Bioenergy as the main source

Since Bioenergy comes from the photosynthesis of biomass with physical and chemical changes to the primary raw materials, there are ways to convert this energy into infinite energy. Co-Combustion is the most popular technology to convert biomass to Bioenergy and

provides the best result. The Co-Combustion method has obtained international accreditation due to the availability of materials and places moreover ease of performance (World Energy Council, 2013, 289-291). The plan in 2050 will be to plant 550 million hectares representing half of the earth's area, 950 million hectares of new agricultural lands result from the transfer part of Pasture Lands that non-oriented in the correct manner. 40% is the percentage added to the previous rate if dealing well with the factors that conserve Bioenergy (IRENA, 2018, 4).

b) Financial considerations in bioenergy

The implications for biofuels are more than production, which is not preferred to using this method. In biofuels, chemical elements come from oil extracted diesel, bioethanol extracted from sugarcane, etc. This method follows a continuous increase in crop prices, using agricultural lands and price fluctuation, different food costs, which means a difference in the bioenergy cost. It creates social problems, health issues, and environmental implications facing bioenergy extraction by traditional methods. Currently, the Studies are replacing the materials biofuels produce with not eat materials and more sustainable such as extracted fuel from algae (World Energy Council, 2013, 289-291). According to the future vision, in 2030, the demand to produce electricity bioenergy will be increasing up to 90% but in modern unconventional ways (IRENA, 2014, 20 and 38).

c) The use of bioenergy in dwellings

Some factors control the amount of bioenergy production. The extent of continuity, such as temperature change, is the first factor, water availability, soil quality, and genetically modified living organisms. The logistics services department is the most significant part of bioenergy investing because the supply requires an organized infrastructure and a high measure of efficiency (World Energy Council, 2013, 289-291). Biomass is used in the residential field to search for lower costs, benefit from existing resources, or reduce environmental pollution. Houses in snowy cities usually use bioenergy for heat by dry tree branches (BERC, 2010, 46). Bioenergy is resorting to the treatment stage so that the raw materials don't rot. Houses store biomass for the time of use, so they resort to methods according to mass types, starting with

felling passing to screening, grinding, and thermal processing end of storage (IRENA, 2019, 18).

2.3.4. Geothermal Energy Overview

Geothermal Energy has existed inside earth layers without human intervention, linked to the Earth's physical composition and internal structure. Geothermal energy is located in different zones, including the oceans and highest ice caps around volcanic and mountainous regions. The first type is called volcanic geothermal from the name, it is related to volcanic areas, and the magma is the source of the heat generated. The least sturdy site where thermal water comes out is cracks and fissures in the surface of mountains and volcanic. Another type is controlled convective fracture, specializing in part of the Earth's -thermal crust. Several factors are the basis for determining the systems used for geothermal energy, such as heat sources, state, sustainability, steps to maturity energy, etc. (ESMAP, 2012, 15, 16).

a) Geothermal energy harvesting

The way to extract hidden energy inside rocks is access to groundwater deep in the Earth's around 1 km through ground cracks. Sedimentary geothermal energy is the primary method for obtaining energy above depth from the Earth's surface. This method has focused on the conduction of heat from the ground to the outside, unlike other methods that depend on heat transfer. Geopressured system is classified as vital and has a high-pressure capacity in the underground earth layers, and it produces heat besides fluid. (HDR) The primary system working with high-temperature rocks does not conduct heat to the crust, either the ground or volcanoes (ESMAP, 2012, 15, 16).

b) Challenges of using geothermal energy

Geothermal energy exists in different underground layers, and more depth means a large amount of geothermal energy, but it faces a problem in which no holes allow power to get

outs. There is a system for extracting the imprisoned geothermal energy underground, and it depends on the (EGS) technique that activates the water inside the inner layers of the earth. The hot water is extracted from the earth's depth by adding chemical or hydraulic materials to the interior. The rocks are exposed to high pressure, together with hot water and hydraulic or chemical injections, producing cracks that proving by buttresses to get small holes that allow geothermal energy to pass out (IRENA, 2017, 15-17).

c) The use of geothermal energy in dwellings

Usually, geothermal energy is used in homes for heating, but pumps can also be added and used for different purposes. The system works through pipes containing water connecting the source of energy with houses, which is not visible underground figure 2.5 shows. The system works very efficiently in the winter and summer seasons. In the winter, it takes the heat from the ground and transfers it to the house because the earth maintains a high temperature throughout the year, between 45 - 70 degrees Fahrenheit. In the summer, the system works differently, transfers heat from the house, and returns it to the earth. There are four ways to install and move geothermal heat into the house horizontal, vertical, pond, and open-loop. The Horizontal system needs a large area that for installed and is the most prevalent among the systems. The vertical system works within small spaces, installing vertically through tiny holes far apart. The pond takes the heat source from the water and is seated at eight feet below the earth's surface. The open-loop system is the least used and the most expensive because the water source is either a well or a sea (Krietsch, B, 2020).



Figure 2.5: Geothermal Energy installation (Krietsch, B, 2020)

2.3.5. Use Of Solar Energy

Generate solar energy by the intersection of a neutron and a proton transforms radiative energy into electrical power when a photon is absorbed. Three things are playing a significant role in the efficiency of solar energy, processes that occur in the solar cell, determining the number of carriers, and the extent of spread. In addition to properties in the electricity transport, materials are dependent on the establishment of the solar cell, either PV or CSP (Girvan , M, 2018, 45-46). The uses of solar photovoltaic energy varied from simple electronic devices to systems that serve establishments, homes, and public facilities. The sunlight interacts with semiconductors mixture such as amorphous silicon, copper indium selenite, polycrystalline silicon, cadmium telluride, etc. Photovoltaic systems inside spaces and modern buildings work by electrical charges produced (Matungwa, B, 2014, 24-25).

The two simple ways for the sun to gain sunlight in space are beam radiation or direct sunlight and direct average insolation. To classify a site as working on solar energy must be receiving sunbeam annually as a minimum of 2000 kilowatt-hours. For naming the site as the best site should receive annually solar power no less than 2800 kilowatt-hours. Countries that aim to implement solar energy systems have strong sunlight and geographical location, such as India, South Africa, West America, Iran, the Middle East, etc. Whether concentrated or non-concentrated, solar collectors convert solar power into thermal power and operate various fields (Nagarajan, S, Barshilia, H, 2010, 9-10).

a) Financial considerations solar energy

Funding establishments must support the solar system projects that work long-term and are highly efficient. The energy projects are a little complicated, require maintenance of the equipment, systems operation and tools modernization, the continuity of funding beyond the installation. Many solar projects failed due to a lack of familiarity with all aspects of project needs in the long term (Ferreira, S et al., 2009, 1568-1569). (IsDB) support the work of emerging projects with a study and a plan to succeed wherever the location. Prokon companies benefited from this funding. In Turkey year 2013, gained funding to install more than 2000

solar panels serving the company field. During three years, Prokon Company produced 1835 megawatts within an hour of energy. These large quantities of energy make Prokon invest and sell solar power to other institutions. The countries that make the most significant proportion of the support from (IsDB), 60.44% in Malaysia, Pakistan, and Indonesia, 26.26% for the Middle East and North Africa, and 13.3%, divided by the rest of the world (ISRA, 2019, 24).

b) Architecturally solar energy

The viewpoint of architects and residents for establishing residential projects based on solar energy is keeping abreast with global development. Integrating solar energy capabilities into homes proves clean energy activities and reduces operational costs. The presence of large amounts of solar energy is a must, so use it avoids wasting opportunities and loss of power. Developing residential buildings with new operating systems supports establishing a stable infrastructure. Finally, it stimulates economic movement and rents effective financing methods (PEG and CEG, 2006, 11).

The use of wind energy, geothermal energy, bioenergy, fuel cells, or others is not a practical option as much as using solar energy in Gulf country's housing. Solar energy is a suitable option for home applications because it is abundant and appropriate for Middle East buildings. Activating solar energy in homes needs to consider the energy used and generated technology. For example, there is a house consisting of two floors. The area of each floor is 140 M². The house comprises a kitchen, three bedrooms, two bathrooms, a living room, and two multi-use rooms. It is compared with designing a studio for two people with an area of 50 M². It consists of two bedrooms, a bathroom, a living room, and a kitchen with a small outdoor space see fig 2.6. The consumed energy in the first building is three times the energy consumed in the second building. According to the previous data, the first house needs more solar energy than the first home by direct gain or solar collectors (PEG and CEG, 2006, 9).



Dwelling space 140 M² (Nuytten, T, Reynders, G, Saelens, D, 2013, 189)

Dwellin Dwelling space 50 M² (Ignite Graphic Design, 2014)

Figure 2.6: Residential spaces

The countries are interested in providing energy-saving buildings, which are getting the attention of investors, developers, residents, architects, energy scientists, etc. In 2018, the residential sector accounted for an estimated 33% of total energy consumption worldwide. High-potential buildings became a goal for comfort life. Between 2000 and 2017, the demand for living in advanced dwellings has increased by 38% (REN21, 2020, 193).

c) Forms of solar energy success

This thesis focused on selecting solar energy technologies from among all energies. Solar energy is successful and prominent in architectural buildings. Around the world in the year 2017, solar energy projects attracted attention was achieving 98 GWs, which exceeds coal, nuclear, and gas energy total together. The sun is the most important source of infinite energy in the Gulf countries. It has a developed vision and upcoming projects that depend mainly on solar energy. The Gulf countries have achieved many projects by using PV and CSP. The projects are extensively located in the UAE, then Saudi Arabia, after that, Kuwait see table 2.3. (ISRA, 2019, 12, 11). Many types of energy, such as wind energy and bioenergy, are the second or third derivation of primary solar energy (Kiss, G, Jansen, H, Castaldo, V, Orsi, L, 2015, 330).

Table 2.3: Numbers of GCC massive projects in 2018 (ISRA, 2019, 14).

Country	Photovoltaic (PV)	Concentrated Solar Power (CSP)
KSA	89	50
United Emirates	487	100
Kuwait	19	50
Oman	8	0
Bahrain	5	0
Qatar	5	0

2.4 SUSTAINABLE ENERGY CHALLENGES

Three problems were a priority achieved by the Energy Council. First, the inability of many countries to use alternative energy for daily needs is one of their rights. Secondly, preserving the environmental system and reducing the side effect of pollution, lastly energy security. Identifying and recognizing problems contributes to finding solutions over the years, realizing that there are risks and threats to the safety and security of the world. Making the most of natural resources like sun, coal, wind, etc., is a way to achieve the goal, enabling the world to meet daily needs (World Energy Council, 2013, 33).

There is future visibility for alternative energies worldwide, where the goal is estimated to be worth 45 billion dollars by 2030. The capital of the project and the stages of development require large amounts of money, so some projects stop at the beginning, middle, or end locations. There are well-studied plans that contribute to reaching the energy goals in 2030 about changing the direction of project financing to an investing money method based on precise results (IRENA, CPI, 2020, 16)

The future conditions of alternative energy consumption constitute an obstacle to accurate predictions and studies. The economic conditions of some countries play a catastrophe due to the rise or fall of the currency. Political and health needs also change the course of the

expected results and studies for the coming years. For example, in 2020, the covid-19 pandemic overwhelmed the whole world e then changed consumption and production rates for alternative energy. This incident recorded new statistics according to the emergency, canceling the previous predictions before 2020 (Hussain, B, 2017, 69). The energy market in the Gulf countries was targeted in 2014. The plan was to reduce oil prices, but it did not work, and the market continued to rise up (IRENA, 2019, 12).

The world has witnessed an important renaissance in replacing electricity with solar energy at the level of megaprojects and the personal consumption of citizens. Specialized systems to connect energy grids have fought renewable energy based on uncertainties of new energy efficiency and political issues that govern countries. In Brazil, there are obstacles to obtaining licenses related to the operation of solar energy and systems. There was an apparent increase in fees due in Australia, also delays in approvals for solar energy users compared to electricity users (REN21, 2020, 21, 302).

Institutions that support working with electricity reduce the chances of spreading solar energy and photovoltaic panels by using specific hours for charging and storing energy. Besides imposing money from the operating companies to compensate for the losses, this decision makes electricity the primary source of work, and solar energy is an additional element. Photovoltaic panels have gone through a crisis of high prices to limit their use. After passing a law in 2010, factories began to spread and prices fixed based on quality (Hussain, B, 2017, 18).

Concerning the (CSP) system, there is a challenge in controlling the temperature, where the fluctuating temperature leads to problems in the internal fluids, thus low performance and lack of efficiency. Also, the temperature may rise when ill-considered signals occur between the operator of the system and the side that converts energy into electricity. Installed a control sensor temperature was to solve the problem. Consequently, the system is dealt with according to the number listed in the device (Machado, D, Rico, J, Andrade, G, 2019.1-2).

2.4.1 The Increase In Average Global Temperatures

Air pollution from fuel emissions results in losses for humans, properties, and the environment. After examining air particles, It turns out there exists plankton, gases, and particles that caused disorders in the atmosphere layers. It also works to reduce the thickness of the atmosphere's protective layer, which is the ozone layer. The ozone layer protects the earth from ultraviolet rays that cause harm to the life system. Many environmentally harmful substances such as nitrogen dioxide, lead, sulfur dioxide, ozone, and carbon monoxide are hazardous chemical elements that stay in the atmosphere for a long time, significantly affecting the ozone layer. Therefore, the responsible authorities worked for laws that determined the use of harmful elements (Demirbas, A,2006, 76).

The Gulf Cooperation Council countries are the most dangerous due to their dependence on fossil fuels. One of the most significant risks that make GCC countries resort to using solar energy is water pollution, climate change, and air pollution. Studies proved that desert countries would be exposed in the future to a rise in temperatures and an increase in drought. The new approach to transforming the main problem into a solution complements the use of solar energy. It takes advantage of high temperatures and is reused in air conditioning and water heating (Praveen, R, Keloth, V, Abo-Khalil, A, Alghamdi, A, Eltamaly, A, Tlili, I, 2020, 2).

2.4.2 Potential Acid Rain Issues

Acid rain or acid deposition is a name that includes more than one way for present chemicals on the earth's surface, either through snow, fog, rain, or hail. The damage comes from acid deposition due to the reaction of sulfur oxide SO_2 and nitrogen oxides NO_x with chemicals that create hazardous and corrosive substances. Previously, emissions only affected the surrounding regional spot, but it has become a global threat and severe environmental problem with continued use in the long term. The resulting impact includes all aspects of life, affecting primary ecological resources such as food and timber. The primary source's loss leads to an

imbalance, an economic recession, and other crises. Studies have shown that acid rain severely impacts buildings and materials in contact with polluted air. The rate of material erosion is 2 to 10 faster than other pollution. Copper and iron are corroded by the echo method and limestone and marble by thawing (Singh, A, Agrawal, M, 2007,15-23).

2.4.3 Environmental Considerations On Greenhouse Gas Emission

International conferences are concerned with issues facing society in the case of greenhouse emissions and impact as one of the frequently discussed topics. Global greenhouse and climate change are still a problem that has not been fully resolved. The presence of greenhouse emissions poses a threat to human health and includes a change in all aspects. The side of these effects is temperature fluctuation and thus melting ice, a decrease in water level, and changes in the natural life system, leading to the extinction of some animals. Fuel consumption is the main reason for the worsening of the global problem. There is a continuous investigation into this problem and an ongoing attempt to find practical solutions (Bastianoni, S, Pulselli, F, Tiezzi, E, 2004, 253).

Emissions result from the presence of harmful energy sources in the long term, even if they are in small quantities. There are suggestions followed by the environment concerned body to solve the emissions crisis, but the focus is confined to the consumer and producer axes. The producer is the source that provides services that provide benefit the community regardless of the outcome. The consumer bears the most significant responsibility for manufacturing and using environmentally harmful energy. Providing alternatives to dangerous fuels with high efficiency and competitiveness is being an effective solution to some problems. In the case of using oil energy, Alternative energy replaces it and even surpasses it in terms of price, efficiency, investment ability, and preservation of the environment (Bastianoni et al., 2004, 254). There is a solution to control climate problems: to impose money on the use of fuel and to increase the marketing of renewable energies (REN21, 2020, 59).

3 SOLAR ENERGY ENABLING TECHNOLOGIES

Solar energy has proven potential to arise among other alternative energies. Solar power is complete and leads because of accurate and highly qualified technologies. There is solar energy in several fields, including health, architecture, transportation, etc. Enabling solar energy in architecture is an interconnected cycle that creates operational energy. There must be electrical power generation systems, which are the basis to create a complete system. It is followed by solar collectors' techniques that differ in shape and performance. Each solar collector works on a building with particular specifications. The energy generated in the home is used to provide services to the population, such as heating water, lighting, air heating, and cooling. Over the years, research will develop, and new technologies will become a reality to reach a better result in solar energy.

3.1. SOLAR ENERGY GENERATION SYSTEMS

Solar energy generation systems are technologies capable of continuous production within the presence of primary data. Solar energy is used to meet human needs and to provide comfort. The systems can generate energy to operate devices within a harmonic environment framework. The technology converts solar power to electrical power to use house systems. Two systems generate energy effectively: (PV) and s (CSP).

3.1.1. Solar Photovoltaics (PV)

The electrical process is created in PV panels by absorbing sunlight through silicon atoms. The atoms interact, passing to different stages until electric current flows. Metal is the element that allows electrical energy to move from the PV panels to operate various devices. Cells are classified into different types, but all are made up of thin layers see fig 3.1. Cells are included either flexible or rigid backing. Panels with very thin films used Flexible support, and normal solar cells used rigid support. The thin-film panels do not carry a heavyweight and are

installed vertically like in walls. In opposite ordinary panels are installed horizontally on the roofs of houses. (Hantula, R, 2010, 15). Solar photovoltaics have assured their ability to give energy with high efficiency and long life. PV panels have been prominent in their effectiveness over the years. The productivity capacity after reaches 10 years is 90% and after 25 years is 80% (Devabhaktuni, V, Alam, M, Depuru, S, Robert, C, Green, II, Nims, D, Near, C, 2013, 557).

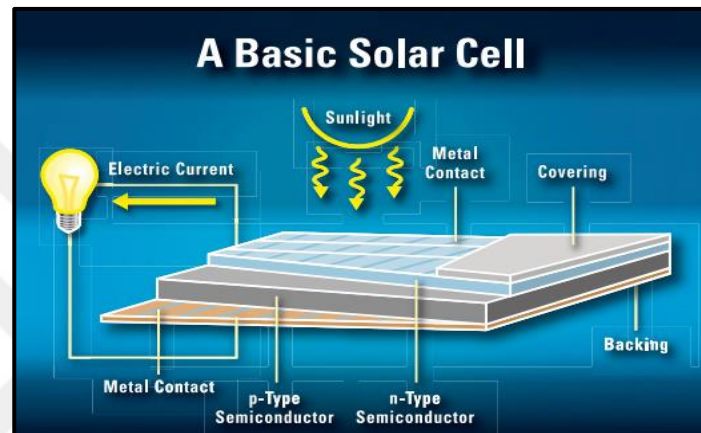


Figure 3.1: Solar cell layers (Hantula, R, 2010, 15).

There are applications of photovoltaic cells technologies classified according to the materials used divided into three generations see table 3.1. When comparing crystalline solar cells with thin-film cells, the consumption of manufacturing materials is less by 99% in thin-film. It is several layers of low thickness between 1 to 4 micrometers layers on top of each other and is inexpensive to manufacture. Thin-film cells engage well with the building and do not form a load due to their flexibility and lightweight. The third generation of photovoltaic technologies is applied and working and other types are under development and modernization. It achieves high efficiencies and overcomes some problems related to crystal cells. Nanotechnologies are used with many semiconductor materials such as (a-Si) amorphous silicon, copper indium gallium selenide (CIGS), cadmium telluride (CdTe), etc. Manufacture is two stages, and the bottom layer is where the film's next step is organized into cells. Thin-film cells are made in one location. Therefore ability is between 5 %to 13% less than crystalline silicon cells between 11% to 20% (Gangopadhyay, U, Jana, S, Das, S, 2013, 2-4).

Table 3.1: PV Modules (Hantula, R, 2010, 15)

Solar cells classifications	Solar cell generations	Description
	First-generation	Classified as a commercial generation Crystalline silicon slides (c-Si) semiconductor material. It could be a single crystalline made up of one large organized crystal (sc-Si), or multi-crystalline is many crystals random organization and different in shapes (mc-Si).
	Second generation	Are founded from photovoltaic thin-film fall under it three groups. The first group is environmentally friendly, amorphous (a-Si) with two cells from the sun their site above each other micromorph silicon (a-Si/ μ c-Si). The second is cadmium telluride (CdTe). The last group, copper indium selenide (CIS), is a rigid copper solution with another type of copper also (CIGS) copper indium-gallium diselenide.
	Third generation	It includes several new ideas under development and is interested in concentrating photovoltaic cells (CPV) and the natural PV, which have not been exposed to new adds.

3.1.2. Concentrating Solar Photovoltaic Systems (CSP)

The first technique may not give an effective result when the sun intensity changes throughout the year. Tech (CSP) is a complete integrated system that contains reception and assembly for large and more developed places. The (CSP) is the best alternative evolution designed to absorb large amounts of solar energy. Concentrator photovoltaic is a multi-mirror that attracts sun power through a steam turbine pumps electrical energy that operable. In addition, it is a perfect energy saver. TRNSYS is a program that works with the PV and CSP systems. In a short time, become the primary operator of power systems. Concentrating solar photovoltaic systems comprises from heliostat field the surface of the catching to the sun power, tower and

receiver, thermal energy storage, and power cycle (Li, F , Li, C, Sun, K, Zhang, J, Li, H, 2020,1-20).

In 1975, the TRNSYS system became available then began to develop until this time. In April 2017, was the last update called (TRNSYS 18.0). Wisconsin-Madison University Worked on programming the system to deliver power to the facilities, On and off control, energy traffic flow, and other services. This system has proven highly effective and has made a quantum leap for solar energy. TRNSYS works with data that affect solar energy, such as space, weather, location, etc (TRNSYS 18, 2018, 4).

3.2. SOLAR ENERGY TECHNOLOGIES FOR BUILDINGS

Solar collectors in buildings are heat exchangers that convert the energy coming from the sun into internal energy able to operate devices. The solar collector is a prominent main component present in all solar collectors. The presence of solar collectors leads to several processes for producing sustainable energy. Solar collectors start by absorption of solar radiation next step is to convert radiation to heat lastly transmit it through a medium, oil, air, or water. Depending on the type of system and the purpose of the work, the resulting energy is transmitted through whether hot water or thermal tanks, space conducting equipment. The solar systems are generally divided into stationary state collectors and sun-tracking concentrating collectors (Kalogirou, S, 2004, 240).

3.2.1. Stationary State Collectors

Stationary State collectors aren't following the sun's movement in the working system. Stationary State collectors contain plates of limited focus due to their vertical or horizontally stability to the surface. It follows the fixed axis system and stays in one spot, and only catches the sun's rays falling on it. This system has four types: evacuated tube collector, flat plate collector, solar air collector, compound parabolic collector (Kalogirou, S, 2004, 240).

a) Evacuated tube collector (ETC)

Evacuated tube collector is usually used in low-temperature countries, which consists of several layers. Each layer has a specific function and characteristics. The upper layer is intended for carriage contains a glass cover for an evacuated tube collector that protects the rest of the elements inside the collector from external factors. This layer conducts heat radiation from the evacuated tube to a tube covered with a protective layer of heat called the collector pipe. The next step is to go to the manifold connected to the heat exchanger head, which water flows into the collector and produces heat energy. Through the stages, transfer fluid contains an anti-freeze substance that is cooled during the process, therefore, reheated in another part of the system, the lower section. The water is stored in the pipes at the last stage, according to the convection characteristic see figure 3.2 (Hohne, P, 2017, 16).

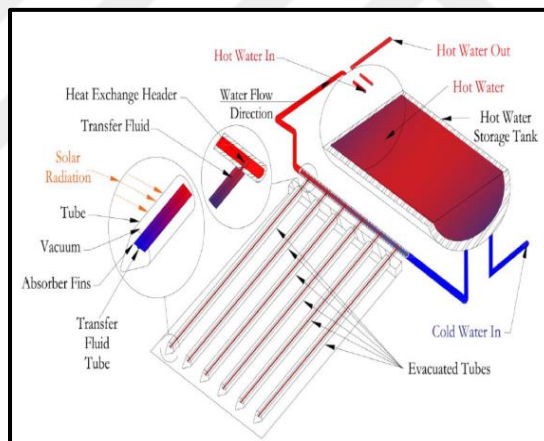


Figure 3.2: (ETC) System (Hohne,P, 2017, 16).

b) Flat Plate collector (FPC)

Flat plate collectors can be unglazed, a simple type that works between 75 to 95 ° Fahrenheit. The more complex type glazed works between 160 to 785 ° Fahrenheit, and the usual type works between 30 to 80 ° Fahrenheit. The first type is generally used in the swimming pool, and the other is used in significant places that need to manipulate a temperature difference, such as hotels (UNEP, 2015, 15).

The collector is the basis that absorbs the sun's rays then goes to the heat absorber to transfer radiation into a liquid substance that increases the temperature. A glazed covering works to preserve and protect the collector from outside factors. The tubes receive heat in liquid form, and the feature for the part is given more excellent absorption by adding heat fins. At the top of the tank, a safety valve is the controlling element of the system that works on equalizing the temperature and pressure. The water temperature must be high inside the tank, so this is a function of the thermosiphon that works to re-send water to the tank continuously see figure 3.3 (Hohne, P, 2017, 15).

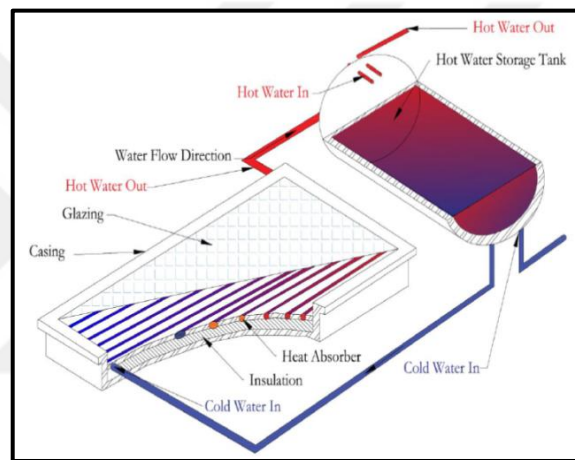


Figure 3.3: (FPC) System (Hohne,P, 2017, 15).

In some cases, it is combined with the Flat Plate and evacuated solar tube collectors. This type of combined solar collector consists of three main sections. The first section is the absorption mechanism, a group of tubes made of copper covered with unique materials that protect it from atmospheric factors. The second one is the transfer section. It consists of a manifold connected to durable tubes that transfer the heat. The last part is storage works to attract heat from other parts then store it inside storage (Devabhaktuni et al., 2013, 557).

c) Solar air collector (SAC)

The solar air collectors that appeared around 1980 are among the most simple and less complex types. Its flat shape is a plate that absorbs solar energy and paths for walking the air

(air ducts). The performance of the SAC varies from one to another, depending on materials used, size, thermal conductivity, and density. The performance improves when the panels are used to attract heat over the absorber, and thus the amount of energy absorbed becomes larger. When checking the quality of materials, using a four-layer coating (4-PGSAC) consisting of insulating and metals is the best performance. Factors surrounding the building are influenced by choosing the appropriate type of solar air collectors. Still, denser pin fins must be considered, leading to high thermal performance see figure 3.4 (Peng, D, Zhang, X. Dong, H, Lv, K, 2010, 2594, 2599).

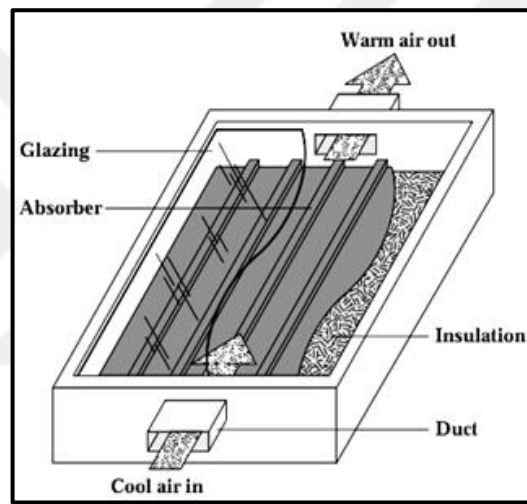


Figure 3.4: Solar Air Collectors (Ksenya, 2011).

d) Compound Parabolic Collector (CPC)

The main purpose was about hot water specifically. After improvements in 1976, they added a new research path to the optical analysis (reflections of solar rays) see figure 3.5. CPC falls under the non-tracking system and is focused on catching radial beams dispersed in the same region. The most important law in the working mechanism of the CPC system is the angle of acceptance and concentration ratios, which the relationship between them is indicator performance. Adding a sun tracking system will increase efficiency by around 15%, but this requires a high cost, and new calculates system settings. The compound

parabolic collector went through many experiments to improve performance, such as combined with evacuated and non-vacuum tubes. Until 1984 when adopting the evacuated tube with the fixed device, the results observed 65% of the optical 50% of the thermal efficiency. During the development of this mechanism, it was passed in several experiments, including using two non-identical shapes of the CPC that have the same efficiency. The researchers are working for the agency because the different shapes of reflectors are based on other forms of CPC, thus more fall angles. There have been attempts to use one or more tanks or change the materials that absorb the solar radiation to obtain more solar radiation. Until now, the development is still proceeding (Bellos, E, Korres, D, Tzivanidis, C, Antonopoulos, K, 2016, 54).

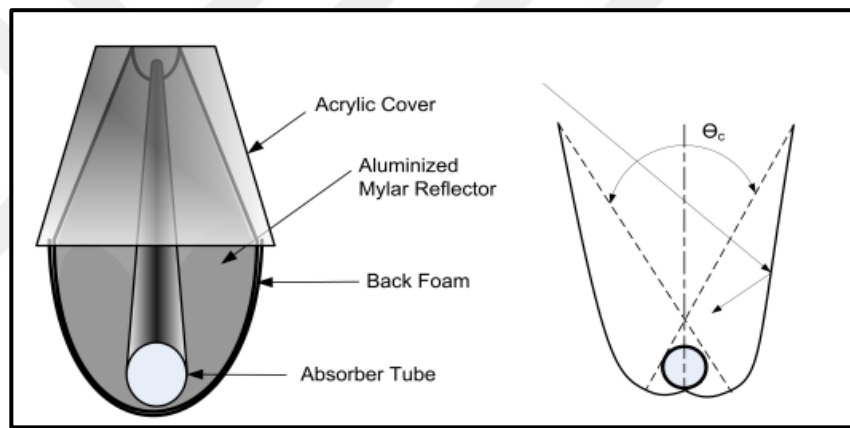


Figure 3.5: Schematic of (CPC) (Milani, D, 2012, 137)

3.2.2. Methods Of Tracking Concentrating Solar Systems

Solar tracking systems depend on axes that allow the system to direct to sun's movement during the day. There are solar tracking devices and flexibility in controlling that will enable it to rotate, in addition to dynamic action. The energy absorbed by the systems is enormous. Therefore the proportion of units of energy produced is more considerable. The solar energy tracking system concentrating obtains more solar energy than the stationary state method. This system includes two sections, one axis and two axes (Prinsloo, & Dobson, 2015, 26-27).

3.2.2.1. Use of single-axis design

The tracking systems are highly efficient, generating considerable energy through solar panels. Two main things have in a single-axis tracking system, which is a light sensor and a stepper motor according to sun rays degree. Single-axis collectors rotate to a limited extent and within certain degrees. The increase in energy absorption rate compared to stationary state collectors is 30 %. It includes cylindrical trough collectors, Linear Fresnel, and parabolic Trough (Racharla, S, & Rajan, K, 2017, 75).

a) cylindrical trough collector (CTC)

CTC is classified under the cylindrical shape, not flat, and the reflective surfaces are large compared to most other collectors. The PTC systems design is very similar to CTC. PTC has a focal line separating the right side to the left side, and the highest points on both sides are the sites that reflect the sun's rays. Figure 3.6 shows. CTC works wholly based on the level, so the entire surface reflects the sun's rays. The mechanism of a cylindrical trough collector is to install solar photovoltaics in the lowest point of the curvature or through a thermal panel from both sides. CTC isn't the best option in terms of little cost, and it is complex and expensive (Hussaina, M, Ménézob, C, Kimc, J, 2018, 128).

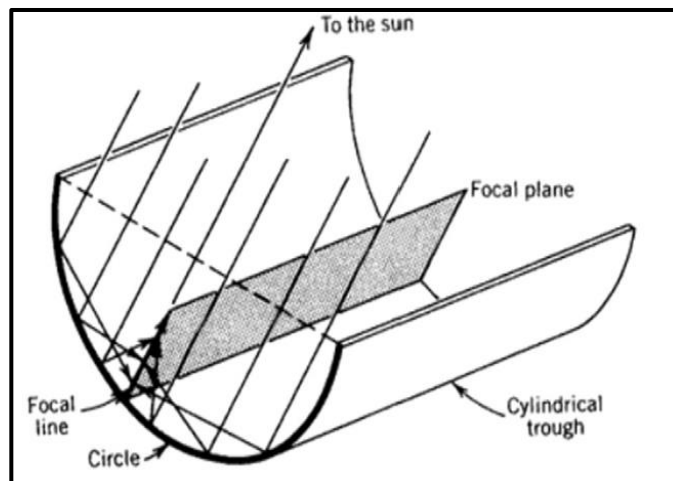


Figure 3.6: Schematic of (CTC) (Hussaina, M, Ménézo, C, Kim, J, 2018, 128)

b) Linear Fresnel Collectors (LFC)

Linear Fresnel collectors contain rows of semi-flat or flat depressions reflecting following the sun rays and sun receptors. The system is designed according to the surrounding atmosphere to produce energy that works for cooling or heating spaces could also be thermal energy converted into electricity used in several processes. The receptors are fixed, rigid, including receptor tubes, and secondary reflections are optional based on need. The concentration ratio is high in the reflectors because they are installed at a low height in line with the wind current, which will do not cause damage to the linear Fresnel system see fig 3.7. There is a difference in height between the Heliostat and Linear Fresnel. Each method has different data proportional to the size and energy produced. When comparing linear Fresnel collectors with parabolic troughs collectors, In terms of thermal efficiency, realize Fresnel collectors are less efficient. Because a flat reflector has one axis, radiation absorption is minor. Inside Fresnel collector, there are many types of designs. The difference is in receivers' format or mirrors rows organization. The kind called compact depends on two split receiver systems and is characterized as highly efficient. The tracking technology is complicated. Linear Fresnel collector has several non- evacuated tubes instead of one line to increase the efficiency of the receiving surface. In addition, operate at low temperatures. (Zhu, G, Wendelin, T, Wagner, M, Kutscher, C, 2014, 639-641).

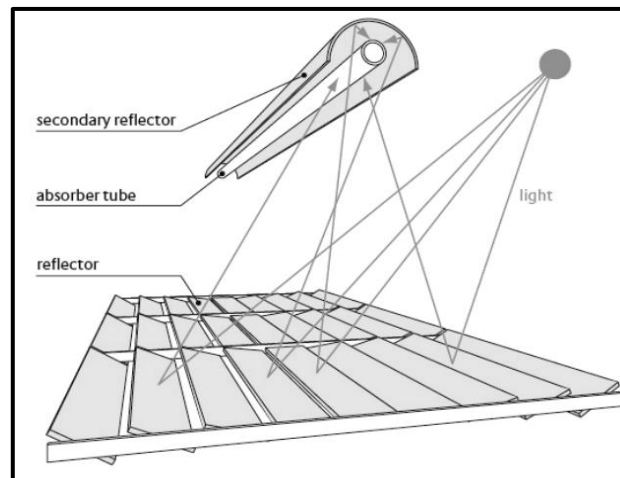


Figure 3.7: Linear Fresnel Collectors (Poullikkas, A, Hadjipaschalis, I, Kourtis, G, 2013, 32)

c) parabolic-trough collector (PTC)

PTC is a straight line of a central solar collector, arched crescent from the middle, the center point more profound than the sides. The dimensions on both sides are equal contain reflectors inside, also installed on a joint that tracks the sun's rays. The tube receiver in a parabolic-trough collector works to receive solar radiation, which is responsible for energy. The tube is covered with a suitable layer of solar radiation surrounded by a glass covering that reaches a liquid specialized to absorb the sun's rays. The tube receivers control heat leakage using the glass cover and applying materials for coating matching with long and short-term solar waves. PTC works very well in the spring and autumn season, but there are possibilities of some dereliction in performance at different times in the day or the seasons' change in a year. This type is classified as insufficiently developed, only capable of benefiting from one-thirds of the highest value, while can be used with other collectors to increase the productive capacity of energy see fig 3.8 (Fuqiang, W, Ziming, C, Jianyu, T, Yuan, Y, Yong, S, Linhua, L, (2017, 1315- 1316).

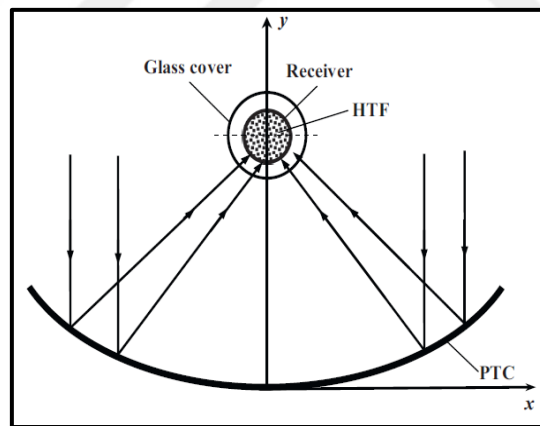


Figure 3.8: Parabolic-trough Collector (Fuqiang, W et al.,2017, 1315)

3.2.2.2. Use of two axes design

The best energy is extracted from the sun through two axes design collectors, giving better movement. The stationary state collectors work with high efficiency at the angle of the sun

90°. It differs from single and double solar collector, which has axes that enable flexibility and follow the sun's movement despite the changeful angles of fall. Two axes concentrating collectors can change direction, control the falling angles, and slope the rays according to the sun's movement. Two axes system produces annual energy that exceeds the one-axis tracking system by about 36% and of the stationary state collectors 48% (Prinsloo, & Dobson, 2015, 26-27).

a) Parabolic dish reflector (PDR)

Many types of parabolic dish reflectors match the construction work mechanism and the system to be operated, such as water heated, cook, or others. Stirling system is one of the famous types, but the designs are similar in the mechanism of action and division of principal components. The first section is the main structure and condensed, in which equal pieces of reflective mirrors are fixed closely together, Supported by a metal sheet. Many glass fibers and reflective materials are available in line with the power concentrator, which diameter ranges from 3 to 15 meters see fig 3.9. The different materials that make up the structure and the capacitor add a feature to the system to withstand different temperatures and high flexibility. The steel covers many pieces in the design and the holder but did not affect the system's weight too much contrariwise, increasing the strength and resistance to wind. Because the metal occupies a wide space, the parabolic dish reflectors system has a long life, durability, and hardness. The second section is the beam receiver and engine. Engines operate on adequate fluid pressure, nitrogen, helium, air, etc. Based on research, Stirling engines that use hydrogen as a pressurized fluid are the best performance. Finally, the part responsible for tracking the energy coming from the sun usually is fixed against the open part of the dish could be a Polar or Azimuth solar tracking system. When using the solar dish system is necessary to realize the parameters factors that affect the plate, Calculation of radiation in line with the site, and Analytical study of the receiver (Hafez, A, Soliman, A, El-Metwally, K, Ismail, I, 2016, 62-64).

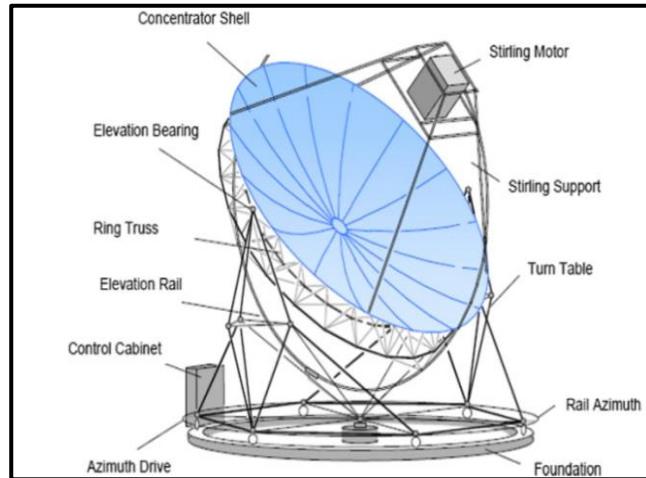


Figure 3.9: Parabolic dish reflector (Hafez, A et al, 2016, 64)

b) Heliostat field collectors (HFC)

Heliostat is reflected the sun's rays and works as complementary groups to each other. The external form is made of low concave mirrors, and altazimuth mounts figure 3.10 shows. According to the energy process in Heliostat collectors, the heat energy converts into steam through the steam cavity under high pressure and high temperature. The receiving surface in the system ranges from 50 to 150 square meters, so the excess heat is stored and used when needed. After receiving the solar rays, the receiver converts the energy into a liquid that transfers heat through valves, pipes, pumps then confined to the area between storage and receives parts. A storage system inside separates incoming energy and stored energy converted into electricity. The heliostat system is highly efficient for obtaining power and converting because the concentration ratio is between 300 to 1500, and it may react with the complete system in different forms. This system is classified as large-sized more than 10 megawatts. Therefore, it has energy storage spaces that separate incoming energy and stored energy. The heliostat system works complement to receiving tower. A receiving tower system is at the top of the tower coated with a transfer's heat layer. It can be the tower located in the center surrounded by Heliostat on the circles' shape, the north side of the tower, or located at a vertical plane and on the north. The method of the system is determined based on heat carrier

fluid (liquid sodium, water) or storage environment (molten nitrate salt, mixed oil with rock) and other several factors (Kalogirou, S, 2004, 251-252).

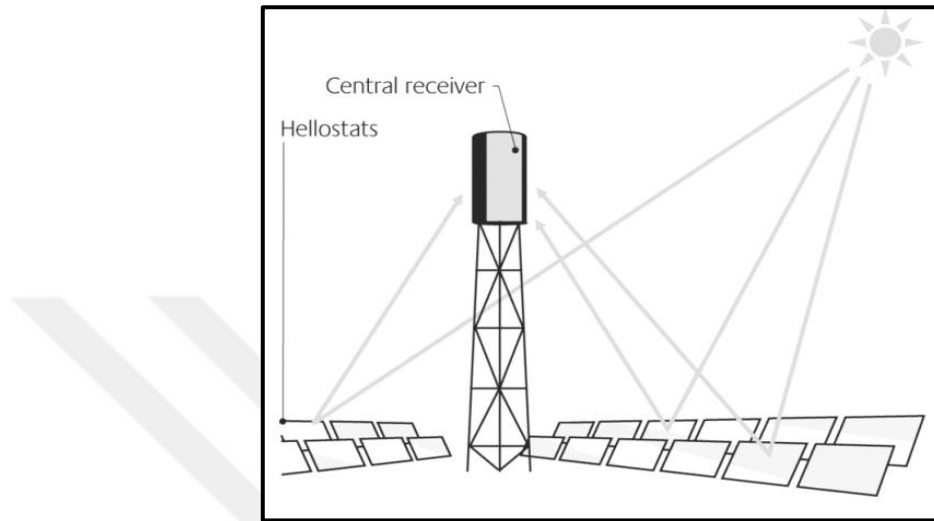


Figure 3.10: Heliostat collectors (Poullikkas, A, et al, 2013, 31)

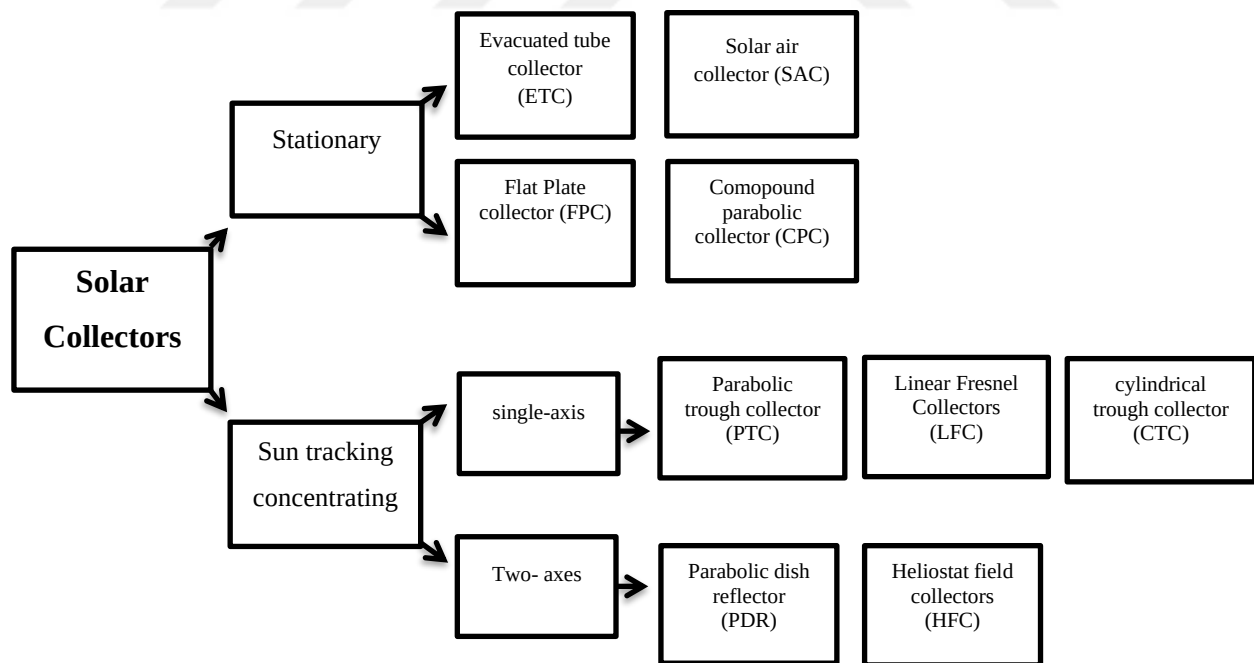


Figure 3.11: Solar Collectors Divisions

Table 3.2: Solar energy collectors with a temperature range (Kalogirou, S, 2004, 241)

Stationary	Collector type	Indicative temperature range (C°)	Single-axis tracking	Collector type	Indicative temperature range (C°)	Two-axes tracking	Collector type	Indicative temperature range (C°)
	Evacuated tube collector (ETC)	FROM 50 TO 240		Linear Fresnel reflector (LFR)	FROM 60 TO 200		Parabolic dish reflector (PDR)	FROM 100 TO 500
	Flat plate collector (FPC)	FROM 30 TO 80		Parabolic trough collector (PTC)	FROM 60 TO 250		Heliostat field collector (HFC)	FROM 150 TO 2000
	Solar air collector (SAC)	160		Cylindrical trough collector (CTC)	FROM 60 TO 300			
	Compound parabolic collector (CPC)	FROM 60 TO 240						

3.3. UTILIZATION OF SOLAR POWER IN BUILDINGS

After 2011, the development and new solar utilization mechanisms increased in construction. Continuity of growth and enabling building systems to operate on solar energy positively affects consumption and efficiency. Solar power systems inside homes are designed with a high profession that saves energy consumed and reduces waste energy. Awareness has increased to use most homes systems that work on technology and combine it with solar energy. The essential systems in houses such as water heating, cooling, heating, and optical technology have basically dependent on solar power in intelligent cities.

3.3.1. Water Heating System

The sun's rays are utilized and converted into energy that heats water through solar collectors. The water heating process is separately working from other solar systems in the building also, no need for ample space for installation. Water heating is conventionally based on (FPC), (ETC), and (CPC) technology, and there are many forms and features for each type of solar energy collector (Tzivanidis, C & Bellos, E, 2019,5-9).

There are details of systems combined with the three most common types that work on Water heating. Some kinds are low-cost and high performance, such as glazed parabolic collectors with tubular. Using different reflectors in one system that allows picking the fall of the sun's rays from many angles is named asymmetric reflector with a tubular receiver. Their also type called air trap with asymmetric solar collector type Uses a reflector with a section for capturing warm air. Asymmetrical solar collector design with two storage tanks includes more than one storage tank inside the system to improve performance. Asymmetrical solar collector design with two storage tanks includes more than one storage tank inside the system to improve performance. There are three types of CPC Conventional CPC, CPC Innovative triple reflectors, and CPC Innovative curved parabolic reflectors (Tzivanidis, C & Bellos, E, 2019, 5-9).

The solar hybrid heating system is used to warm spaces with the help of an external heating source to save a more significant amount of energy. This system relies on FPC and a fan that combines water and air. The solar hybrid heating system is divided into three main parts, and the simple design is solar heating with fan coils classified as the lowest type in terms of efficiency and cost. Solar hybrid heating could be one of those detailing systems. The underfloor solar heating system is the most modern system containing hot water pipes up to 45 degrees underground (Tzivanidis, C & Bellos, E, 2019,15-16).

3.3.1.1. Active systems

The active system relies on a pump that moves the liquid and water inside the system. The weather changes are not very important to the dynamic system, and the performance mainly depends on an external source plus the sun for moving the pump. The HEM system is programming an external power source that supports the solar collector pump works. In addition, this system used antifreeze from the environmentally friendly category for moving thermal energy to the water (solouser, 2020).

a) Pumped Circulation Systems

A pumped circulation system may not be the best system used to process energy coming from solar but is achieved successes for water heating and air HVAC. The solar pumped circulation system has a flexible design that separates solar panels outside the building and energy stored inside the building. The separation between photovoltaics and water storage saves the effort to cool the water because it keeps water inside the building. The benefits of splitting between the two parts in this system are reducing the extra load of water on the surface of the building the tank's location based on consumption place. The tank is installed either on the wall or the floor, based on size and use (Norton, B, 2011, 191).

b) Direct circulation system

The direct circulation system is closed-loop water runs through then goes to the exact place. The design needs to transfer the water in the tank to the heating complexes through pumps. These pumps move water then settle it in storage systems preparation for use. The pumps are working. The direct circulation system has a problem of freezing water or stumbling inside tubes. Can be controlled the pain by activating pumps circulation and running even when the system is not in use at night. When the system is used in low-temperature locations, it can modify the design by adding a back drain. The system has a complete turn-off heating then drains the water outside if not used direct circulation system for an extended period or at a low

temperature. Usually, the evacuated tube collector is keeping up together with the natural circulation system for anti-freeze effectiveness systems in addition to low cost. In intense summer or winter, the evacuated tube collector uses air instead of water by the fan (Islam, M, Sumathy, K, Khan, S, 2013, 13).

c) Indirect water heating system

Activating indirect water heating systems means the water must reach a high temperature through two phases: closed collector loop and open storage. Work begins inside the closed collector loop, whose function is to deal with heat transfer fluid and deliver it to the heat exchanger. The role of the heat exchanger is to transfer temperature to water then go to the second part, which is open storage. The heat exchanger is selected either as an internal system or an external system depending on the situation. There is a system called a pressurized attached to a closed-loop section that works to adjust the fluid pressure and regulate appropriate temperature. In the case of an unpressurized system, all excess outputs are placed inside the tank, so the system does not crash (Islam, M et al., 2013, 13).

d) Pool heating system

Swimming pools need a little heating until the water temperature is moderate for swimming. It can use several techniques to reach suitable thermal requirements, such as an Open absorption heat pump, heat pump dehumidifier, etc. The integration of the swimming pool heating system with a home control system directs running automatically and shuts the solar collector depending on the appropriate temperature. Water heating in pools is often used as a flat plate collector unglazed type. Swimming pools depend on self-discharge of water and continuous pumping of circulation systems. Pumping and draining technology keeps the water pure and free of impurities for the longest possible period (Norton, B, 2011, 194). Also, be used heat pump that works to increase the air humidity and control the temperature in the pool. There are techniques named absorption heat pump is absorbs thermal energy and puts it to the generator and then to the condenser. The next step is mixing two components, the coolant, and

the condenser. After that, the energy has been processed to reach an appropriate temperature, connected to the wireless control service (Li, Y, Nord, N, Huang, G, Li, X, 2020,421-440).

e) Air water heating system

The work of an air-water heating system doesn't depend on stable combustion but transfer air from one place to another. The air-water heating system relates to the surrounding air temperature, profoundly impacting the pump's working capacity. The efficiency of air-water heating pumps for high thermal energy surpasses the electricity efficiency between 1.5 to 3 times. Other cold-area systems probably support this technology powers in full force in hot weather areas. The air-water heating system consists of two types of heaters, a climate system in addition to a circulation pump. According to sequence steps from outside building to inside the water become ready to use. Run the system is begins by capturing the heat from the air by the outdoor unit, then transferring it to the cooler and applying the high pressure. The heat is transferred to the water tank through pipes inside the Construction, which is distributed to the places of the taps. The used water is drained through the pipes then to the outdoor unit, and It can be used by recycling in the environment see fig 3.12 (GreenMatch, 2021).

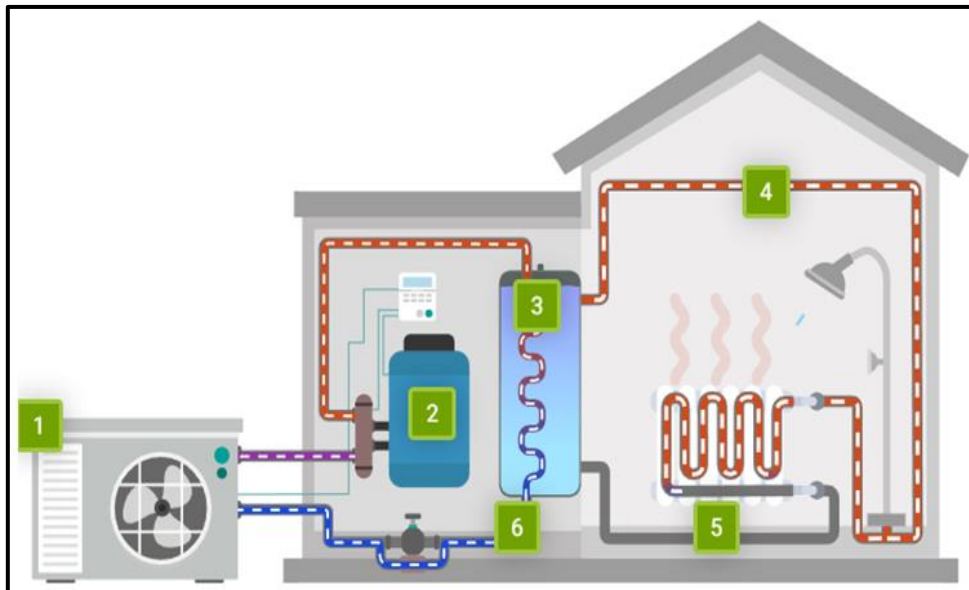


Figure 3.12: Working Stages Air - Water Heating System (GreenMatch, 2021).

3.3.1.2. Passive systems

The passive system doesn't depend on the pump but on gravity for moving the fluid. The mechanism of action is entirely different from the active system, which uses only the sun heat and does not rely on external materials. The passive system works smoothly with stable conditions, as it depends on heating the water through the pipes exposed to the sun. There is a latch for controlling exiting the water to the outside (solouser, 2020).

a) Thermosyphon solar water heaters

Thermosyphon is the type that regulates the flow of hot water inside solar water heaters, designed in compact units or the distributed form, see fig 3.13. Due to the different water densities in the solar heater collector, the thermosyphon is equivalent and works with varying water densities. The system contains a liquid hydrous that prevents water freezing and is located in the manifold or water store. Some plans are designed to utilize this fluid to facilitate the movement of the flow. Still, others may make water flow more difficult because the calcium carbonate is deposited in the tubes. Thermosyphon solar water heaters have two forms named dry type and wet type depending on steps of water walking inside the system. in a dry style, the heat is transmitted through the tube to the direct circulation round to the store or the indirect circulation round to the thermal exchanger. The wet type doesn't have thermal exchanger features. Tube and storage are responsible for the formation of water (Norton, B, 2011, 189-191).

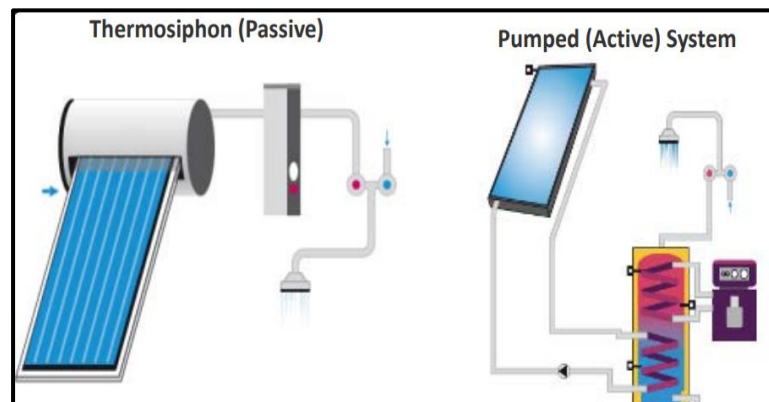


Figure 3.13: Thermosyphon solar system (UNEP, 2015, 17)

b) Integral Collector Storage (ICS)

Integral Collector Storage systems are used to heat water, and it is one item that contains tanks and collectors without any auxiliary elements like pumps. This system is classified as one of the most uncomplicated and effortless systems to install, as it also works as an addition to a previously traditional installed system. The modus operandi of (ICS) is that the solar collector receives cold water, the pressure force coming from the normal waterworks to heat then store high-temperature water. The (ICS) has a glass box containing tanks connected to large-sized pipes with a diameter of 100 to 200 mm. This system faces some drawbacks that restrict selection as the leading solar collector, such as simplicity of the structure and components limiting efficiency in keeping water warm for a long time. Although it is a one-unit assembled, the weight of water carrying needs a form capable of high weight support. With the continuous development of solar energy technology, a cover is placed over the (ICS) to last the heat longer. Still, this solution is not practical enough. The tank has covered one or more layers of glass to solve the trouble of rapid heat loss, but this solution is also classified as useless because it increases the weight and does not preserve heat for a long time (Alternative Energy Tutorials, 2021).

3.3.2. Indoor Solar Power System

Despite the high potential of heating and cooling, solar air heating systems use is less than water heating solar systems. Forty-nine countries have developed a plan to focus on heating and cooling renewable energy indoors of buildings in 2019. The potential of solar energy to meet the building's heating and cooling needs is enormous. Some countries have banned electricity consumption for water heaters and only allow heating by solar energy systems. After 2010, the heating and lighting took more space in energy consumption. The average consumption rate inside buildings has increased by 1.4% for heating and 1.7 for illumination (REN21, 2020, 60-193).

a) Solar air heating

Solar air heating has transferred the air to the interior space and raises the temperature through heating systems. The primary air solar heating system components are two main sections: the outer part is a solar collector, and the inner part is the distribution system and fan. Solar air heating system detailing is a panel full of holes that allow collecting air then exposing it to a high temperature by solar energy. A small distance should be left between the wall and the air heating plate, allowing air to collect and enter the space. Some systems use bypass to help the area's control ins and outs perspective. These bypasses are designed in slices form can be controlled to open and close according to the place needs, shown in figure 3.14 (RETScreen, 2005, 7-8).

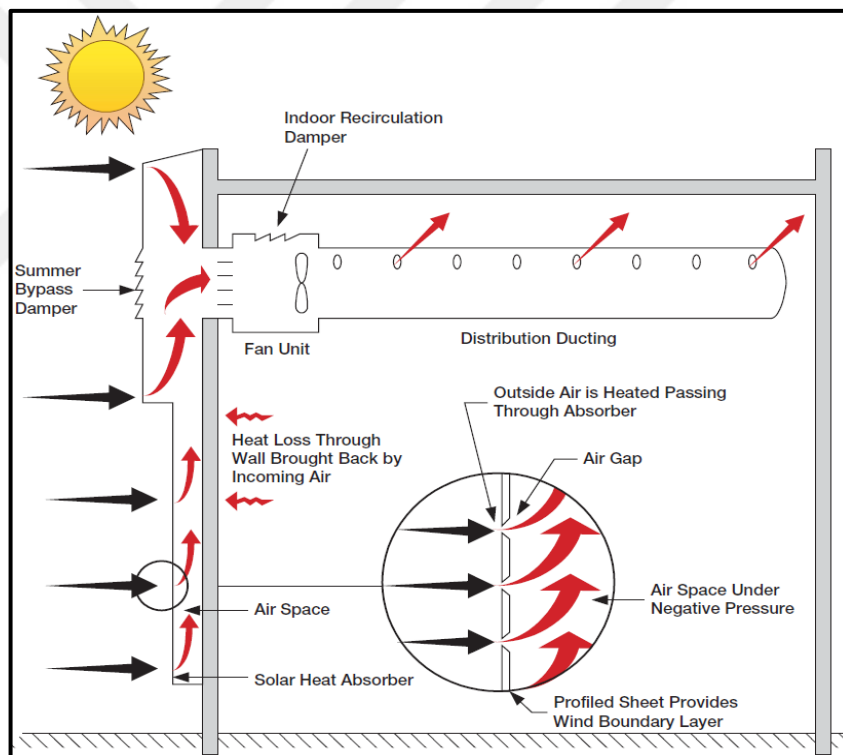


Figure 3.14: (SAH) System (RETScreen , 2005, 8)

Many successful strategies have proven the ability to use air heating systems inside buildings. These types are the cheapest, best for the environment, and the most effective solar air heaters. Solar air heaters with tubes are the least complicated heater, traditional one plus numbers of

pipes. Two types of heaters depend on the presence of the obstacle named solar air heater with barriers, and several blocks differentiate both types. This strategy extends the air time inside the system and thus absorbs more heat (positive correlation). A wavy-shape absorbent base in the middle of two solar air collectors is a double-flow with a solar air heater (Tzivanidis, C. & Bellos, E, 2019, 12-13).

b) Solar air conditioning

Solar cooling has appeared recently, but he didn't get enough development like heating. The Solar cooling systems consist of 3 sections, a closed section, an open section, and absorption Chillers.

Closed systems are cooling systems (chillers) derived from sun power produce water that works on operating cooling. There are two ways for water distributed in the close systems: pump it to air unit devices such as (air conditioner, dehumidifier) or distribute water through decentralized extended net inside construction such as fans. Typical cooling ability is different in a closed cycle, the solid sorbent in between 50 to 430 kW, and the liquid between 15 kW to 5 MW. The concrete and liquid sorbent are used in vacuum tubes and flat plate solar collectors to absorb solar power (Tsoutsos, T, Mugnier, D, Heunemann, F, Korma, E, Piteru, L, Delorme, M, Quinette, J, Wiemken, E, Dallo. G, Lopez, J, Six, R, Richler, N, Henning, H, Fragnito, P, Enciso, Y, 2004, 10).

Open systems are air cooling systems and dehumidification at the same time by using a rotating wheel and materials that pull moisture from the air. Open cycles are used for flat plate collectors and solar air collectors to apply liquid and solid sorbent. The typical cooling ability for open-cycle per module is between 20 kW and 350 kW. (Tsoutsos, T et al., 2004, 10).

A Absorption chillers are the most common cooling technology globally that operates, either a liquid refrigerant or sorbent solution. It works by thermal pressure in the dynamic system without electricity consumption. Water is mixed with liquid refrigerant inside a pump and used to produce cold air. The mechanism of absorption chillers work is decreasing the temperature to reach the evaporation of the used material is liquid refrigerate. The liquid

reaches a dilute concentration after passing through the cooling process, then absorbed by the refrigerant. The solution is continuously pumped into the generator then goes through a condensation phase to refrigerant by water use. Absorption chillers are highly efficient in operating within large areas of up to hundreds of kilometers (Tsoutsos, T et al., 2004, 11-12).

3.3.3. Solar Optical Technology

Residential buildings pay considerable attention to making solar lighting reach every interior space. Designs provide access to lighting and ventilation for interior spaces through windows. As time progressed, atriums, movable ceilings, and light shelves were designs that made interiors modern and practical at the same time. Should consider Some regulations during designing openings for a house, such as the glazing system, opening size, insulating materials, building orientation, types of building, and the geographical location. During the day, these openings work to take advantage of the light or rays of the sun, but at night, they resort to the use of different systems. The optical system works on lighting dark places through solar energy. The systems use a solar collector that gathers light and delivers it through optical fibers, and fig 3.15 shows the details of an optical system (Sapia, C, 2013,114).

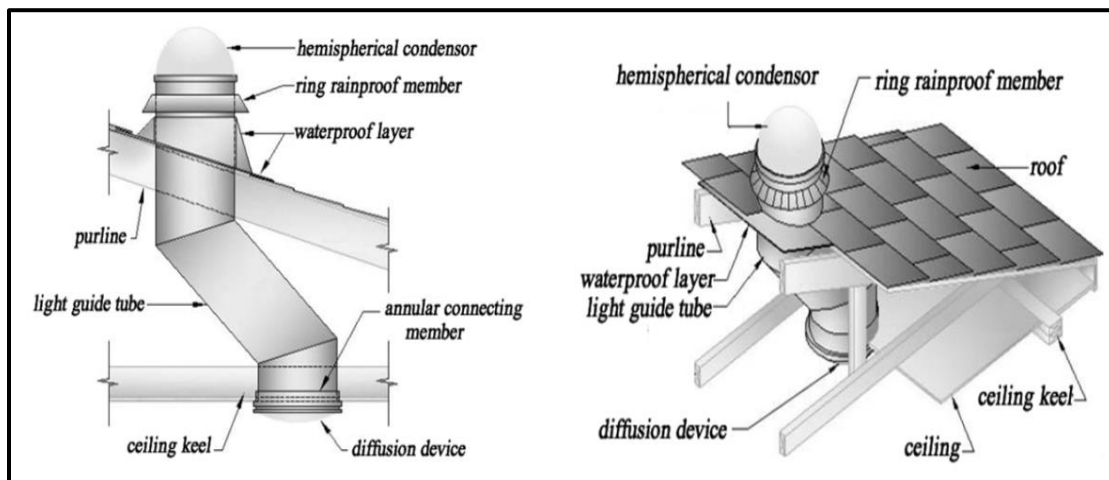


Figure 3.15: Solar Optical Technology (Ma, D & Xue, Y, 2013,11).

Solar optical technology specializes in supporting and enlightening the place by redirecting the sun's rays. It consists of a light collector that catches the sun's rays, a tube that transmits the beam, and a light diffuser. This type supports artificial lighting and average daylight due to obstacles in the atmosphere that sometimes prevent light from arriving at the collector. Solar optical system works in places with no windows or openings for direct rays to enter, such as warehouses and car garages (Ma, D & Xue, Y, 2013, 11).

Light shelves can manage sunlight inside residential buildings and reduce energy consumption. The concept of a system balances lighting distribution within the space and the provision of energy consumed. Lighting shelves system installation follows the sunlight through the direct way such as ventilation and lighting openings or indirect way, for example, the solar optical tubes. The shelving strategy is to distribute the light within the deep interior space using reflections on the upper surface of the shelf. Lighting shelves aren't burdening the building, distinguishing owing to being lightweight and highly effective. (Mohapatra, B, Kumar, M, & Mandal, S, 2019, 168). Light shelves configurations are the angles of fall of the rays, geometry, materials, and dimensions. A light shelf technology helps equalize natural lighting and allows movement in dark places. There are three types of Light shelf situations installation, either external, internal, or both together shown in fig 3.16. Glare decreases, and the light's intensity varies in interior space by changing height and selecting the solar ray angles of fall. There are cases of adding PV panels to the exterior light shelves to provide the building with more solar energy (Mesloub, A, & Ghosh, A, 2020, 1-4).

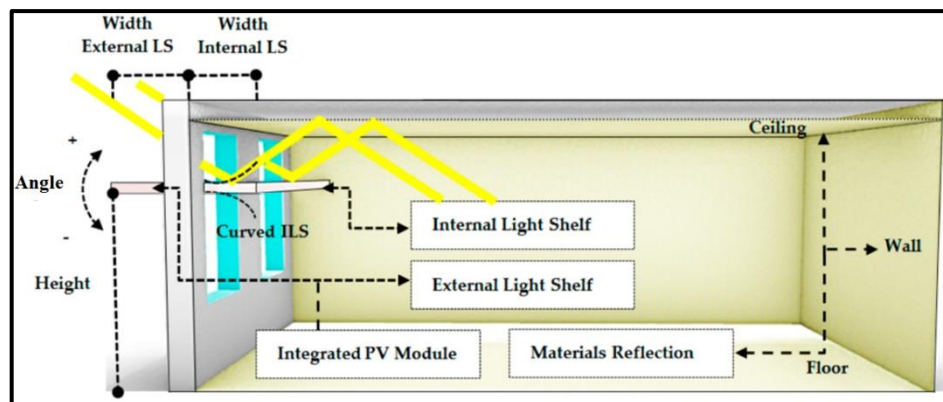


Figure 3.16: Light shelves system (Mesloub, A, & Ghosh, A, 2020, 2)

3.4. SOLAR ENERGY TRANSITIONS OVER THE YEARS

Solar energy has been in life for a long time. Still, interest in it began when reviewing Einstein's research on the photoelectric effect, in addition to the theory of relativity that was in 1905. Solar energy technologies began to protrude then expanded in 1998. It aims to continue and stimulate all renewable energy sectors from that time. Studies show that many countries worldwide are making clear progress in solar fuels, and by the year 2020, there is a clear difference improved over the years shown in figure 3.17. One of the purposes of the continuity of solar energy is development, keeping pace, and linking with modern technology. It requires flexibility in energy development, so it achieves a balance between consumption and continuous generation. The flexibility includes the joining of new investors in the solar energy sector. Consequently, industries will increase new technologies and heat storage methods (Heffron, R, Halbrügge, S, Korner, M, Obeng-Darko, N, Sumarno, T, Wagner, J, Weibelzahl, M, 2021, 72-73).

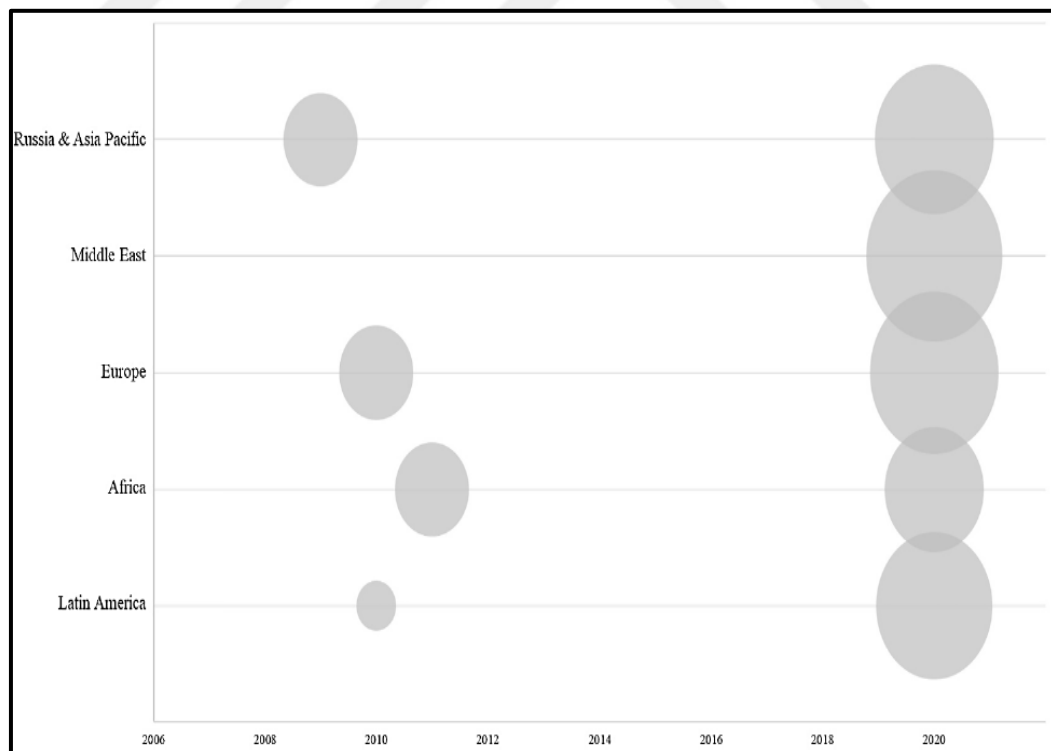


Figure 3.17 Solar Energy Progress (Heffron, R, et al, 2021, 72).

The rate of technology costs in photovoltaic energy is low, and the demand for it is high. Solar energy achieved significant investments and apparent demand. The year 2013 to 2015 was in the years that made a qualitative leap, the increase amounting to 59 billion dollars. There was a crisis in investment from 2016s to 2018s. The amount number of assets ranged between 131 to 171 billion dollars. Solar energy systems realized the decline after 2015, so marketing and showing the capabilities of photovoltaic cells was the solution. After marketing campaigns, the world knew the ability, flexibility, and importance of photovoltaic energy then recognized the value of investing in solar energy for the future. By 2050, the investment volume will reach 6.4 trillion dollars, an annual increase of 68%. After 2018 s to 2050s, the investment is estimated at around 192 billion dollars annually see fig 3.18 (IRENA, 2019, 31).

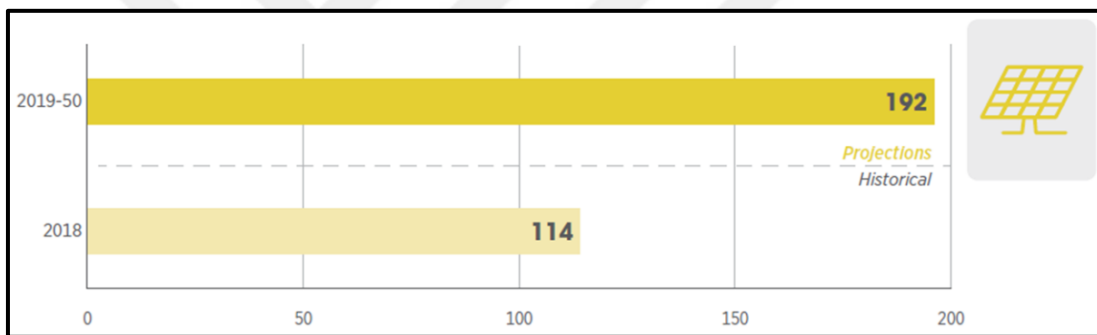


Figure 3.18: PV Energy Investment Progress (IRENA ,2019, 31).

For the Gulf countries, Saudi Arabia Kingdom is aware of the geographical location and possession of the most important renewable energy sources (solar energy). Accordingly, drawing up grand plans and laid goals in 2016 was a future base for a vision 2030. It aims to develop the financial sector through investment and savings in renewable energies. It also works to support manufacturing and development processes, depend more on renewable energies, and reduce the use of oil. Saudi Arabia has set clear initial goals, where 9.5 GW is the energy generated within the Kingdom cities. The energy sector has dealt with several parties involved, such as the project development Office and Ministries. In 2018, the Saudi Arabia Kingdom began drawing a plan for the NEOM project, which relies on renewable

energy and a future vision, in addition to the Sakaka solar energy project (Bhatt, Y, 2021, 165-166).

After the Kingdom of Saudi Arabia, the UAE is the largest market in energy and has dispensed with electricity resulting from oil in many projects. The UAE is looking towards growing renewable energies, and there is a goal to increase power by 24% within ten years between 2014 and 2024. In 2017, the UAE created a plan to advance clean energy by 50% and reduce carbon by 70% in 2050. Emirates Attitudes to a Huge Project named (Mohammed bin Rashid Al Maktoum Solar Park) include the solar power plants divided into five phases. The production of each stage ranges between 13 megawatts and up to 900 megawatts (Bhatt, Y, 2021, 168-170).

Oman has been a pioneer in solar energy, and it has been using the sun's rays extensively in the operation of the projects and water desalination. Oman works rapid movement and intensively to increase the available capacity of solar energy to get an important place in the world. A large project was run in 2015 by a leading company in solar energy, where it will generate solar electricity for 20 years. In addition, support small projects in the residential and commercial sector and massive projects under electricity companies' management, all within the framework of improving consumption and the growth of the solar energy sector (Bhatt, Y, 2021, 173-175).

Since the decision to host the World Cup 2022, Qatar has witnessed an urban renaissance and significant population growth. There is a Qatari institution for solar energy, and it has reached 200 megawatts by the end of the year 2020. After proving a success in the first stage, the target increased by 500 gigawatts for the following steps. There are systems towards development and improvement. National Convention Center has raised awareness and the section of investment in solar energy by PV with a capacity of 667 kilowatts. Bahrain is also trying to support solar energy by agreeing on a BAPCO project, which installs 21,000 solar panels to increase the electric income coming from the sun. The Kingdom of Bahrain has also cooperated with the United Nations Development Program to deploy solar energy generators

on 66 buildings in different locations within the city. Despite these projects, Qatar, Bahrain, and Kuwait are new in renewable energy, and they're trying to come up with projects that replace the use of oil with solar power (Bhatt, Y, 2021, 171-173).

3.5. SOLAR ENERGY SECURITY STANDARD

At the beginning of 20 century, the concept of energy security appeared. In 1960, scrutiny began on energy needs and protecting the sources. When the researchers started an interest in energy security, the focus became on finding revenues that would ensure the continuity of the existence of energies. Attention to minimizing the adverse effects on the sources is likewise a continuous attempt to deliver energy services to all segments of society in sufficient quantities. The International Energy Agency stipulates the response of energy security to the changes that arise suddenly from the environment or socially. Therefore, energy security links the main perspectives: control and sovereignty, strength and robustness, flexibility, and resilience alignment with the development (Proskuryakova, L, 2018, 203-204).

The energy policy in the European Union is based on four factors: sustainability survival of the systems over time, competitiveness, supply security, and protection. There are two main axes when detailing the term energy and security, including many fields. Firstly, the energy system is exposed to requirements that could change the path comprising the safety and protection of the supply. It includes maintaining the existing resources, knowing the market requirements, and keeping pace with the exact specifications also, the continuity of the availability of materials as well as the security and protection of demand that guarantees the abundance of cash flow that works on the continuity of work and save the proportions that belong to the market. Second, the energy system and the factors that affect the instability security are stresses on energies Continuity. The economic and political changes lead to the struggle for availability, where there is a scarcity availability of some energy resources materials. There are technological factors a slight disturbance in work causes disasters such as gas explosions, walls dams, and fuel tankers. For the environment part, there are artificial

factors that impulse damage, such as pollution, biodiversity changes over the years, and factors out of control, such as climate change and natural disasters (Johansson, B, 2013, 598-599).

There are significant challenges facing energy security, such as a carbon-free atmosphere, shaping energy as part of buildings, preparing energy work, and increasing efficiency. The plans currently running to occupy the near future are developing renewable energy systems that operate on tank energy, integrating the end with smart cities, and building future cities. But some sources that constitute horror for the origins of energy security are nuclear energy production and the threat to use. That is why the advancement of powers and progress is limited. In addition, fraud crimes hinder expansion and mastery in the market (Proskuryakova, L, 2018, 204).

The production of solar energy is one result of fear for energy security problems. In 2018, the production of photovoltaic energy worldwide reached 480 gigawatts without CSP-only PV. There are applications for solar energy that work off the grid, either because the cost is high or if the electrical grid is cut off from the area. Solar energy works off-grid may not be the best choice or the option that reduces the economic cost, but it improves energy security and spread acceleration. Strengthening the link between devices such as the sensor system and others enhances the devices' capabilities and increases future predictions for performance. In the PV, energy is connected to the Internet of Things, will become a clear network inside the systems platform, and increase security. Lastly, towards the safety and security of solar energy in the future, the manufacturing of new solar panels ensures the continuity of solar energy use over the coming years. After studying concluded the age of the solar panels that the average life is 30 years, the efficiency of the panels' work decreases, but the internal raw materials remain suitable for recycling. New panels are manufactured periodically using the raw materials in the expired panels, thus ensuring the continuity of the presence of PV panels (IRENA, 2019, 19, 26, 48, 51).

3.6. LEVELIZED COST OF SOLAR ENERGY AND INVESTMENT

Solar energy is classified as one of the most competitive energy generation sources. The research states the standard cost rates will decrease in the coming decades for renewable energy sources, including fossil fuels, as the year 2030 per 0.014 dollars amount of solar energy 0.05 Kilowatts per hour (IRENA, 2019, 29).

The fossil fuel cost plan goes up like stairs, starting with minimal cost to the maximum. Low cost is spent on equipment, then ending with expensive fuel costs. The CSP cost is summarized in a hierarchy shape, but the working capital and financing affect the size and produce energy in the project. The base represents the initial costs of high-priced solar power, followed by the lowest cost, which is maintenance, insurance, and operations. The top of the shape represents the fuel cost almost non-existent compared to other costs. There is apprehension about investing in CSP because it is classified as the vast and newest solar energy technology. It constitutes a risk from the suppliers, but the future vision is the next for CSP to run mega projects (IRENA, 2012, 30).

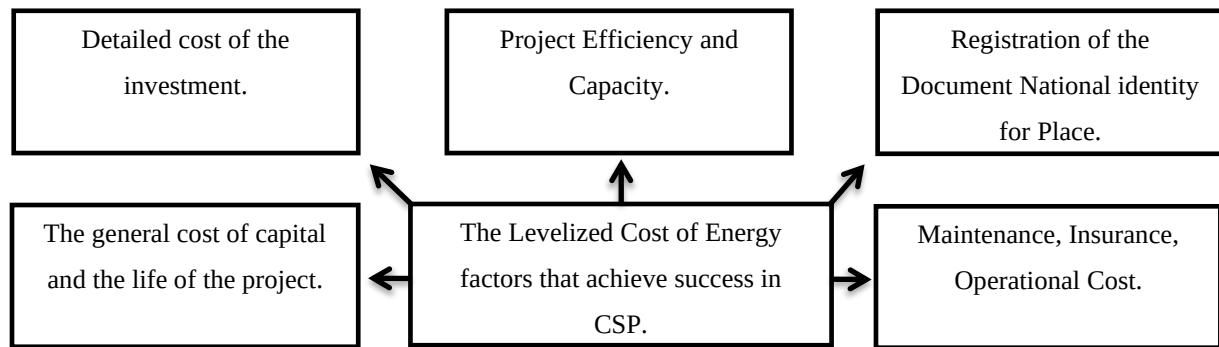


Figure 3.19: Levelized Cost steps for CSP (IRENA,2012, 30)

It may represent solar energy projects (CSP) or (PV), but the start-up cost is the biggest obstacle. Usually, borrowing from banks is a solution to finance solar energy projects, but banks only deal with massive projects. For example, in the UK, the minimum amount to borrow from most banks is 20 million dollars, and this amount is huge for a start-up solar

energy project by a single investor. Small projects are not supported and face financial support problems. There is a problem unifying transaction prices related to the energy sectors, whether on large or small projects. Select uniformity price without considering the difference in funding was burden investors in small projects (IRENA, 2014, 142-143).

The Gulf countries have achieved a great success if comparing modern methods of generating energy with traditional ones. There are several reasons for the strength of investing in solar energy in the Gulf countries, such as documenting an agreement with (UNFCCC) and the Paris agreement on air pollution to reduce greenhouse gas emissions. The leveled cost of solar energy in Gulf countries was too high, equivalent to the fuel. In 2014 the rise started, but after 2016, the Gulf countries began to deal with the price problem, and the Leveled cost became economically compared to fuel. The cost of the Solar electricity PV was 0.085 (USD/kWh) and CSP 0.185 (USD/kWh). Between 2017 and 2018, reduced the leveled cost in PV 26% and concentrated solar power by 13% (Praveen, R et al., 2020, 3).

3.7. OVERVIEW OF CONSUMPTION DATA

Many daily services are based on solar energy, where energy consumption has become automatically as basic of living. Energy consumption rates are affected by social status, geographical location, economic situation, behavior, characteristics of the operating place, Variable energy prices. Solar energy reduces bills, ensures quality power with minimal damage, and keeps pace with development and civilization. The federal program is cared to the consumption field and supports solar energy to reduce the financial burdens of low-income families. Continuous efforts are being made to reduce energy consumption and achieve luxury significantly. The solar panel is divided into several sections so that each consumer has a one-part. Thus, the cost price is reduced for the consumer and feels the same efficiency. This system can be applied in homes, public utilities, offices according to need and financial capacity (Brown, M, Soni, A, Lapsa, M, Southworth, K, 2020, 11- 49).

3.7.1. Household Consumption Around The World

Sustainable energy at present includes all sectors, especially solar energy. Knowing the global energy consumption in households is the foundation for building a proven information base. The relationship of consumption to production is based on the worldwide economy of development and access to the better. A proven base of data is reached through statistics representing countries and the household consumption of solar energy. Household consumption and other name are family consumption vary according to the city location, energy prices, and rationalization of consumption (Matuszewska-Janica, A, Zebrowska-Suchodolska, D, Mazur-Dudzinska, A, 2021, 2-3).

Statistics show that 25 million people are gaining home solar energy services. Home services from solar energy are widely available to people quickly because the home systems and solar panels are small and straightforward to implement. In 2017, 80,000 solar power stations provided services for homes not included in global networks. Figure 3.20 shows the rising rates of used solar home systems across the globe from 2007 to 2016 (IRENA, 2018).

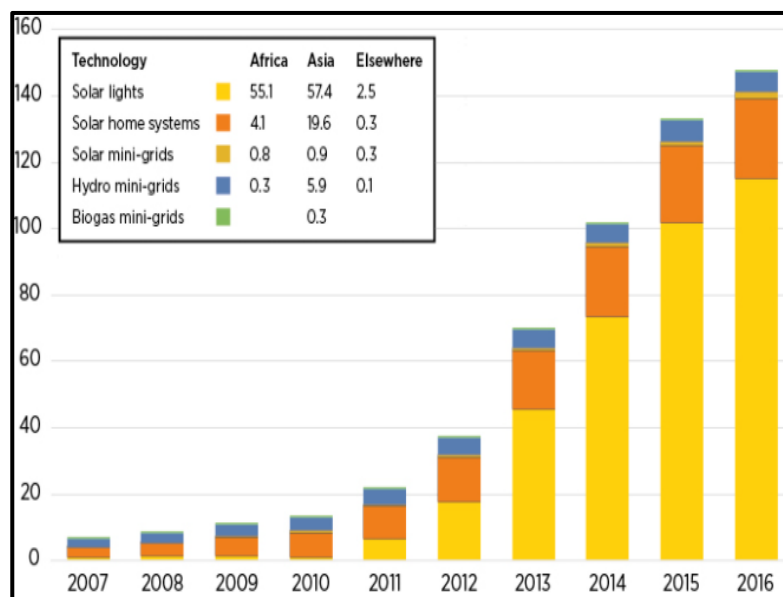


Figure 3.20: Growing Solar Home Systems (IRENA, 2018).

3.7.2. Household Consumption In The Gulf Countries

Energy consumption in the Gulf countries is high. Every year the consumption rates increase compared to previous statistics. In 2013, the annual per capita consumption was approximately 12370·91 kilowatt-hours. When comparing other countries, this number is exaggerated. For example, China consumes around 3762·07 kilowatt-hours. Gulf countries consume 47% of the residential sector, while the global average is only 25%. Recently, the Kingdom of Saudi Arabia and Oman are witnessing an increase in consumption by 2% annually (Umar, T, & Wamuziri, S, 2016,1-2).

The Gulf countries can invest in solar energy. 60% is the area discovered to receive new solar energy systems. Each one percent has a production capacity of approximately 740 gigawatts. Lately, it has increased consumer awareness in Gulf countries and balanced consumption with renewable energies. The cities of the Kingdom of Saudi Arabia are ranked among the best in the installation sites of solar power plants among the Gulf countries. Kuwait is the second country, then the Abu Dhabi city in the Emirates after that, some areas in Qatar. Configuration of regions depends on the (DNI) present in the air, which varies from one city to another based on humidity and dust (Praveen, R et al., 2020, 3-4).

A secure energy system supports the economic growth of the Kingdom of Bahrain. In previous years, Bahrain attended instability in the supply and consumption of energy, which led to pressure on country energy systems. The power supply was 4.2%, but the consumption energy system exceeds the supply where is 5.3%, so Bahrain's consumption is very high compared to the size of the country. The Kingdom of Bahrain is classified as not having sufficient solar energy systems, highly dependent on oil and gas. The past few years have followed plans and projects to strengthen infinite energy systems such as Al Dur PV Plant Askar solar farm. There are currently no clear consumption rates for solar energy, but the state is negotiating to enable the roofs of buildings as areas to install solar collectors. In addition, the NEEAP sets short-term goals in 2025 to reach the efficiency of solar energy to 6% through a series of new initiatives (ISRA, 2019, 12, 36-37).

Kuwait is a country that consumes high energy also, the level of well-being of the individual is high compared to the world. Between 2000 and 2015, the statistics indicate that the individual consumes 5% each year, and this percentage can increase. Kuwait isn't considered countries operating in renewable energy, but it seeks to develop. Not long ago, Kuwait realized the extent of the derelictions in the energy field after that developed a plan to end by 2030, covering 15% of the needs through renewable energy (BHATT, Y, 2021, 167).

Saudi Arabia is the largest city in the Gulf in size and population, so it consumes 50% of the total energy distributed to the six Gulf countries. Latest stats n Saudi Arabia between 2010 and 2016, the consumption energy was about 74%. The solar energy generated inside the Kingdom in 2018 amounted to 90 megawatts, but there was an agreement about producing more solar PV power in the coming years (BHATT, Y, 2021, 164-166).

UAE production of many solar panels to take advantage of its geographical location of the Sunbelt region and Meets high consumption demands. The UAE has achieved high living standards, with well-being rates higher than other Gulf countries. It has experienced rapid growth to become a pioneer in civilization and advance in recent years. There is awareness by the UAE in converting a large part of fuel energy services into solar energy. More than 40% is the rate of household energy consumption, where air conditioning occupies the most considerable part. The consumption rates of air conditioning are rising due to temperature reaching high levels for more than seven months of the year. In 2010, there were housing electricity consumption studies by the Municipality of Abu Dhabi to analyze consumption rates. The analysis of the housing indicated that energy consumed is as follows exhaust air fans occupy 1.6%, external consumption 0.1%, lighting 7.44%, fan coil units 8.1%, hot water boilers 8.4%, other common equipment 11.8 %, Chillers 57.5 %, other internal 5.1% (IRENA, 2019,44).

4. SOLAR HOMES IN SMART CITIES

The future smart city aims to develop and improve life quality to raise the standard of living. Daily life becomes not devoid of advanced technologies such as paying water bills through a phone application, printing paper without using wire, controlling lights system via Wi-Fi. The transformation for all this development is due to the founding of accurate networks and renewable energy, advanced techniques, and intelligent infrastructure. Building a city interested in technology highlights the new perception and directs the visibility towards innovation, recycling, and sustainability (Awad, J, Hyder, A, Irfan, A, 2017, 44).

Twenty-five years ago, intelligent cities didn't exist in the actual world. Economic, civilized, social, and technological development cycles made smart cities touchable. Smart cities were not created by chance. Smart cities result from a union in architecture with urban planning, environmental sciences, financial and economics, computer science, and another purview that presented evolving environment. It has been researching, studying, planning, and implementing for several years. The new vision of cities made solutions to problems present in societies, including incompetence, unemployment, pollution, etc. (Angelidou, M, 2017, 1-2).

For having a booming smart city, three categories must be taken into account first, collecting information and data while being familiar with the latest technologies. This category includes everything related to geographical location, sensor systems, the Internet of things, places where data is saved. The second category is marketing and sharing new technologies with the community to the maximum extent through publishing via the Internet, social media, or live conferences. The third category is the basics of future life that make a difference between intelligent cities and ordinary cities, including energy, surrounding environment, transportation, infrastructure, etc. (Angelidou, M, 2017, 4).

4.1. SUSTAINABLE DEVELOPMENT IN SMART CITIES

The development of the smart city is different from any other city through ecological balance with the comprehensiveness of a place to live, work, and comfort. The idea of sustainable development in smart cities is to provide all the needs of residents and visitors over many generations safely and intelligently. Sustainable development is always surrounded by the framework of improvement and keeping pace without harming the environment. There are three main concepts include the growth of smart cities.

- a) Meet all current and future needs.
- b) Adhering to environmental restrictions and the search for practical solutions.
- c) Finding for technological invest (Batagan, L, 2011, 81).

The Gulf Cooperation Council countries are working hard to develop the future aspiration of the smart city, as it has promoted several concepts. Support wireless phones in new cities, solar systems, and expand services for easy access to all people within the intelligent city framework. The Gulf countries are interested in the smart future and provide all the needs to create an integrated environment by providing housing, schools, health care, hospitals, and shopping centers with sustainability Constraints. Infrastructure is the base, so it takes care to provide all services with high efficiency. Moreover, it integrates government transactions with wireless networks facilitates electronic procedures and extension of renewable energy grids. The GCC designed smart cities with high standards and provided all possibilities to become a future tourist center. All of these services need intelligent mechanisms that support industrial growth and the creation of substantial job opportunities that help reduce unemployment. Indicators of the successful smart cities in the Gulf Cooperation Council countries are wireless cities that include a mixture of intelligence in health, business, industry development, real estate, housing, and infrastructure. The innovative sectors in the city lead to the creation of job opportunities, the use of renewable energies, and the provision of a city that supports tourism and a future vision. Finally, the presence of a specialized faculty or institute in the city is a

continuation of the development and provision of science, shown in fig 4.1 (Awad, J et al., 2017, 60-61).

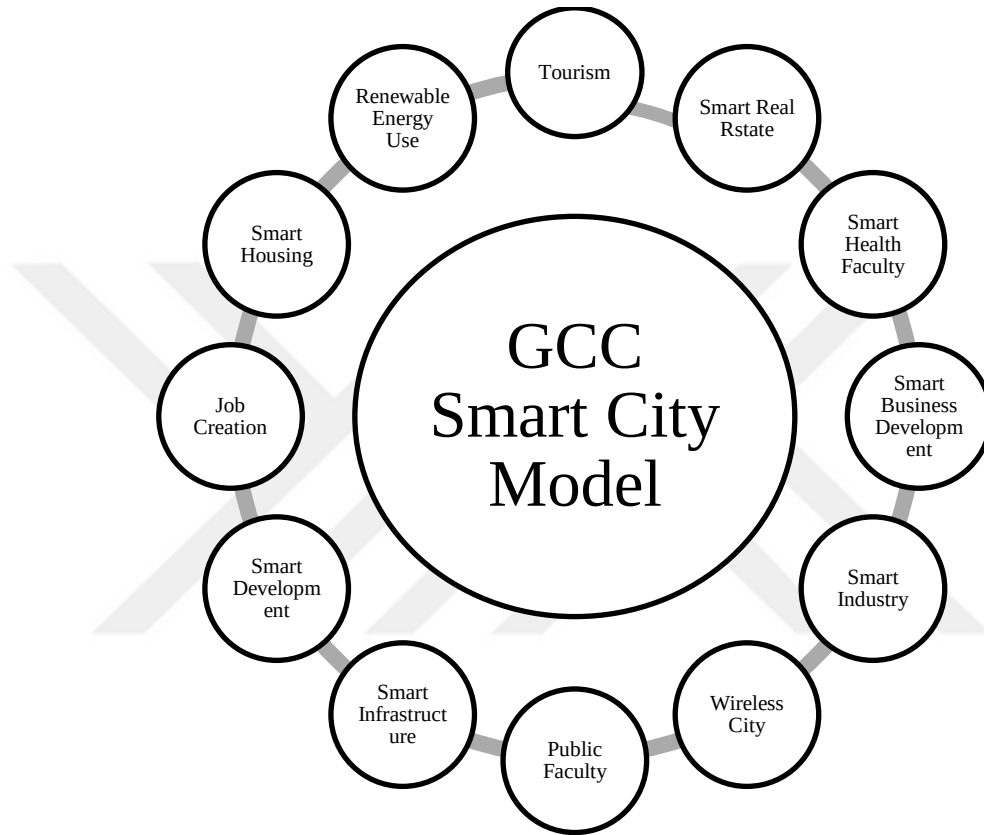


Figure 4.1: GCC Smart City Indicators (Awad, J, et al., 2017,60).

4.1.1. Development Smart City Networks

Massachusetts Institute of Technology discovered the Internet of Things (IoT). It has been globally recognized by communication Networking and information network technology. The revolution taking place in the world is networks that connect the surrounding world and verification all its services. Each service has a different identity and a changing physical name, all of them are governed by one system (IoT) that seeks to spread across the world by investing. Due to its great spread, it is expected that in 2050 each person can connect 6.58 devices, which means more than 50 billion devices worldwide (Suzuki, L, 2017, 173-174).

The innovative city development started from the infrastructure, where the networks are located. Networks send and receive information while working to control and operate the external section tangible above the earth's surface. It sends signals through underground pipes and cables connected to sensors and data analysis programs. The location of intelligent city networks underground the installation depth depends on service and situation. For example, the transmission section is installed between 2 to 4 meters and the distribution section from 0.05 to 1 meter of the surface (Al-Hader, M, Rodzi, A, Sharif, A, Ahmad, N, 2009, 94).

Planning is the foundation stone drawing the landmarks of the smart city and knowing the locations of buildings, roads, electricity, etc. The intelligent future towns are monitored closely by (GPS) and (GNSS) to protect the systems from disturbance and determine the dimensions in high professionalism. These two systems are global in activating high technology also the most accurate for controlling and identifying distribution and reception stations. Notifications arrive at the location via high-accuracy wireless frequencies to process any disturbance before it occurs. The smart city builds a base for data that works to process data accuracy and integrity from flaws by geospatial platforms. The above surface part is the constructions and energies, is fall under the name building management system. (BMS) is working on transferring the idea of a traditional building to an intelligent, energy-saving building with a high level of technology. This section is concerned with cost reduction and environmental safety by promoting alternative energy (Al-Hader, A et al., 2009, 94-95).

The Internet revolution has caused a fuss in the Gulf countries, and there is considerable flexibility in dealing with advanced technology. Previously, handled it with traditional networks, but now wireless networks are a modern revolution, as happens in Dubai Internet City, Masdar City, Dubai Media City, and Neom city in Saudi Arabia. The Gulf countries use networks to connect the GCC countries. By 2026, significant investments are expected to reach 1.68\$ Billion see fig 4.2. Gulf countries changed old orientations to investing solar energy and focusing on activating technology and the advancement of networks, making the spread of intelligent cities a foregone conclusion in six countries (Okedu, K, & AL Salmani, L, 2019, 97).

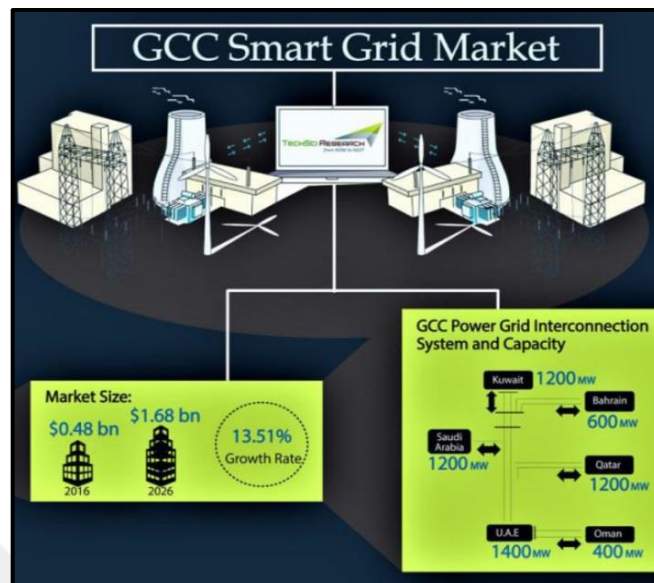


Figure 4.2: Gulf countries' networks investment (Okedu, K, & AL Salmani, L, 2019, 97).

4.1.2. The Future Of Solar Energy

Future smart cities will be self-sufficient in solar energy, and oil electricity will not be there. Now the operation of solar energy is clearly in many areas, some of which are implemented, and others are in preparation, such as electric cars, traffic lights, water treatment, and others. Modern cities are developing solar energy storage systems, which are supposed to preserve heat for months without leakage. Among the plans, there are storage systems in the infrastructure linked to the city's facilities that allow solar energy to reach all places, including homes. Since now there are cars powered by solar panels in the future, planes will be configured to work on solar fuel. In specific proportions, the fuel derived from solar energy will be combined with hydrogen fuel or other lightweight fuels to produce energy able of moving planes (Kiss, G, Jansen, H, Castaldo, V, Orsi, L, 2015, 330-331).

In the Gulf countries, the growth of solar energy consumption has been growing annually since the year 2000 is more than population growth and local production. The Gulf countries continuously change and renew the solar energy sector, starting from developing plans and ending with the resulting profits. The Gulf state governments placed strategies to achieve tremendous future success in solar energy (Kearney, P, 2017).

Specific regulatory and policy regulations are the main factors that must follow for success without harming other aspects.

- a) Setting achievable goals
- b) draw a ceiling for ambition
- c) Finding institutions that support workers in developing the solar energy sector
- d) Establish rewards for energy development staff
- e) Paying attention to the framework that works to develop the energy sector
- f) Develop skills (maintenance, discovery, calculation) (Kearney, P, 2017).

Much research is being done on future improvements and percentage analysis on increasing energy efficiency in future cities. Table 4.1 shows the rates of the solar energy sector increase and future improvements for the year 2050 around the world (Kiss, G, Jansen, H, Castaldo, V, Orsi, L, 2015, 333).

Table 4.1: The progress of solar energy in 2050 (Kiss, G, et al,2015 , 333).

Improvements in GCC countries	Item	Improvements percentage
	PV efficiency	200%
	Building energy consumption	75%

The increasing demand for solar energy raises employment rates and jobs in this field. The rates of job opportunities in much solar power are growing. The number of jobs will reach 11.7 million in the year 2030. The high quality provided by the solar energy sector in most continents and the low cost will increase production and demand annually. The most recent study is in 2050, where the number of jobs will reach 18.7 million job opportunities, shown in figure 4.3 (IRENA,2019, 54).

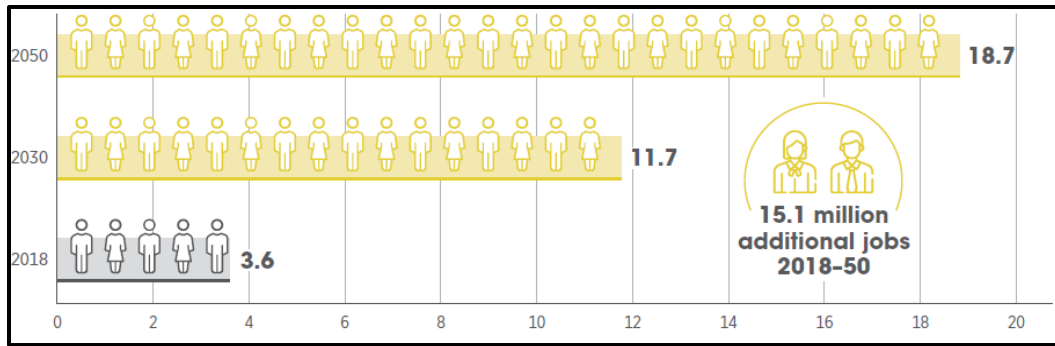


Figure 4.3 : Job opportunities clarification (IRENA,2019, 55).

4.2. RESIDENTIAL BUILDINGS IN FUTURE CITIES

Some may think residential buildings within a specific environment are just a group of simple constructions placed randomly. The truth is that building within a particular ecosystem, exceptionally if smart, is a complex idea and requires a set of economic, political, and social processes. After the political phase is completed, the second depends on statisticians, architects, city management, environmentally responsible, civil engineers, economic, urban planners, physicists. When observing the building regulations, it turns out the environment's health affects the building performance side by side with the systems used inside the building (Santamouris, M, & Cartalis, C, 2017,130).

The housing department has taken interest among the decision-makers in GCC smart city designing. Paying attention to the climate surrounding housing, reducing pollution, Settlement, tax exemption, and affordable costs, it aims to attract the most significant number of people from all over the world (Awad, J et al., 2017,60).

4.2.1. Communication Technologies

There are systems linked and programmed precisely that make technology and strategies easy to use. The presence of networks allows providing comfort and achieving the transition to an environment depending on life facilitation systems see fig 4.4. Despite the different types of

networks, choosing the right network inside the home depends on the compatibility of the smart city. The selection process needs a specialist depending on the organization, standards, technical criteria, and strategic decisions. Two communication technologies are used inside the spaces, wired via wires and cables or wireless through waves and sensors. The financial cost of wired communication is higher than wireless communication (Haidie, A, Hassani, S, Aqqal, A, El Hannani, A, 2016, 61-64).

Figure 4.4: Network Services in House (Gwiazda, A, Banas,W, Sękala, A ,Sokol ,M ,Foit, K Monica, Z ,2018, 5).

a) Wired Communication Technologies

For wired communication technologies, there are six sections suitable for the differences of houses within intelligent cities, named Ethernet, ITU G.hn, Power Line Communication, Serial, HomePNA, and MoCA. These communication technologies combine digital data with power lines and display it on phone screens. The types differ in features. Some technologies have a wide-scale network and others narrowband. All the wired communication technologies are generally considered acceptable, but the data rate varies for each country's energy policy (Kuzlu, M, Pipattanasomporn, M, & Rahman, S, 2015, 2-3).

b) Wireless Communication Technologies

The wireless communication technologies bifurcate into ten sections different in advantages. Wi-Fi is the most popular and widespread in the entire world, characterized by high speed and safety. ZigBee, Bluetooth, Z-Wave, IEEE 802.15.3, EnOcean, Wave2M, RFID, ONE-NET are

the other wireless communication used in houses. Some communication technologies are pick up the signal over long distances, others short distances. Installation and maintenance prices are different depending on the type, and the sensitive network needs more servicing and caring. The cost, consumption, and work method varied from one network to another. Depending on the smart city, the appropriate network is selected. In the same space, some wireless communication technologies are working with a supportive wireless network, such as RFID working with Wi-Fi or ZigBee. Each of these Wireless networks has specific ways for transitioning the data in and out of the system (Kuzlu, M et al., 2015, 2-3).

4.2.2. Smart Home Energy Management

After selecting the appropriate network, there must be an operating system for the home technology appliances. In 1976, the invention of the (HEMS) system began to automatically control and operate the systems using the energy generated for the home. During the highest use rate per day, the (HEMS) system saves about 30 % of the energy used. Furthermore, it reduces the operational cost of energy by around 23%. Home control systems are a necessity and priority in smart city homes. The replacement of electricity with unlimited power is causing a difference in pricing from time to time. (HEMS) works according to the data set by the customer from the block rates, time of use, to reduce consumption at peak times, and others. In this way, daily tasks are performed at the lowest cost and the best quality, see figure 4.5 (Lobaccaro, G, Carlucci, S, & Lofstrom, E, 2016, 13).

The services provide a home area network and metering system that monitors and controls home technologies in a smart city. Smart city houses have technologies (maintenance, security, energy, HVAC, services) that rely on high comfort and remote directing in figure 4.6. The network services inside and outside the home are under the intelligent category, starting by signal or automatic. A screen device is located on the customer site responsible for organizing services with network infrastructure systems. The device work mechanism is

divided into sections to determine the direction of the orders and prioritize the services (Kuzlu, M et al., 2015, 2-3).

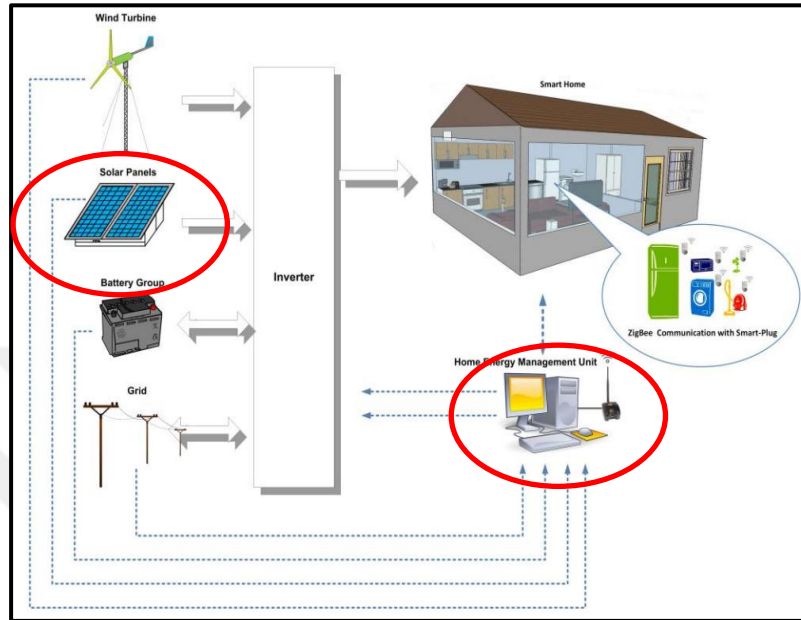


Figure 4.5: Relation between Solar Energy and Home Services (İnce, A, Elma, O., Selamoğulları, U, & Vural, B, 2014, 3)

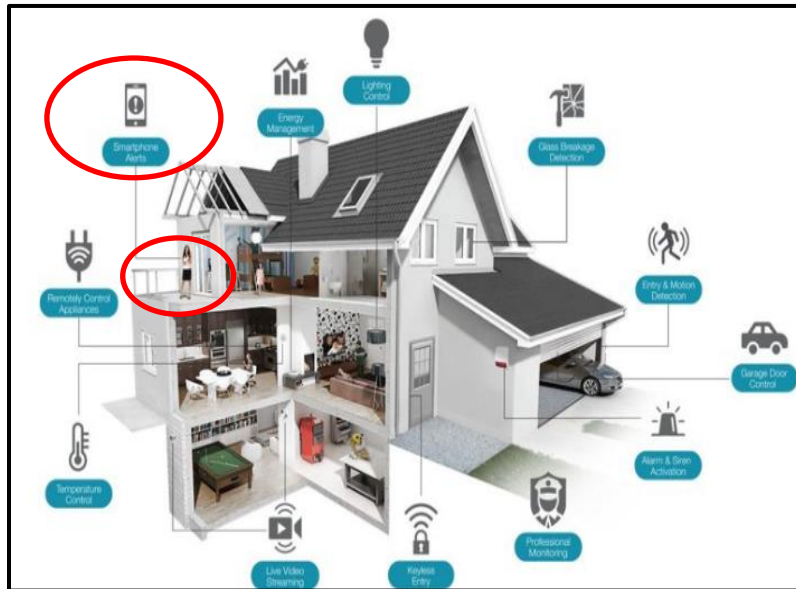


Figure 4.6: Screen control device for Smart Home (Mal, N, 2019)

(HEMS) has three main sections able to perform daily functions. The primary control device is energy management and giving orders. Enabling technologies are the sensors that measure the house's factors, such as air temperature, wind rate, and lighting. User Interfaces (gateway) is a platform that receives signals. It connects with a control section and adjusts the amount of consumption, the volume of available energy, and the peak of consumption (LaMarche, J, Cheney, Roth, K, & Sachs, O, 2017, 166-167).

Each section has several types that interact with the building in one way or another, as shown in fig 4.7. In the control devices, there is a type that allows two internal systems to be combined, such as lighting with security. Independent control requires for another kind of scheduling system, such as turning on the air conditioning at a specific time of the day. The third type is the On-Board control that reacts to grid instability. The User Interfaces operates to display data and information on consumption, budgets, and times of use. It can use the data displayed on a phone, home, computer, or TV. The user interface allows pairing supportive, innovative applications Such as smart meters. There is a specialized type house for Enabling Technologies from the inside and outside, such as sensors, cameras, or temperatures. Physical devices specialized in network settings such as waves and modems. The last type allows combining more than one operator network inside one place, such as Z-wave, ZigBee (LaMarche, J et al., 2017, 166-167).

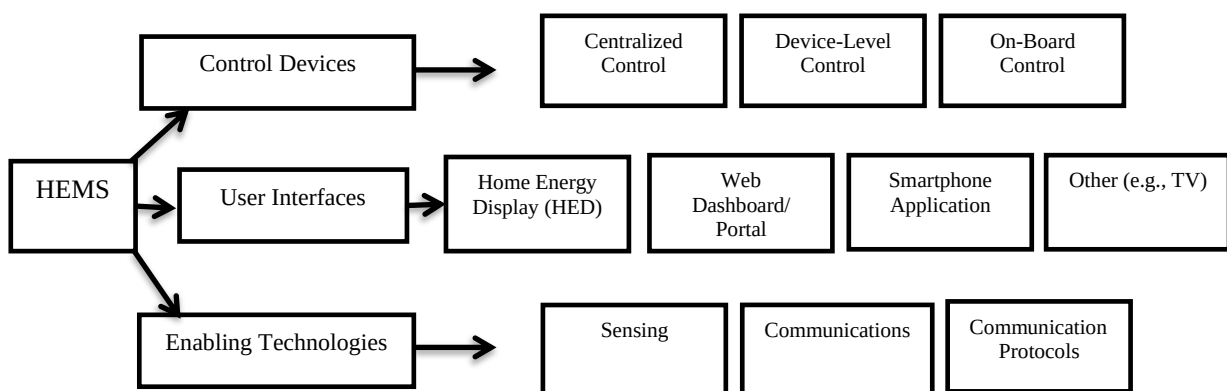


Figure 4.7: HEMS Sections

The availability of high-level administrative services and systems for intelligent dwellings is a sequential element between home and the city. It starts with choosing the required task at home by selecting the device's procedure linked to home applications systems. The sensors located in the place pick up the signal then send it to the transmitter and receiver devices connected to the communication network. The procedure arrives in the main device in the home that connects all other devices distributed in the space. Software application performs the function and sends it to the center. In this step, if the house is in a smart city, it goes to the center located through the city's infrastructure. The Processing is done very accurately, and the city's production and energy consumption rates are connected in the same system. The last step required action has been performed inside the house (Miller, M, 2015, 16).

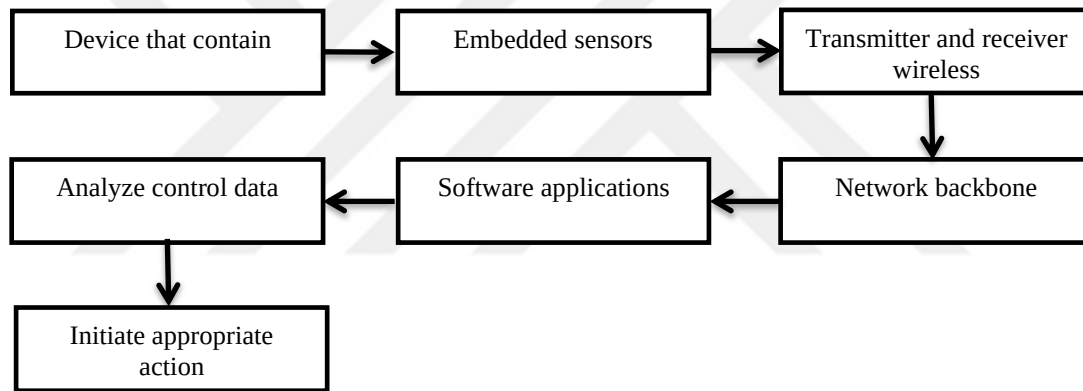


Figure 4.8: Steps of connecting smart home and smart city

4.2.3. Building Compatibility With Photovoltaics - (BIPV)

BIPV system merges traditional construction with solar panels, either on the roof, wall, balcony, curtain wall, or sunshade wall, to become an integrated building. Several installation methods of BIPV are available in the market, covering the exterior of the building in horizontal or vertical shape. The systems are classified as energy-saving, low-cost installation, easy absorption of sunlight. Each house applies the PV as connected Series with the construction according to the sun's direction and the installation angles. The BIPV system

needs a control unit inside the house, combined in smart homes with HEMS (Liu, B, Duan, S, & Cai, T, 2010, 1419).

Nine architectural ways are the total Implementation ways of PV panels on the house structure. Tiles and shingles are pieces divided into the exact lengths fixed on top of each other to be a central part of the housing roof. A mounting system is simple parallel rails installed over the roof. The solar panels are located between the two rails line, which is easy to install and remove. The full roof solution system converts the roof of the main building to solar panels mixed with other materials. The solar panel roof performs the function of a regular roof and its aesthetic shape and ability to absorb energy. Glazed roofing works with the same previous system characteristics by adding a layer of glass, which gives more protection. Metal Sheet is a lightweight layer made of solar panel cells with metal, Installed on the roofs. Flexible light modules don't need a fixing system, only glued to the ceiling or wall. It is available in the market in the form of slices or rolls. Non-ventilated façade elements are classified as warm facades installed in the form of curtains on the walls. Rainscreen is classified as cold facades. There is an opening hole for ventilation between the original wall of the house and the Rainscreen cladding. BIPV accessories include shading, balcony, and balustrade. It is possible to be one of the previously installed types built-in or additionally, according to the design of the house see figure 4.9 (ICARES, 2018, 9-10).

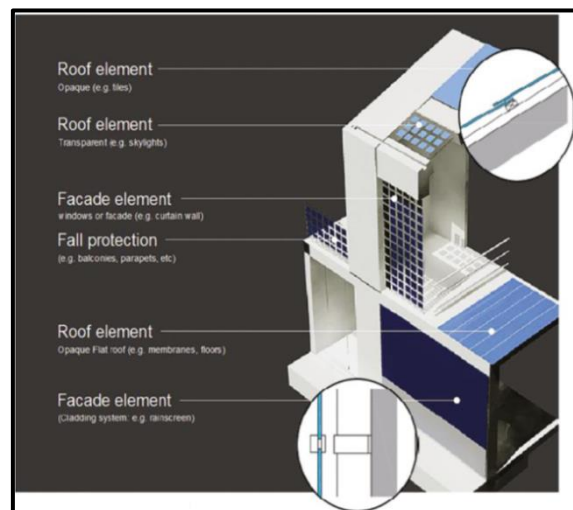


Figure 4.9: Installation PV on building (ICARES, 2018, 10)

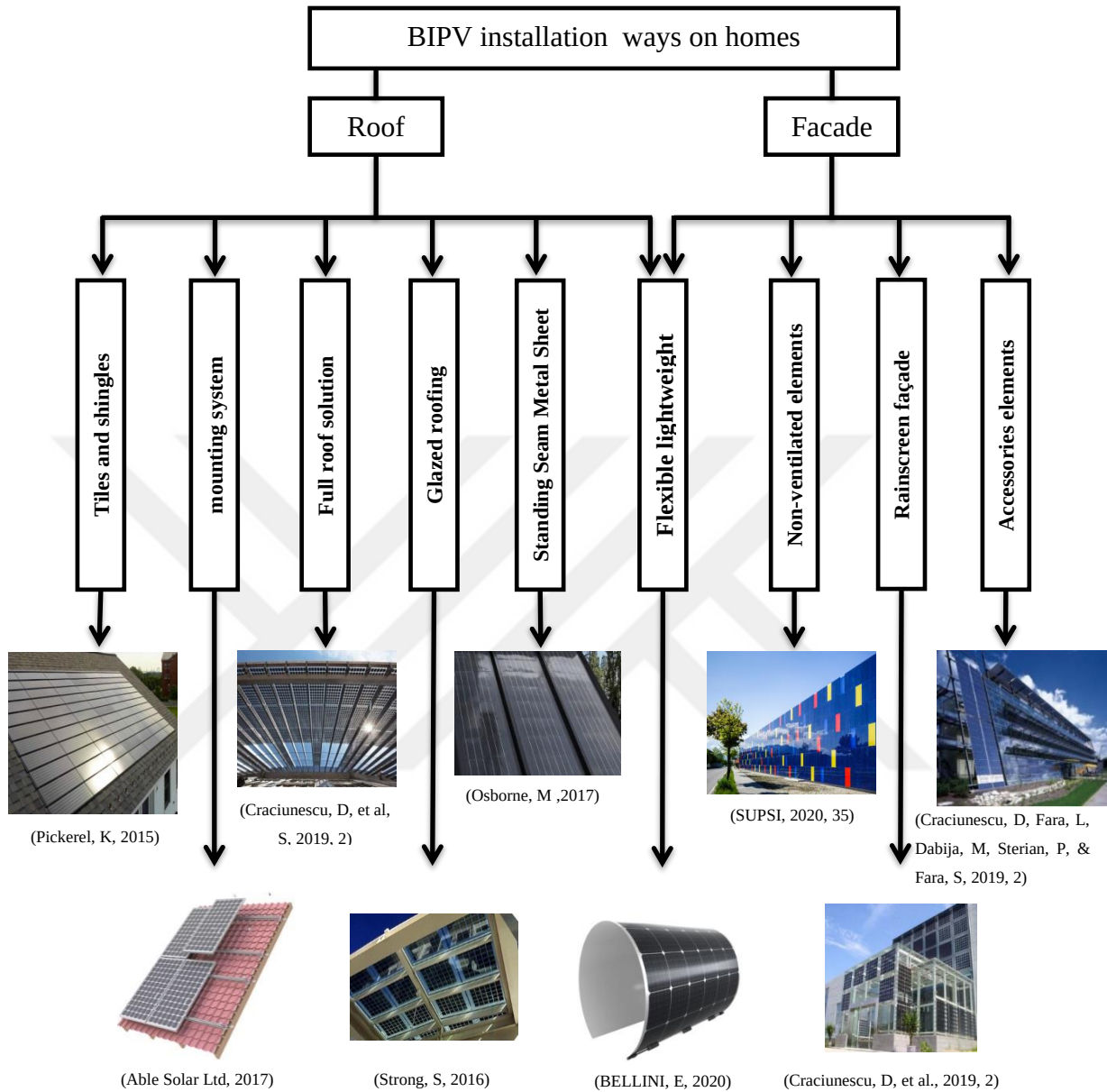


Figure 4.10: Diversity of Building Integrated Photovoltaics options.

Architectural aspects of installing BIPV, Before implementation, the integrated building considers all factors, such as plan and design. Architectural vision in solar panel installation is divided into BAPV and BIPV. The mix of solar panels with the building structure is classified as BIPV like Non-ventilated façade. Adding solar panels after completing the construction is classified as a BAPV-like mounting system. There are several options and ways to install PV should choose the suitable method matching each house. The proportions, colors, dimensional,

structure shape, and design concept must be observed by installing solar energy collectors (Wang, W, Liu, Y, Wu, X, Xu, Y, Yu, W, Zhao, C, & Zhong, Y, 2016, 99).

The BIPV system needs to decide at an early design stage. There are houses with curves that must using flexible and lightweight modules types. A different kind of house has transparent fixed slopes used glazed roofing. The BAPV system may be used consistently with the general form, so it's always considered an uncivilized style. In the case of smart cities using the cottage as structural, the mounting system is the best way to set up the solar panels. Installing the panels is essential to use a thoughtful approach and avoid randomness, see fig 4.11 and 4.12 (Wang, W et al., 2016, 99).



Figure 4.11: BIPV Pre-installation design (SRNE, 2021).

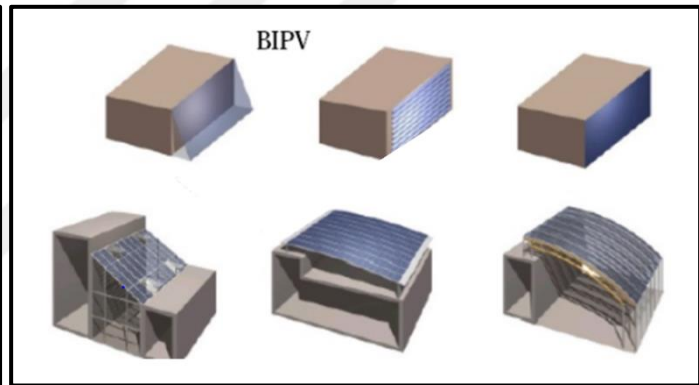


Figure 4.12: Installation after design (Wang, W et al, 2016, 99).

4.2.4. Element Analysis

Constructing a residential building in a future city needs to analyze the details and study the house's factors. Analyzing solar energy and choosing the type that matches housing quality is necessary to avoid future mistakes. Based on activities and working systems in homes, it requires the assistance of an energy expert to determine the kind of solar collectors and the operator system. Also, take consultation from urban planning and architecture to select the house's location and materials and choose the places of windows (Al-Hader, M et al., 2009, 94).

4.2.4.1. Analyzing solar energy performance intelligent

Every period created a new way to develop the implementation of concentrating PV in buildings. The compound PV with parabolic concentrator is a simple concentrator classified as unpretentious Primitive manufacturing compared to other types. The compound PV with parabolic concentrator is applied reflectors use from both sides that increase the ability of a concentrating system thus more productive. The high efficient concentrator is the three-dimensional type mean Sun tracking collector that collects energy incredibly due to angles that deal well with radiation. Fresnel lenses are used with a three-dimensional concentrator to concentrate the incident radiation in a specific zone that generates very high energy. The rising temperature of concentrator panels leads to negative performance in PV concentrators. After studying, moving the collector at a certain distance and healthy position achieved temperature improvements (Tzivanidis, C, & Bellos, E, 2019, 26-29)

Solar systems in smart homes are multiple, so they need strong operating starters to activate. Operator systems can adopt the integration of more than one system or regulate the consumption process with the help of tanks. Smart solar energy operating methods uses the previous types of solar collectors and adds a new system to increase performance and efficiency. The cogeneration method depends on integrating and programming the existing systems within the space of a specific plan. The hybrid approach can combine different types of solar power collectors with working with a high capacity (Meister, C, & Beausoleil-Morrison, I, 2017, 4-7).

a) Hybrid solar system

A hybrid system is a mixing PV with a CSP system, used to reduce the Levelized cost of energy. There is coordination in the use of systems according to the situation and the need of the place. The solar panels remain connected to power, in addition to the presence of a TES to store excess energy. When all the stock is consumed, the electrical grid is available to use. There are two processes under TES in the CSP hybrid system, (SM) the time that the solar field is spent at a specific time and (FLHS) the loading hours for the energy

cycle. Using the CSP system when the PV system is down or at night when the sun's power fades, in the usual case, the energy is picked from PV figure 4.13 shows (Li, F et al.,2020,20).

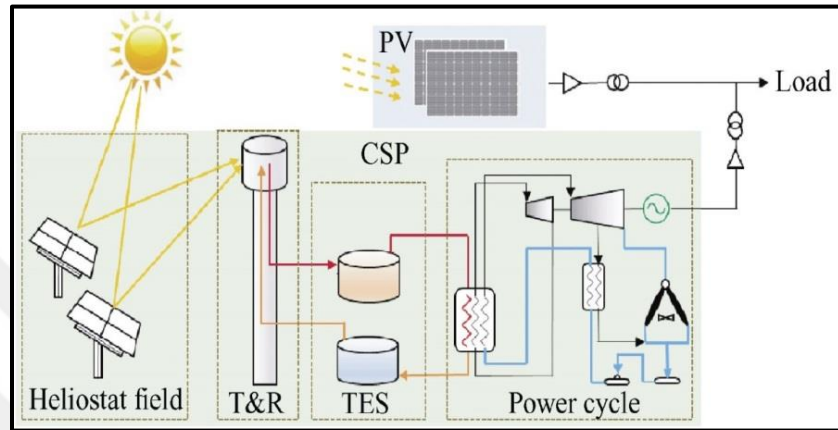


Figure 4.13: Hybrid system (Li, F, et al,2020 ,20).

b) Cogeneration technology system

Solar combi systems combine several techniques of solar energy systems, in some kinds adding a subsystem other than the sun. The solar combi system can work HVAC or heating water inside large buildings, similar to central systems. The solar collectors are tilted to specific degrees to absorb the sun's rays in the winter season. Some valves have a role in heating energy, and two types of storage are season and daily work through heat exchange anti-freeze. The thermal tank can be divided into more than one section based on the area and size of the building consuming solar energy see fig 4.14. This system often requires a pump to transfer air or water from the leading stores to the secondary stores. The sizes of tanks, pipes, inlets and outlets are depending on the production volume and consumption in space. A solar combi system must spray tanks with an insulating layer to protect them from destruction and corrosion and extend their life (Meister, C, & Beausoleil-Morrison, I, 2017, 4-7).

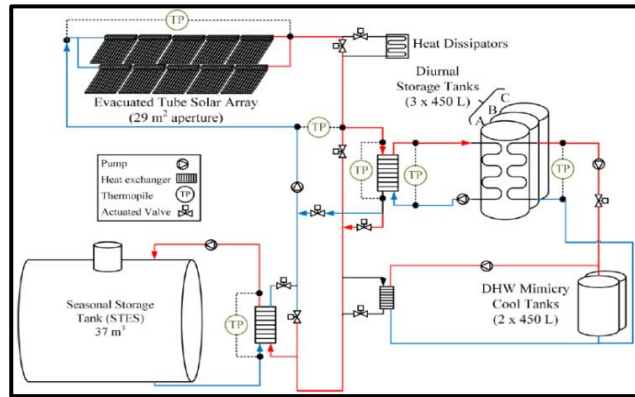


Figure 4.14: A simple schematic of cogeneration technology system (Meister, C, & Beausoleil-Morrison, I, 2017, 4).

4.2.4.2. Ability and efficiency

Several factors must consider connections between solar generators and the houses. For the intelligent performance of solar energy, the suitable position allowed absorbing a large amount of solar power. The job performance is changed return to the study of solar energy characteristics and its interaction with the location next to the forests, sea, or mountains. Also, the housing presence in the sun's brightness site for more than eight months increases the efficiency of the solar generators. Building restrictions and controls are essential observed according to the residential neighborhood, and It must be considered. A unified shape appears for all housing in some residential areas, so installing solar panels on the facade or solar collectors raised on the building is impossible. There is a basic need to match all home systems to be compatible with appropriate solar collectors to prevent problems after installation (Kodis, M, 2011,28).

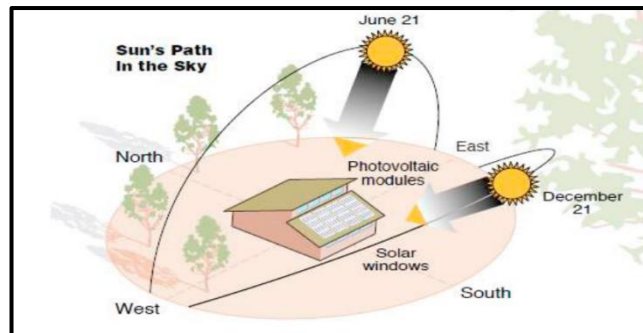


Figure 4.15: Housing interaction with solar power (Dixit, A, Kumar , S, Khanna, P, Pragya, 2020, 1754).

Advanced research and application of modern technologies inside buildings improve their performance by 90% over conventional structures. The presence of systems concerned with regulating ventilation, cooling, and heating, makes modern buildings 15 to 25 times more efficient than typical buildings (Santamouris, M, & Cartalis, C, 2017,139).

More than half of the energy for each region in the Gulf countries is spent on buildings, consuming between 60 to 70 %. The installation of solar systems on residential buildings is cost-effective as well. The cost is covered within eight years. After that, the system will continue giving for 17 years. The study shown on one of the buildings in the Kingdom of Saudi Arabia that used the BIPV system has proven the possibility to dispense with external energy by 60%, as it covers 40% of the building's needs. Using a BIPV system, such as ceilings, glass, and floors, gives a more aesthetic look. The BIPV cost is varied. If the system uses battery storage, the cost will rise. Unlike generating electricity without storage, the price goes down (Praveen, R et al., 2020, 4).

4.2.4.3. Materials and methods

Diversity of building designs where the well-being systems can be basics in construction or adding after finishing the structure. Each building has specific construction methods, but the basics remain the presence of windows and doors, which indirectly allow sunlight to enter spaces. If the structure is more complex, there are other ways to enter the sunlight and heat in the interior space. Smart cities seek freedom from CO₂ emission in every element within the city of harmful radiation, traffic congestion, construction materials, car pollution, wastes...etc. In smart cities, the materials chosen for construction undergo standards that help create a pollution-free environment (Ma, D, & Xue, Y, 2013, 10).

a) Solar gain methods for residential building

Solar energy technologies are applied in buildings, another concept to benefit from light and solar energy. The interior houses can gain the sun's energy in three main ways (direct gain, indirect gain, and isolated gain) shown in figure 4.16. There are two sections for photovoltaic cells in the building (Ma, D, & Xue, Y, 2013, 10).

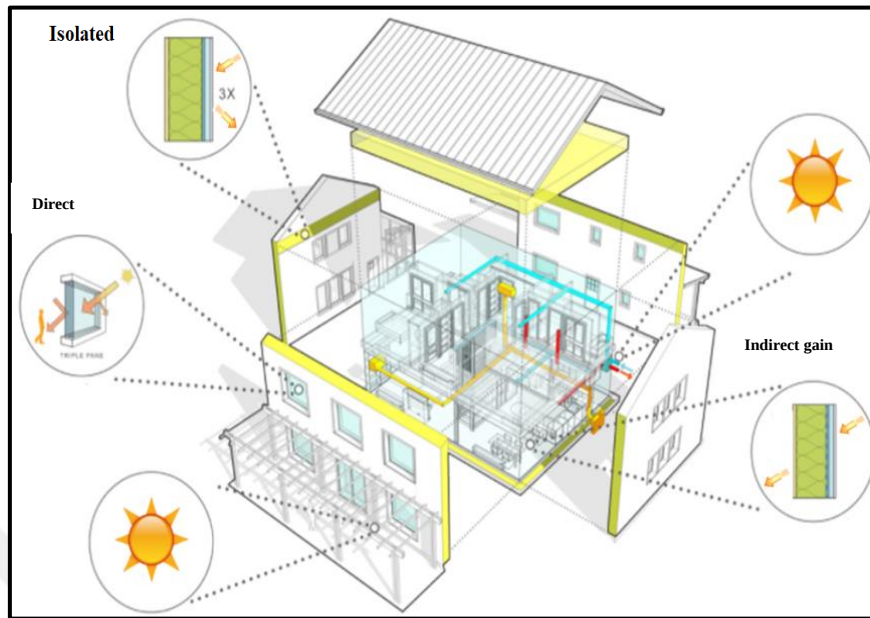


Figure 4.16: Way of Solar Gain in Housing (Pedranti, R, 2019).

In Direct gain, the solar gain is between 66% to 70% in the direct method. This system works inside open spaces that do not have barriers or walls. The sun's rays and heat enter the house through the glass, either the windows of the first openings or decorative glass. The sun drops the heat on the floor or interior walls of the house, and then these parts absorb heat in the morning and release it at night. Solar energy is used for heating and lighting (Chel, A, & Kaushik, G, 2018, 559).

The area benefits from solar by indirect gain method from 30% to 40%. Indirect gain is based on the intermediary system. After the sun rays fall on a specific surface, it keeps the heat then spreads it into interior space. The cover could be a thermal mass wall system, Water wall, Trombe wall, roof pond. This system works on lighting, heating, and cooling spaces, where the sun power absorbing surface has a movable heat insulator. In the winter season, heating is wanted, so the solar insulator moves away, and the construction surface absorbs the energy. The indirect solar gain system stores solar rays and uses them when needed. In the summer, there is no need for heat, so the system reverses the mechanism of action. The insulator covers the surface that catches the sun's heat, and the interior space remains cold (Chel, A, & Kaushik, G, 2018, 559-560).

The indirect solar gain to the building through a technique called trump wall. Trump wall is a wall made of the same materials used in the construction of the dwelling, which heats the air before entering the building. Trump wall contains a solar collector that stores thermal energy. It is painted in dark colors, and sometimes a glass cover is added to the front face. This system is dealt with by adding the insulation feature to prevent impact on the main building wall. The storage capacity of the wall is significant so that it can cover internal space with the necessary solar energy. The working mechanism's main elements are the weather conditions, including radiation intensity, clouds, and wind speed. The mechanism action in summer is best than in winter. The better performance is shown when the radiation increases, clouds and wind speed decrease (Al-Waeli, A, Al-Asadi, K, Fazleena, M, 2017, 68-69).

Isolated gain transfers heat through the solar collectors and is distributed inside different housing parts. The isolated gain system includes heating water, heating and cooling spaces, and intelligent network systems. The system works with the help of antifreeze, water, or air, through convection and forced convection. It gains energy inside spaces between 15 to 30% of the solar power, and it is the lowest system among the two previous methods. An isolated gain system is characterized by the ability to distribute heat according to the needs of the space. It does not depend on openings or windows like the first system or the insulator surface like the dual system, as it is designed within the construction walls of the house. The isolated gain system serves all spaces, whether on different floors or without windows, such as the storage rooms (Chel, A, & Kaushik, G, 2018, 561).

b) Construction Materials

The more the population and residential lands are expanding, the higher the carbon dioxide emissions. Paying attention to the selection of building substances and knowing the materials that support the environment is a significant part of future cities. The construction sector accounted for 39 % of the total energy-related carbon dioxide emissions worldwide in 2018. 28% of the total percentages are specialized in construction and consumer electricity, 11% in building materials, which is called construction industry include (cement, glass, brick, and

steel) shown in figure 4.16. Disregard implementation of solar energy buildings internal services become harmful to the environment. The years from 2010 to 2018 and increased carbon dioxide emissions in cooling, heating, and water heating services (IEA and UNEP, 2019, 13-16).

There are reflective materials that reduce heat in the buildings that can arrive in 15 Kelvin, such as infrared-reflective or Nano technological doped or white paint. The rate of heat drop is closely related to the lighter paint colors. A statistic about an increase in the percentage of whiteness in buildings by 0.1 leads to a decrease in building summer temperature to reach almost 0.9 Kelvin. The reduction in the demand for energy consumption runs from 20 to 40% and may arise by applying external materials that cool from the roof of the building or interior fabrics. Incredible ceilings in facilities are the least expensive techniques starting at 0.5 to 2.0 dollars per m² (Santamouris, M, & Cartalis, C, 2017•141).

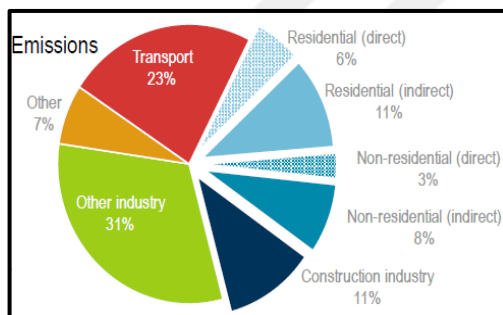


Figure 4.17: Global construction materials (IEA and UNEP, 2019, 12).

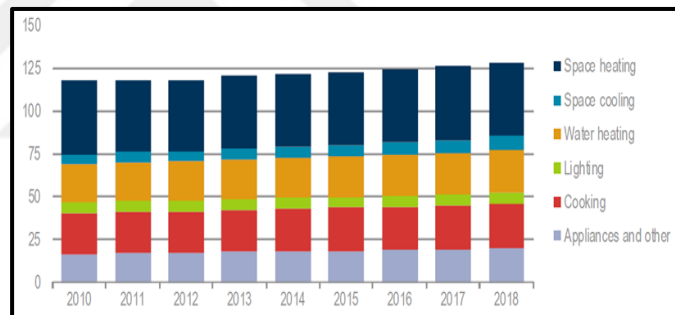


Figure 4.18: Increased CO2 emissions in the home(IEA and UNEP, 2019, 13).

The other side of building construction is the impact on the environment, as buildings withdraw 17% of the world's water level and 25% of the wood. Each material used in the construction has a percentage of carbon dioxide emission and embodied energy that creates item identity. In architecture, choosing suitable materials in the proper place is the basics of successful design. The rate of carbon dioxide emissions in the construction materials is considered while designing a new project. The table below shows the materials and the percentages of CO2 emissions (Shams, S, Mahmud, K, & Al-Amin, M, 2011, 366).

Table 4.2: Materials and CO2 emission (Shams, S , et al, 2011, 367).

construction material types	CO2 emission kilogram / kilogram	
	Aggregate	0.16
	Concrete	0.1311
	Brick	0.189
	Plywood	4.2
	Glass	0.748
	Aluminium	9.964
	Steel	2.95
	PVC	2.6904
	Plastics	2.2
	Timber	0.003
	Lime	1.352
	Cement	0.9698
	Gravel and sand	0.018
	Ceramics	0.349

4.3. SOLAR ENERGY CONSUMPTION MEASURING IN BUILDING

The consumption of buildings in smart European cities for economic activities was 283 billion EUR. After relying on energy, it became 166 billion EUR in 2011. Around the world, improving the performance of buildings using energy technologies requires 14 trillion dollars of investment in 2050. The benefit comes from energy savings reaching 58 trillion dollars in the same year, exceeding three times the investment amount. The statistics indicated that zero energy buildings by the year 2050 would have energy exports to 1.3 trillion dollars, every year will increase by 4.3%. Another statistic suggests that between 2014 and 2035, the construction sector will mainly increase investment until it reaches 2.33 trillion dollars. The construction sector in the future is considered as the highest tendency to increase financial profit and

market development (Santamouris, M, & Cartalis, C, 2017, 143-144).The person spends almost half of the day at home, so building technologies have become the basis for a stable life. Those with low and medium incomes are preferred to use the least expensive heating and cooling technologies that work on solar energy. At the same time, the solar power technique is highly efficient, reduces air pollution and harmful gas emissions. A project named (COOL_ME) implemented in the Middle East countries works to support the expansion of the sustainable cooling circuit, is being funded by the Climate Initiative in Germany (REN21, 2020, 193).

In the Gulf countries, recently continuously work to improve the population's living conditions, increasing the local electricity production. The electricity consumption rates in the year 2016 for the residential fields in the Gulf countries are shown in figure 4.17. Every year, the percentage change based on many factors such as financial status and projects in progress, etc. in 2018, Kuwait and Saudi Arabia's consumption rates of solar energy in the residential sector are more than 50%, and the rest of the Gulf countries are about 50%. Qatar is the country that oversees the rise of annual electricity consumption between 10% and 11% percent in the residential field. Because of the geographical location of the GCC countries, the need for air conditioning is the most significant percentage that consumes solar energy in homes (IRENA, 2019, 44-45).

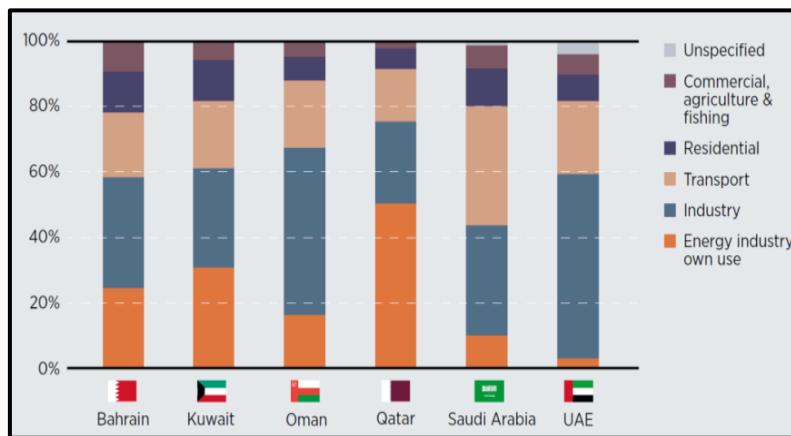


Figure 4.19: Electricity Consumption in the year 2016 (IRENA, 2019,118).

5. CASE STUDY ANALYZING

A case study of two projects in one city looking forward to improving the conventional residential environment for an intelligent housing environment that works with solar energy. There are different ideas for two massive projects in Abu Dhabi, Masdar City and the Al Falah community. Masdar City is proved a very successful example of the application of solar energy in the Gulf on all levels. It has shown a vibrant, sustainable, future city with intelligent planning and superior buildability. Masdar City has a history full of awards and honors, the most important of which is the award for the best sustainable city in 2007, the energy company of the Year in 2012, and the World clean energy award in 2007 (Nambiar, S, 2011). Al Falah community is developed traditional residential complexes not rely heavily on solar power.

5.1. MASDAR CITY IN ABU DHABI, UAE

Masdar City is an example in the United Arab Emirates of a competent, sustainable, zero-carbon city. Abu Dhabi Energy Company has signed contracts with Foster and Partners to create a masdar city with high standards and not harmful to the environment. This city aims to prove the ability of intelligent cities in implementing effective solutions. It relies on 100% renewable energy. Energy efficiency, transportation, and waste reduction are aims achieved by Masdar city in high competence. The smart city consists of residential homes, green spaces, restaurants, and work areas. It is estimated that the population of Masdar City, upon completion of all stages of development, will reach 90,000 people shown in figure 5.1 (Nambiar, S, 2011). The city of Masdar is interested in recycling and sustainability, as it is attached to many fields. Depending on energy-saving, Masdar City undergoes sewage treatment then reused such as irrigation (Palmer, R, 2011, 2). Masdar City applies modern concepts of energy and creates unique technologies. The project aims to create three concepts within the city: consistency, vision, and stability (Griffiths, S, & Sovacool, B, 2020, 5).



Figure 5.1: Plan for Masdar City (Daley, C, 2017)

5.1.1. Project Data Analyzing

Masdar City is divided into two parts of unequal size, separated by the main street, completed the first section in 2008 at the cost of approximately 1.4 USD. The second part is under construction and will likely be completed in 2025. Both pieces are related to the exact nature and facilities. On the other hand, according to the location, the type of building, the number of blocks, and the size of the structure are different. The completed part of the construction phase contains six extensive facilities, a library, and an institute. As for the next part, it is still under development, but so far, it includes a lot of residential apartments, restaurants, and shops. The multi sectors have been merged under one system that creates an integrated ecosystem that reduces the need to go outside the city (Afkhamiaghda, M. 2015, 11).

There is a line connecting Masdar City with the airport via a train and it on the way passes through a group of other cities. The city is interested in the infrastructure, where navigate through the underground and upper streets only for pedestrians. There are energy driverless

cars in the upper streets inside Masdar city, transporting visitors and residents to the facilities. Low carbon electric cars and buses are used to serve students and faculty from inside the institute.

Residential buildings occupied around 62%, which is the most significant percentage of construction in Masdar City. All community facilities, offices, and retail shops are taken 20 % of the project, followed by research and development places at 7%. Hotels and services located in the middle of the project occupied 4% and light Industrials 3% of the whole project, shown in figure 5.2. The research centers within the city include a center for solar energy PV and another one for CPV and Institute solar platform. The research center is interested in applying HEMS systems inside a group of residential buildings and finding special centers to store electrical energy coming from the sun (Griffiths, S, & Sovacool, B, 2020, 4).

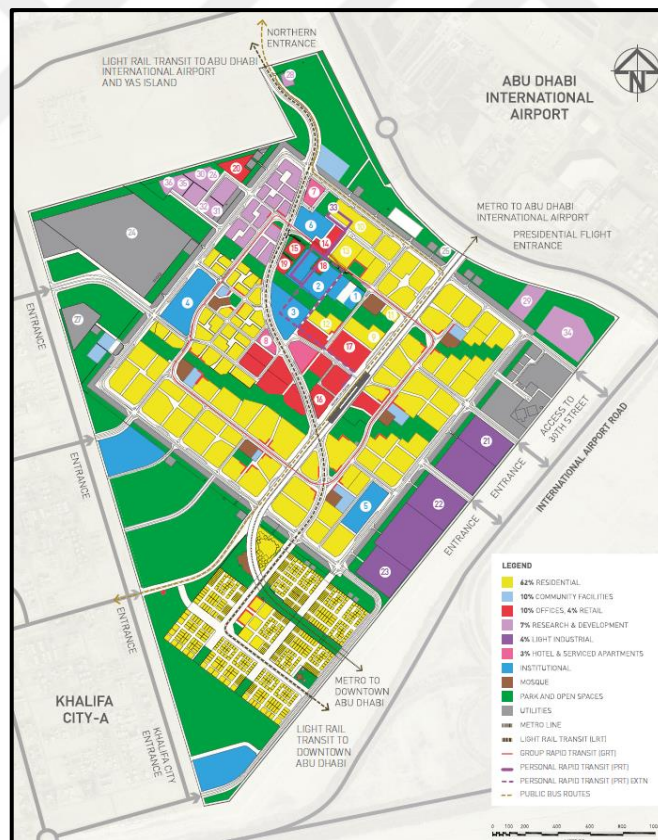


Figure 5.2 Divisions in Scheme for Masdar City (Griffiths, S, & Sovacool, B, 2020, 4)

5.1.2. Solar Energy Levels

Masdar City was designed as the first zero-waste and carbon-free smart city. It relies mainly on solar energy to generate electricity, around 93%. Masdar City used monocrystalline silicon, thin-film, and polycrystalline silicon panels to meet the project's needs (Masdar (PV), 2021). The city's planning and implementation strategies made the PV panels occupy a very high percentage. Masdar City includes the most important solar energy institute, which focuses on research, postgraduate studies, and specialized courses in the solar field (Palmer, R, 2011, 2).

Masdar city used CSP for generating energy for large projects or running places inside the city. The solar powers are divided as follows, the PV occupied 53%, and the CSP 26% see fig 5.3. Masdar City maintains the presence of thermal energy 24 hours a day in high capacity by using TES. The city is also working on developing solar energy technologies inside it. A tower with a Heliostat group works to store heat with molten salt for producing steam. It takes the benefit of steam to operate the turbines, thus working in more than one form simultaneously with reception and storage heat heater (Masdar CSP, 2021).

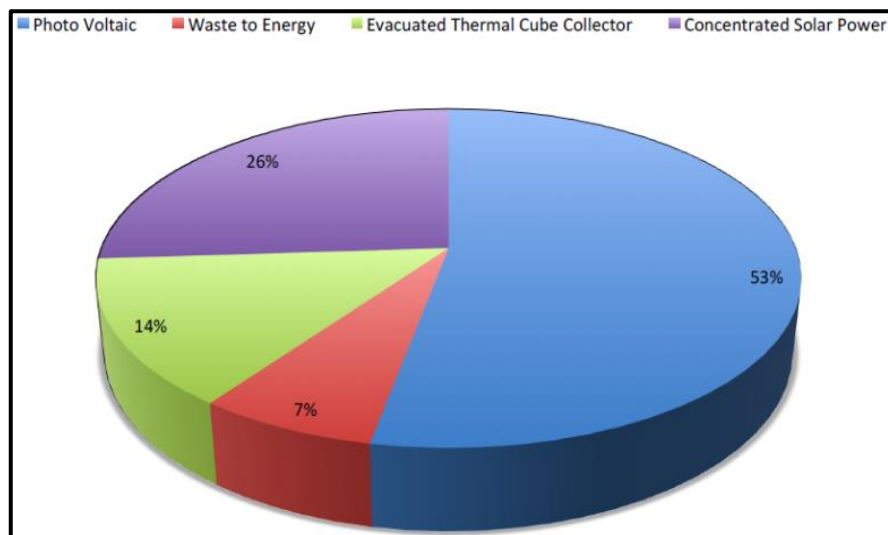


Figure 5.3 : Solar energy in Masdar city (Afkhamiaghda, M, 2015, 9)

Edison company is responsible for regulating and supplying solar energy inside the masdar city, either Photovoltaic system or solar collectors. Solar systems photovoltaics in buildings provide 1800 MW per hour, and solar collectors for hot water are reduced 75% of home demands. Residential buildings are used natural systems to benefit from sunlight and reduce the load on solar energy systems. Because Masdar City is located within the Abu Dhabi, the sun's rays are powerful at noon. The designer added atria in housing to benefit significantly from sunlight and reduce the heat entering the building. The buildings use the indirect sun gain method, where the walls retain and store heat to equalize the temperature of the interior spaces (Nambiar, S, 2011).

Masdar City sets a per capita consumption of fewer than 30-kilowatt hours per day. It also uses more than one type of solar panel, Monocrystalline silicon panels, Polycrystalline silicon panels, and Thin-film panels. Masdar City doesn't depend on one manufacturing company but more than one global company such as Suntech Canadian Solar and First Solar. According to the statistics, the more consumed panels are from polycrystalline silicon panels and Thin-film panels as 5MW for each (Sankaran, V, & Chopra, A, 2020, 3). Masdar City is one of the best cities for manufacturing solar panels, as it has a robot for manufacturing and cleaning panels. Inside the smart city, there are stations to produce and supply solar energy panels to some countries, such as Egypt and Mauritania (Masdar (PV), 2021).

a) Siwa Solar PV plant

One of the projects financed by Masdar City in terms of solar panels is Siwa city in Egypt. This project is related to a town and 264 villages adjacent to Siwa city. Abu Dhabi city assigned Masdar smart city to represent it and support one of the vast projects that bear the name of the United Arab Emirates. The year 2014 was the beginning of cooperation and the signing of contracts between the two parties, the Masdar City team and (NREA) in Egypt. The area in the Siwa project expands 10 megawatts (PV) panels, representing 30% of the electricity network capacity in the city. In 2015 the project began working annual production of renewable solar energy is about 17,551 megawatts per hour, where is there 74,640 solar

panels from thin-film kind. More than 6000 homes in the city and neighboring cities benefited from the implementation of the project, in addition to reducing the amount of carbon dioxide in the air annually by 14,000 tons (Masdar- Siwa, 2022).

b) Power Plant in Mauritania

There is a large project on solar energy in Mauritania, specifically in the capital Nouakchott that achieved a lot of success in 2013 as 15 megawatts. The project is called the Sheikh Zayed solar power plant, one of Africa's massive alternative energy projects. In 2016, it reached an agreement between the government of Abu Dhabi and the government of Mauritania to expand the project and supply energy to eight different regions. Masdar City added 16.6 megawatts, equivalent to more than the previously produced quantity. Masdar city targeted remote areas that needed power, as the project covered 30% of the electricity networks in Mauritania. Thirty-nine thousand houses benefit from the Sheikh Zayed project, thus saving vast amounts of harmful diesel, amounting to 10 million liters every year (Masdar- Mauritania, 2022).

c) MBR Solar Park

Masdar City supports projects based on solar energy, as it has laboratories and institutes focused on this field. Mohammed bin Rashid Solar Park, located in Dubai, consists of several phases. Masdar City contributed to operating the third phase. The establishment of the third stage was in 2017. The mechanism of work provides for dividing the scene into several parts. In 2018, it started operating 200 megawatts, and in 2019 increased to reach 500 megawatts out of 800. In 2020, the third phase was completed with all divisions and started working at total capacity. Project (MBR) Solar Park is rated as the largest project in the Middle East, working on a plant that follows the sun's path (Sun tracking concentrating). The third stage, in specific, provided 240,000 houses with solar energy, thus reducing pollution and adverse effects on the climate such as CO₂ and acid rain (Masdar- MBR, 2022).

5.1.3. Buildings Characteristics And Details

Masdar City differed in building designs as it combined development and civilized form with high functionality. Each building has different characteristics and interactive methods with solar energy, but the comfort and abundance of services are common. The library's design on 180 meters in circular execution with observe solar energy conditions shows modernity and development. The presence of housing with precise Islamic carving has successfully explained the Islamic identity. The strength of structure design for protecting other facilities is a strong idea and functional in Masdar City.

5.1.3.1. Types of construction

The headquarters of the Masdar City Company is located at a vast structure that supports renewable energy. Masdar City is an integrated city that gives residents all requirements without exiting. Masdar City has presented a clear picture of the integrated project, including residences, shops, workplaces, mosques, restaurants, institutes, etc. The Housing design is classified as residential apartments within high standards and advanced technologies.

a) Residential Sector

The diversity of residential projects within Masdar City has apartments and residential units for students and faculty. A project called Chic is located on 33,000 sq meters consisting of high luxury apartments. The apartments are characterized by easy access to the surrounding services from the spa, sports centers, swimming pool, and shops. Tristar is the buildings that follow after Chic space 26,900 sq. meters. This project is located in a lively area between schools, restaurants, and community facilities. Leonardo buildings are the third residences project in Masdar city contains 170 units. Oasis complex is located in the middle of the city overlooking Masdar Garden and includes 612 units. Etihad Eco Residence buildings are classified in the second phase of constructing masdar city. These dwellings have LEED and sustainability certificates. It contains more than 800 residential units of different classifications on a land area of approximately 100,000 sq m (Masdar City, 2018).

Masdar City has designed a unique facade design scheme for the residential aspect. The exterior shape of the building was not just a design idea but an application of physical and mathematical calculations programs. The dwellings got a different character from the rest of the buildings, distinguished by wave shape and motifs to protect the interior space from dust and bright sunlight. The design consists of three layers: the balcony or exterior design, the main wall, and an insulating layer. The residences in Masdar City revived the Islamic culture through decorations and designing something similar to Mashrabiyas. The thickness of the design ranges is between 25 to 30 millimeters. The design of the facades includes the civilization and nature of the Abu Dhabi city, the curves and gradation of waves respect the residents' privacy, shown in figure 5.4 (Palmer, R, 2011, 3).



Figure 5.4: Masdar City Islamic housing design (Palmer, R, 2011, 13).

The Masdar city relied on wavy-wall design buildings overlooking the pedestrian streets. This wave starts from the first floor to the end of the building. The idea of the design is to create a shade on the ground that helps people reduce the sun's rays at walking in the noon see fig 5.5 and 5.6. There is a unique study for installing solar panels on the roof of buildings. According to accurate calculations, the solar panels are arranged sequentially and at a certain angle. In addition to the primary function of absorbing sunlight, it works to create shadows on the earth's surface (Hassan, A, M., Lee, H, & Yoo, U, 2016, 54).

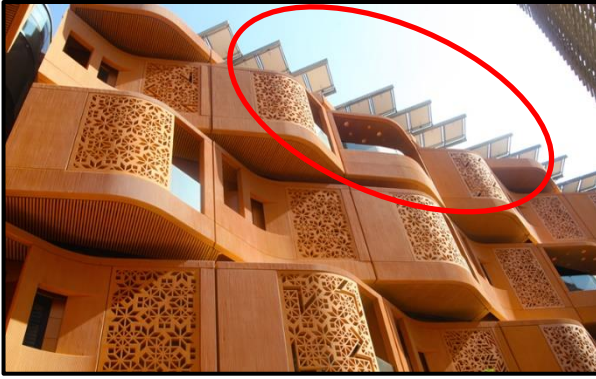


Figure 5.5: Solar panels installed (Digital, T, 2021)



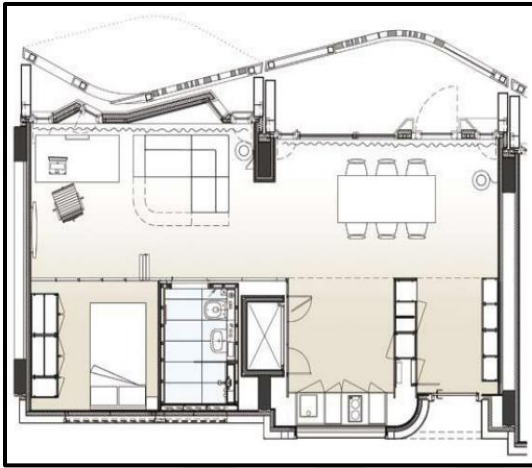
Figure 5.6 : Wave facade design (Digital, T, 2021)

There are two types of buildings with an Islamic design and modern design. Islamic design is the distinctive character within Masdar City contrary to contemporary design, familiar in many intelligent cities see fig 5.7. According to the location and size of the house, the interior space varies from one home to another. Masdar City relied on the system of multiple houses within one building (apartment), as it varies between a studio of one room, two rooms, or three rooms. Each dwelling has a private balcony, which views the project (Arabian Sunrise Properties, 2019). The interior space of the apartments is medium in size, fully insulated, capable of heating and cooling quickly, and of low consumption (Palmer, R, 2011, 3).



Figure 5.7: Masdar City contemporary housing design (Arabian Sunrise Properties, 2019)

The houses inside the traditional-style buildings have uneven balconies because of the specific design. The houses in Masdar City follow the system of clear external terraces, which in some homes equals living space. The interior space doesn't focus on walls or partitions but rather on the open space. The kitchen is combined with the dining room and the sitting area with no barriers, and the bedrooms contain sliding doors see figs 5.8.



Floor plan for Studio (Ibrahim, I, 2016, 53)



Floor plan for two bedroom (Arabian Sunrise Properties, 2019).



Floor plan for two bedroom (Arabian Sunrise Properties, 2019).



Floor plan single bedroom (Arabian Sunrise Properties, 2019).

Figure 5.8: Interior design in Masdar City housing

b) Institute's library

The institute's library was designed very professionally covered with zinc material in the shape of a hedgehog. In addition to characteristic shape, it works highly effectively with solar power. The PV panels are fixed on the roof harmonious with the building shape. The cover design does not surround the building from all sides, the front facade allowing sunlight to enter the interior, shown in fig 5.9. (Nambiar, S, 2011). The structures of Masdar City have achieved the production of a large amount of energy, zero carbon emissions, using recycled materials, and access to a minimum level of waste (Elgendy, K, 2010).



Figure 5.9: Institute's library in Masdar City (Nambiar,S,2011).

c) Headquarters

The office buildings are designed in a new way and utilize the space to serve people. The building uses aluminum in addition to heat-insulating materials. The design occupies a large area divided between facilities and services. The sites contain areas for pedestrians and workers. It unifies the environment through sales places, reception offices, and others. A unique design covers most of the spaces in Masdar City, consisting of two different materials layers, a cement wall and an aluminum wall, shown in fig 5.10. The external office design is a group of funnels that partially block the sun's rays to the building and provide ventilation. The

office area used flexible flooring materials, increasing efficiency by about 90 % compared to other floors and being tolerant of the sun's heat. Sustainability is one of the important rules in Masdar City, where the percentage of sustainability materials used in offices was about 60 percent (ArchDaily, office buildings, 2014).



Figure 5.10: Masdar City headquarters design (Elgendy, K, 2010)

The project used high-tech insulating materials in line with the main idea of a carbon-neutral city. The scientific research centers in the institute designed walls made of ethylene tetrafluoroethylene kind of treated plastic that prevent emissions from reaching outside air. It also used high sensor systems inside buildings and laboratories to alert when air ratios are disturbed. Masdar City is interested in adjusting the energy-powered sensor systems and determining the percentages of temperature, carbon dioxide, particles in the air, in addition to the advanced techniques inside the homes (Nambiar, S, 2011).

5.1.3.2. Construction materials and proportions

The material used in the Structural system is based on reinforced Concrete and low carbon concrete (PFA and GGBS). For the cladding step after concrete, the designers used different

materials depending on the building type shown in table 5.1 (Nambiar, S, 2011). Construction of residential buildings is consists of aluminum panels interspersed with windows made of glass and surrounded by wooden frames. The percentage of glass is an average of housing 35%. There are designs for some dwellings on the lower floors that contain 25% and on upper floors 25%. In residential buildings, selected high quality and recycled aluminum allowed thermal conductivity. Accurately choosing building materials helps homes to heat and cool faster. One of the most important materials used for residential homes is insulation materials that prevent heat from leaking and preventing harmful radiation (Palmer, R, 2011, 3).

Table 5.1: Masdar city - buildings materials (Nambiar, S, 2011).

Masdar City Buildings	Building types	Materials Name
	Residential	GRC Cladding Contractor - Glazing+ Timber framed+ Recycled Aluminium
	Laboratories	Cladding+ ETFE
	Screens	Timber Palmwood
	Center Roof	Zinc + Glulam

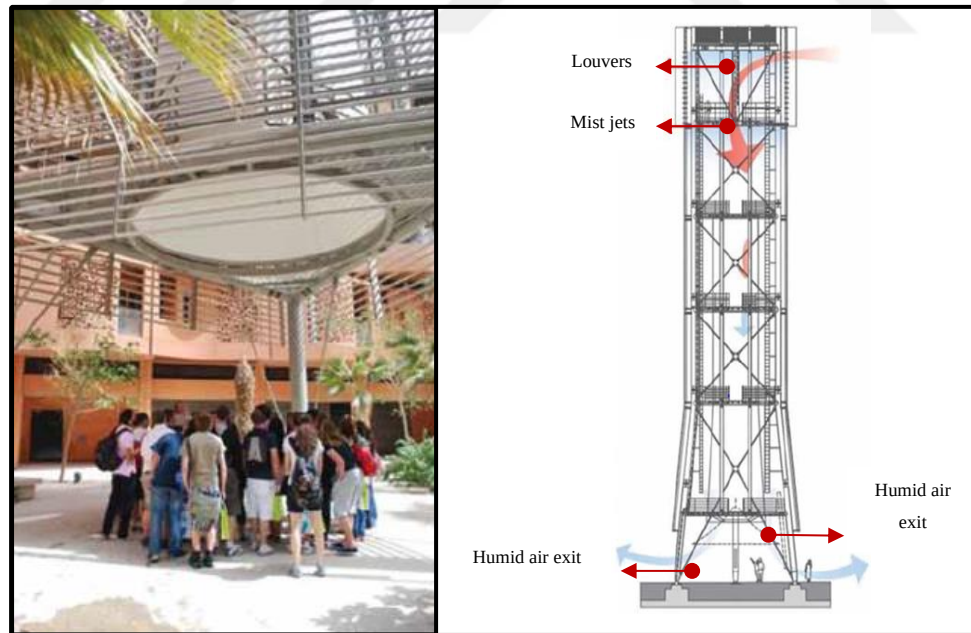
There are buildings, whether offices or homes in Masdar City, designed in a highly insulated way to reduce thermal conductivity. The offices used aluminum material for construction covering to minimize solar energy absorption into the interior (ArchDaily, office buildings, 2014).

Residential buildings use concrete and glass materials in the exterior, considering the carbon emission rates. There are towers distributed in the city made of steel material concerned with a specific dynamic to equation temperature. Each smart city has surrounding conditions, enabling it to create things that make it compatible with the nature of life. There is a type of cement called Portland used for the construction industry, and it may replace conventional

cement by 80%. This type was recently discovered and worked to reduce carbon and heat. Reducing the building surface absorption of heat keeps the interior cool for a longer time. Also, using HEMS based on solar systems and wind power helped reduce water consumption by 54% (Nambiar, S, 2011).

5.1.4. Interaction With High Temperatures

The city of Masdar reacted with the high temperature of the climate by having technologies that help to occurrence airflow in the place. Wind tower and shadows by solar panels are two methods used by Masdar City to use renewable energy and deal with high temperatures (Palmer, R, 2011, 2). In the middle of the project, a wind tower around 150 feet long is considered a landmark and deal with the weather. The wind tower enhances the current and increases the wind productivity in place. The tower was designed vastly, higher than surrounding buildings, works in a convective way see fig 5.11.



Moist Air Exit Place

Wind Tower elements

Figure 5.11: Wind Tower Components (Hassan, A, et al, 2016, 45)

The wind column works by entering air from the top of the column through Louvers. The passage of air in the first stage is like a scan knowing the direction and strength of the wind. The air passes in mist jets to increase the air current and the thrust force towards the bottom of the wind tower. Mist jets are sensors that recognize how to deal with wind and turn the air from dry to moist. The air gate is upper side and exits from the lower side, passing by 150 meters, thus facilitating the cooling process. The directional speed and the mechanisms used to produce a larger air current (Hassan, A et al., 2016, 45).

The wind tower was given an efficient solution to improve the temperature and walk in the hot summer climates. Moreover, Masdar City was built at a height higher than the ground surface by about 23 feet. The use of zero carbon emissions technologies improves the heat and increases the airflow for the project. (Afkhamiaghda, M, 2015, 12) The wind tower has variable lighting according to the population's consumption inside Masdar. The sensor system works to determine the percentage of consumption throughout the day. The blue light indicates the normal consumption rate by population. The red light signals to be careful because the consumption has exceeded the normal limit shown in figure 5.12 (D'Eramo, A, 2021, 10).



Figure 5.12: Wind Tower lighting (D'Eramo, A, 2021, 10)

5.2. AL FALAH COMPLEX HOUSING IN ABU DHABI, UAE

Al Falah complex is located in the center of Abu Dhabi city, close to the airport, and contains around 5000 houses. The complex is designed to illustrate the concept of housing within a realistic and relatively sustainable environment. The city consists of six adjacent parts, all regions for housing and one for services. The parts gather at the middle point, the active center town in the southwest of the city shown in fig 5.13. The project includes hospitals, homes, hotels, malls, retail shops, mosques, and schools (Hira Industries, 2017). The most important goal of the Al-Falah project is to reach homes with high quality, sustainable, and acceptable prices (Eyre, J, Hart, R, Connolly, G, 2013, 3).



Figure 5.13: Plan for Al Falah Complex Housing (Almemari, I, Alhammadi, A, Alsalami, E, Hassan ,O, 2014)

5.2.1. Complex Housing Analyzing

Al Falah dwellings are classified as one of the best housings that rely on sustainable technologies and overcome the challenges facing most complex housing. In cooperation with the Abu Dhabi (UPC), the Abu Dhabi government is responsible for designing Al Falah City

and providing housing to satisfy citizens. This project is high-standard and relatively low-cost shown in figure 5.14. The project has adopted the repetition for one type of housing, single residential unit (villas) different in exterior design, size, and area. There are large and deep plots of land under the superstructure of Al Falah City. The presence of deep sewage nets is one of the project's priorities to ensure comfortable housing and the exploitation of large areas (Eyre, J et al., 2013, 2-4).

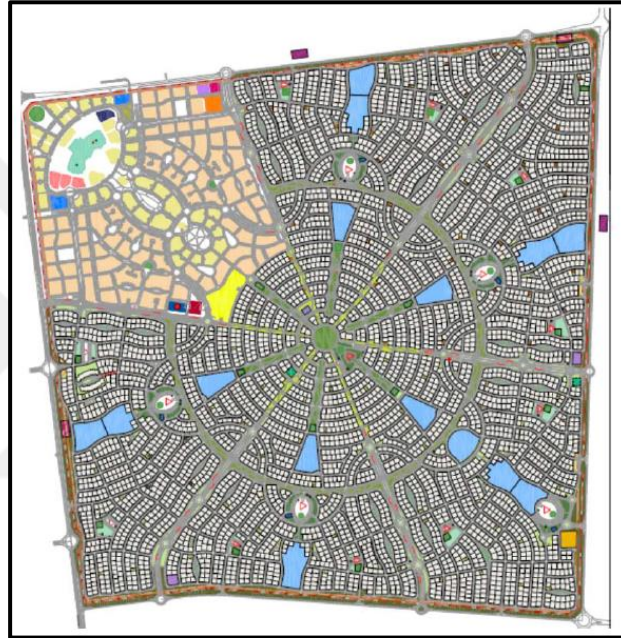


Figure 5.14: Al Falah Complex Housing Scheme (Abuimara, T, & Tabet Aoul, K , 2013,4).

5.2.2. Energy Consumption

Al Falah project has a massive size and a lot of housing. The five-room villas represent 50% of the homes in the Al Falah project, so the properties of this type of house will be detailed. Accordingly, the properties of the other villas are estimated. Because the project is located in the UAE, the annual percentage of Electrical consumption and air conditioning is high. The rate of glazing is 65.45% on the outer surface villa's facade. Thus, the energy consumption calculation is based on a location, either north, south, east, or west, shown in table 5.2 (Abuimara, T, & Tabet Aoul, K, 2013, 6-7).

Table 5.2: Annual percentage of consumption in Al Falah Complex Housing (Abuimara, T, & Tabet Aoul, K, 2013, 6-7)

Direction	Home location	Electrical Energy	Cooling Loads
	North	46,087.18	29,455.98
	South	46,048.50	29,434.24
	East	43,200.68	27,163.91
	West	47,393.95	30,400.48

The components of Al Falah housing consume an amount of energy, including the ceiling, floor, walls, and doors. The roof consumes 0.31 W of power, doors are 2.19, the outer wall is 0.54, the floor is 0.78, and the windows are 1.67. In the UAE, the north side is classified as the lowest in energy consumption, depending on sunset and sunrise. Al Falah project is large includes four sides. Based on housing direction, the saving energy is arriving at 5.2% (Bande, L, Young, K, Adan, R, Khoukhi, M, Aldarmaki, A, Aldhaferi, A, & Alneyadi, A, 2019, 4-5).

5.2.3. Residence Sector In Al Falah Complex Housing

Al Falah complex is based on separate housing units of various designs. There are nine different designs in shape, distribution, and space. Residential units are between three to five rooms with suitable building materials and HVAC systems. One-story houses include three rooms, and two-story homes have four or five rooms. The design of the villas varies between three types, the modern form, the Emirati heritage form, and the Andalusian form shown in fig 5.15. The number of houses is different from one section to another within the project. The first village has 1036 dwellings, and the second village includes 1012. The third village has 1010, and the fourth village content is 730. The last village consists of 1,044 residences

(Abuimara, T, & Tabet Aoul, K, 2013, 4-5). front of the houses, natural landscapes surround each house, protected by a fence that provides complete privacy for the residents (Eyre, J et al., 2013, 5).



Figure 5.15: Al Falah Dwelling Types (Abuimara, T, & Tabet Aoul, K , 2013,5).

Al- Falah Complex used concrete structures in houses to speed up the delivery process. The project is interested in delivery quickly, and it depends heavily on pre-made items precast, figure 5.16 shows. Al-Falah city used seven factories for getting pre-prepared items to reach an integrated project in a short time. Al- Falah Complex Housing is characterized by selecting high-quality materials, finishes, casting molds, and mechanical floats. There is a merging

partition wall with conventional blocks to become mess-free of misalignments. 200 mm is the insulation used in Al- Falah housing walls, and the value of thermal conductivity used for the walls is between 1.4 to 1.85 W/m.K (Eyre, J et al., 2013, 2-6). The most critical materials used in construction are regular concrete, insulated concrete panels glazing, concrete slab, glazing-ceramic, and clay (Abuimara, T, & Tabet Aoul, K, 2013, 5).

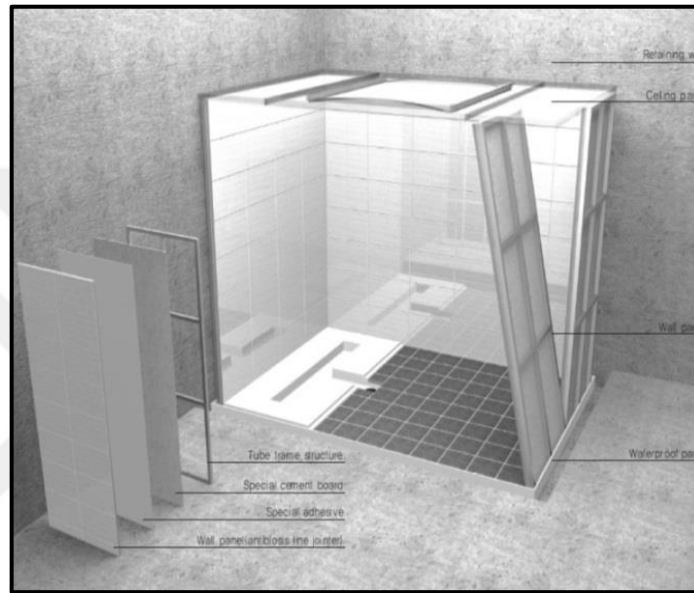


Figure 5.16: Pre-made items in Al Falah Complex housing (Eyre, J, et al, 2013, 5).

a) Buildings Systems Interactive

The design of the residential buildings in the Falah complex is a combination of aesthetic form and high resistance. A building structure focused on bearing heavy loads with supporting well-executed foundations. Some items are dealt with in a building structure to resist wind currents and earthquakes. The working mechanism is the presence of hollow panels that have conduction properties. The panels transfer the weights on the ground to the external walls, and thus the load becomes above building columns figure 5.17 shows (Eyre, J et al., 2013, 3).

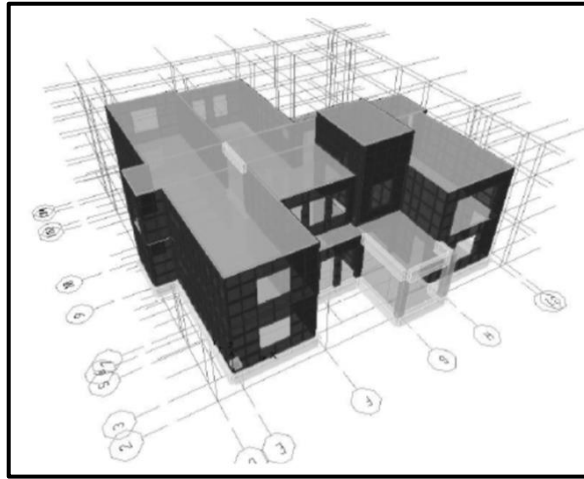


Figure 5.17: Structural System of Al Falah Housing (Eyre, J, et al, 2013, 3).

b) Housing details

Housing interior, the division of the plan in the Al- Falah project, distinguishes the Emirati identity and the general character of the country. The houses depend on the multiple divisions and determine the function of each area. The plan is divided separately and completes privacy by interior walls. Men's corridors and unique sitting places are wholly separated from women's sitting places. There is also a family gathering room, dining room, kitchen, and room for guests on the ground floor. The ground floor is classified as the service and reception floor in the homes. The first floor is unique for family members contain bedrooms, a gathering, a living area, and internal bathrooms for each room (Bande, L et al., 2019, 3).



Figure 5.18: Al- Falah Complex Housing Plan (Bande, L, et al., 2019, 3).

6. COMPARISON AND A NEW APPROACH BETWEEN MASDAR AND AL FALAH CITY

Gulf cities, in general, continue to use solar energy instead of other renewable energies. It is well known that solar panels are located on the roofs of buildings more than in other places (facades, floor, and wall). Since the sun is the energy source located at the top, the power is distributed equally over the collectors. The location of the Gulf countries and their interaction with solar energy result in advanced and successful projects such as Masdar City and Al-Falah Complex Housing. Using other renewable energies in Gulf countries has different factors that prevent them from continuing effectively. Wind energy is the second renewable energy used in the Gulf countries after solar energy. Regardless of the high cost and the large size, the different heights of the buildings block the airflow, which is the main factor for the operations shown in fig 6.1. In addition to the weak air current in the Gulf countries unquestionably, it can apply this type of energy in parallel with complex factors. It needs space devoid of big mass or buildings to check specific height and is explicitly designed for wind energy.

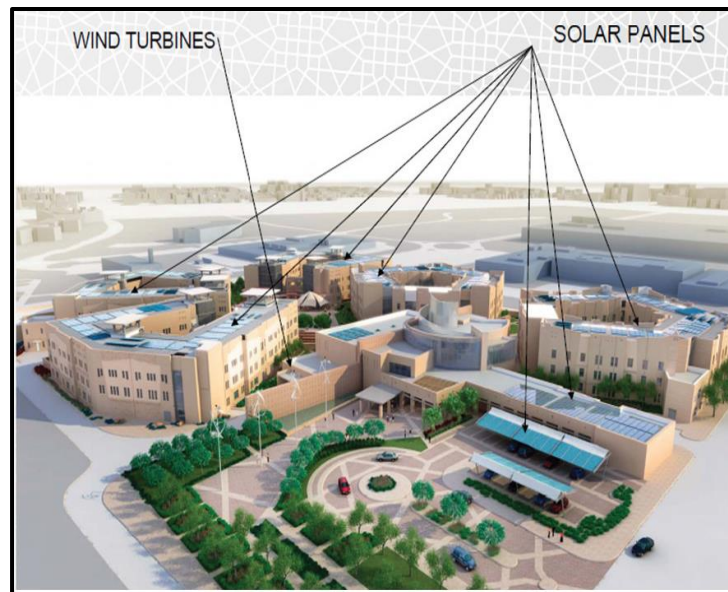


Figure 6.1: The renewable energy suitable for the Gulf countries (Moghbelli, H, Silva, C, Sabih, S, Ali, F, Mueller, M, 2009, 6)

Fuel cells are not used in the Gulf countries due to the inability to store energy and contain low emissions compared to solar power with zero emissions. Bioenergy is rarely used as it is linked to elements that are difficult to achieve balance when produced in the Gulf countries. The ability to make bio-energy requires healthy soil, moderate climates, and plenty of water. Geothermal energy is present in the world without human intervention, and presence is very few in hot weather. It is either in the ground, the mountains, or volcanic areas, and all these places are not available in the Gulf countries.

6.1. RESIDENTIAL ENVIRONMENT DIFFERENTIATIONS

The concept of Masdar City differs from the Falah Complex, which is an embodiment of the idea of the smart city and the use of solar energy systems. Comparing two different case studies of complex housing will aspire to ways for gaining solar energy housing within an intelligent environment. Masdar City is a distinguished smart city and integrated housing. It has won many awards for including high standards of solar power, whether inside the residences or exporting solar panels outside the Masdar city. Al Falah Complex is a developed sustainable residential environment but does not represent a smart city. Several factors and studies are must improve in the Al-Falah complex to reach a residential and smart complex simultaneously. Providing comfort in the outer perimeter of the house is an integrated image of the smart home within the criteria of a smart city. This analysis will show some suggestions to the Al-Falih project that makes this residential complex an intelligent community that applies solar energy systems.

6.2. IMPORTANT CRITERIA FOR CONVERTING HOUSING COMPLEXES

There are standards designed to restructure the traditional building into a smart and advanced structure. Depending on the existence of intelligent residential construction, the development of the normal environment within a group of factors helps raise the housing city's level see fig 6.2. The analysis of the Al-Falah project helped to reach the weakness in the residential

environment and try to provide complementary solutions that do not need to be restructured. Business Layer, Services, Communication Networks, Sensors, Devices, Dashboards and Applications, Data and Information, and Physical Infrastructure are factors that move buildings to an intellectual level. Masdar City has fulfilled all the conditions that made it the best smart city in the Gulf country. This classification helps Al Falah Complex Housing enhance the residential environment and reach a high comfort level.

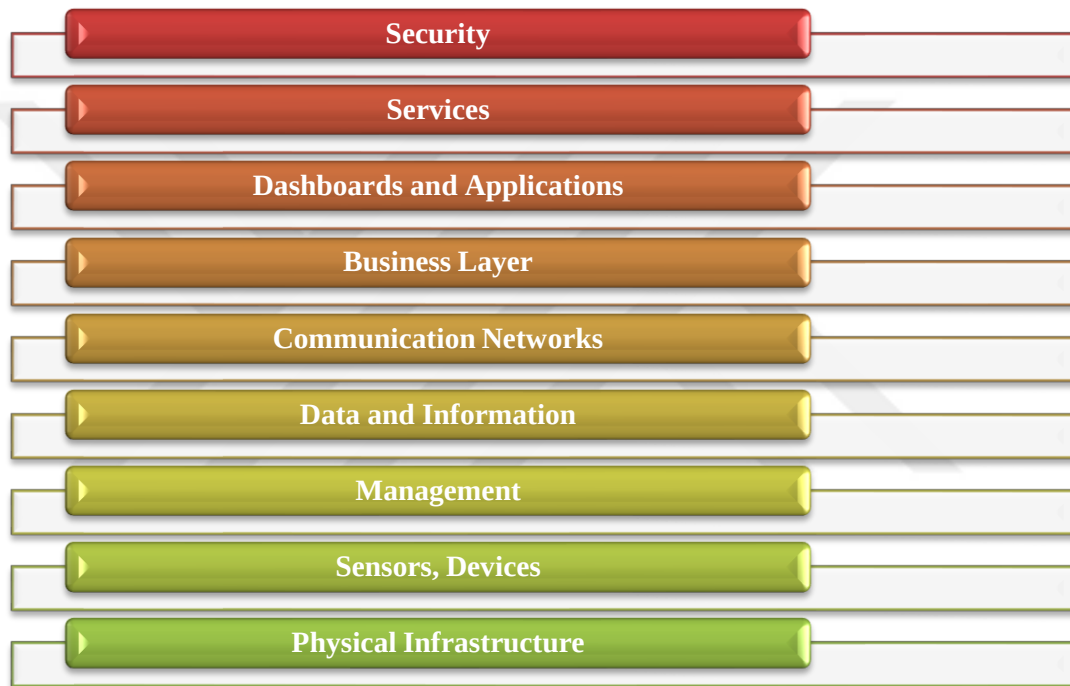


Figure 6.2: Layers of successful Smart City (Haidie, A, et al, 2016, 61)

Smart cities are the solution to all present and future challenges in the field of environmental, economic, and social. Smart cities respect the concept of recycling, a clean environment, and providing comfort in a balanced way. Masdar City has fulfilled all the conditions that made it the best smart city in the Gulf country. It designed and developed the data according to all generations under temporal and spatial clauses. According to the case study analysis data, a comparison is shown in table 6.1 between Masdar City and Al Falah Complex Housing.

Table 6.1: Comparison between Masdar City and Al Falah City

Projects	Masdar City	Al Falah Complex Housing
Area	135,000 sq.m	Around 12 Million sq.m
Project Cost	\$22 billion	\$51 billion
Building Years	2008 to 2025	2011 to 2012
Housing Medium	Multiple housing units	Single housing units
Building System	Open system	Privacy system
Building Design	Developed	Conventional
Waste	Reduce waste Recycling	Landfill
Transportation Types	3	1
Access Road	Organized	Random
Ease of Movement	Easy	Difficult
CO2	0	Low emission
Energy Generation	Renweaable	Oil, Gas, Renweaable
Infrastructure	 Developed	 Ordinary
Sensors, Devices	There a calibrate sensors regularly	Sensors connected to homes, but not in every space in the city

Table 6.1: Comparison between Masdar City and Al Falah City “ Table continued ”

Projects	Masdar City	Al Falah Complex Housing
Solar Energy	The entire project uses solar energy PV panels, (CSP) and (ETC).	Home solar collectors
Urban Planning	Integrated planning	Missing things in planning
Communication Networks	Strong internet networks	Strong internet networks
Facilities Locations		
Residential Percentage	52%	85%
Transportation	Electrical solar	Fossil fuel
Dashboards and Applications	yes	yes
Data and Information layer	yes	no
Materials	Low emission Materials	Normal building Materials
Business Layer	yes	no
Management	yes	yes
Security	yes	yes

6.2.1. Housing Complex Planning Management

Masdar City was built in several stages on the calculated basis and well-done plans, from 2008 to 2025. The steps are divided over 17 years of research and development. Al Falah Complex was built in 2011 and 2012, where all phases were completed. Through the concept of smart cities, there is a future vision and a continuous attempt to develop technologies to correspond with the intelligent city system. The whole world did not witness the real existence of smart cities 25 years ago. There are still discovering and searching for ways to continue for an extended period of comfort in high-tech cities. There is an idea for continuity of work in different phases while living a part of the population within Masdar City. The stability of the people in Masdar city and using facilities allow city officials to add the missing needs. Therefore, one of the foundations that Al Falah City must have is developing continuous plans for the project's Improvement. It is assumed each stage must be better than the previous stage in terms of efficiency, capacity, and endurance. Building a complete project in a short period is given a double effort for developing and applying solutions in all stages alike. It is necessary to acknowledge the strengths and weaknesses of the Falah Complex based on residents' opinions to be able for project development.



Masdar City plan (Palmer, R, 2011, 6).



Al Falah City Plan (Almemari, I, et al, 2014).

Figure 6.3: Master plans of Masdar and Al Falah City

6.2.2. Housing Environment Improving

The urban planning of Masdar City focused on integrating the residential part with other services. The center of Masdar City in the middle, where all facilities are within a reasonable distance, isn't far from the center. The transportation stations are around 1.5 meters, and the facilities are around 0.5 meters distributed in all directions to the serve different housing sites. All homes can easily access mosques distributed throughout the city. Facilities and hotels are parallel to the metro line to make transporting passengers easy. Furthermore, Institutes and research laboratories are located on the city's outskirts for easy access from inside and outside Masdar City. All roads and buildings are well-planned in line with the intelligent environment. In Masdar City, open spaces and parks distribution are integrated considering the size of the project and the ease of access..

Al Falah City adopts symmetry in the planning, each section an exact copy of the other. Water decorations, houses distribution, and green spaces are elements repeated in each village in the same design and location. The repetition in large spaces is given a boring impression in the urban plan. The presence of the city center (live part) at the edge of the project is difficult for all homes to reach services. Due to the size of the project, the design does not serve each house equally. Houses located in the northeast need a very long distance to reach the service center with the city's core. On the other hand, there is no clear goal in the project's planning in many forms of curved, waves, straight, and diagonal lines. Falah Complex Housing has a problem of distance, difficult for the houses located in the middle to reach the main streets surrounding the project shown in table 6.2.

Some solutions help Falah Complex plan by laying foundations that make it a smart city. The project needs to add innovative elements, including drawing a new approach through distribution between homes, services, and green spaces. Reaching the goal is to determine a specific identity for planning the project. Estimating the distances is a significant point in the housing environment for high comfort and ease of anywhere-access.

Table 6.2: Urban planning problems in Al Falah City

Falah Complex Housing	Town Center location	Street	Middle houses
Defining the problem			
Explanation	There is no distance rating between the town center and the houses, located in the north-east.	There is no link between street shapes straight, curved, and waves. The planning methodology lacks a clear idea.	The middle houses have difficulty accessing the main roads.

6.2.3. Smart City Infrastructure And Services Considerations

Masdar City relied on community planning, which is the balance between architecture and infrastructure at the same time. Pre Planning helps to be aware of the details and sustainable elements by laying the foundations to avoid future problems. Masdar City was clearly interested in the streets, the exploitation of spaces, and transportation underground. In tandem, planning and implementing space to integrate the individual into the environment see fig 6.4. The construction of Masdar City succeeded in providing perfect access to water and sewage channel management. It is also preserving the environment and achieving zero carbon emissions. Meticulous design, robust construction, and organization made Masdar City is saved water resources by 70 %.

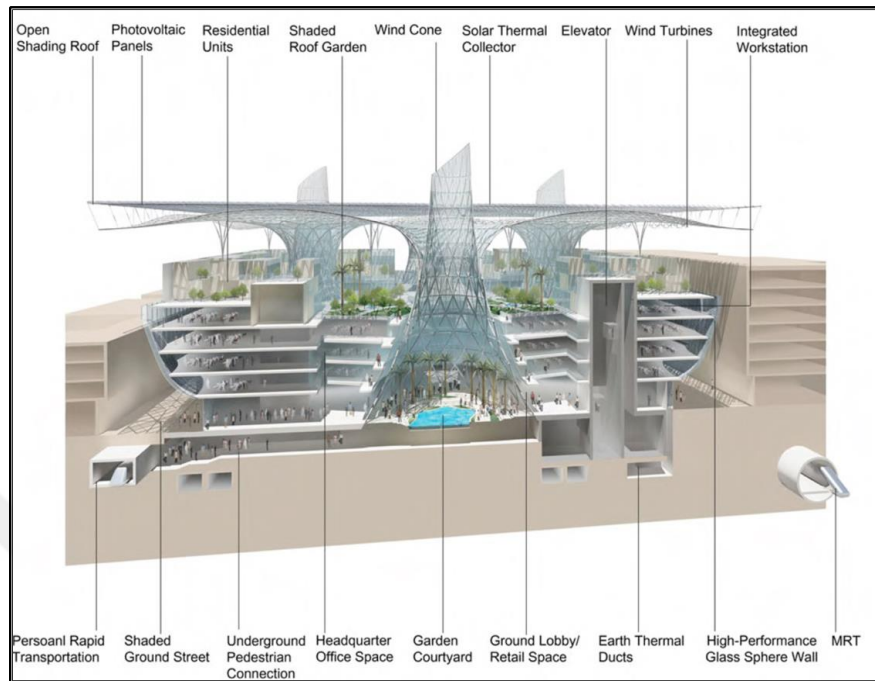


Figure 6.4: Vital infrastructure in Masdar City (Elgendy, K, 2010).

The presence of playgrounds, shopping places, and gardens in the middle of the residential environment makes Masdar City an integrated environment for housing, living and working. According to statistics, 90,000 people visit Masdar City every day, some of them reside inside the city, and some are just working. There were many ways of transportation in the project between electric cars running on solar energy and a train linking Masdar City with the airport. This train passes through six stations distributed throughout the city that allow everyone to use. The new means of transportation are capsule cars rapid transport assigned for Masdar City within an underground floor road. Capsule cars carry four-passenger with four screens installed that allow self-driving. Masdar City took advantage of the underground space and made it parking, capsule cars railway, pedestrian connection road, and basement floors. The infrastructure of Al Falah City contains internet lines, pipes, sewage nets, and some systems related to environmental sustainability. Infrastructure is classified as uncomplicated and straightforward according to the simple housing system. All services related to the residents are located on the earth's surface, shown in fig 6.5, and 6.6.



Figure 6.5: Infrastructure in Masdar - Capsule cars (Rooij, D. D, 2016).

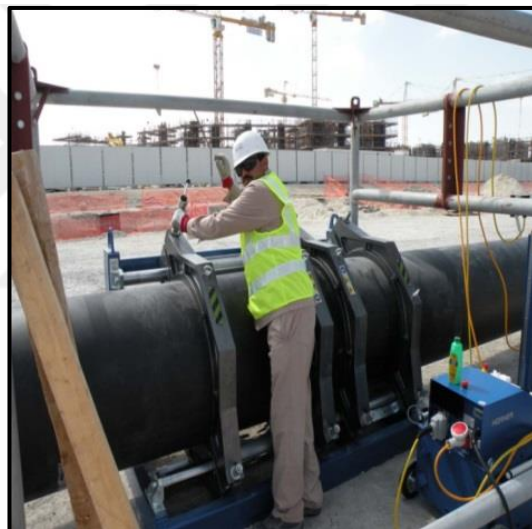


Figure 6.6: Infrastructure in AL Falah Cites -installing pipes
phase (Techno Smart ,2018)

The urban division of Al-Falah city is vast lands containing a group of houses, and each home has a private fence and garden. Each plot of land is separated from the other by asphalted roads on which cars can travel shown in fig 6.7. There is only one transportation way is cars. Only the residents frequent Al-Falah city because the residential villages are five times bigger than the center area, so the services are considered very few. Al-Falah city maintains a healthy residential environment to some extent with low emissions due to the application of the home sustainability system.

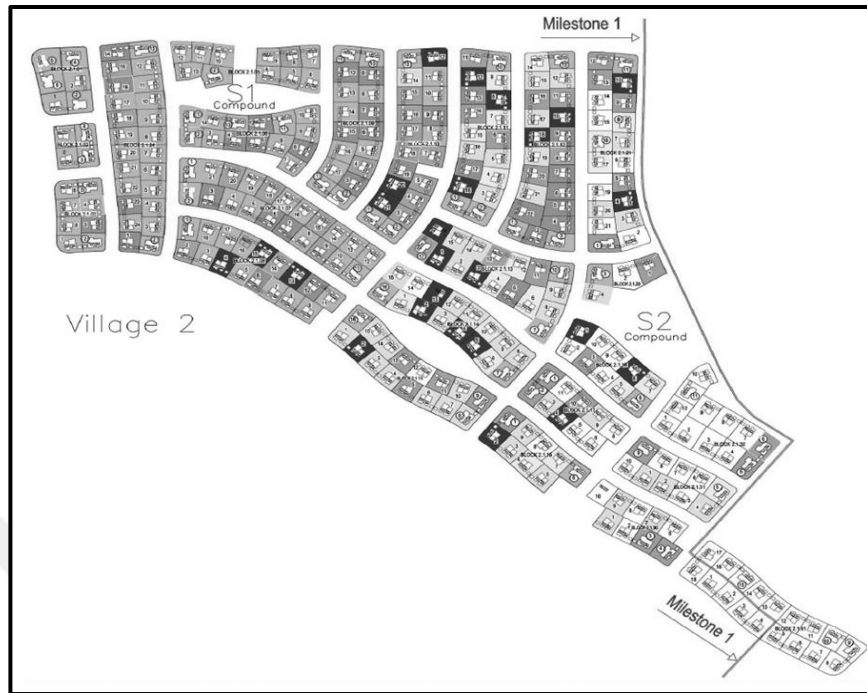


Figure 6.7: Part of Al-Falah city plan (Eyre, J, et al, 2013, 8)

Increasing facilities and services can develop Al Falah City. Attention to facilities and making it a strong point will be continuously frequented by visitors and residents. One means of transportation is not enough, designing a railway for transporting people from one place to another. Al Falah Complex Housing can apply sustainability in all parts of the city, building areas, transportation routes, and service places. The future vision can strengthen the infrastructure and take advantage of more space in activating the project. Exclusivity in ideas and creating new concepts make the project unique and distinct from the rest.

6.3. METHODS OF TRACKING CONSUMPTION

The building structure of Masdar City is classified as interacting with the people, dealing with energy, water, and waste. Masdar City has achieved the theory of producing more power from the construction than the energy consumed, thus supporting Emirates city. The correct understanding of intelligent building is using renewable energy, achieving zero waste and

more significant savings in consumption, In addition to comfort and the use of high technology. The idea of a wave's facade expresses the road's continuity and attracts attention to the winding cylinder. The wind tower is a remarkable example in Masdar city, where it helped residents conserve energy. The robust infrastructure that connects all parts of the city is led to the presence of sensors when increased consumption, shown in fig 6.8.



Figure 6.8:Wind Tower location in Masdar city (Palmer, R, 2011, 9).

The Al Falah Complex Housing didn't use robust infrastructure and control the overconsumption of water, electricity, and energy resources savings. Al Falah City can use biodegradable and environmentally friendly materials and thus reduce waste. The high water and electricity consumption can be reduced when rationalizing and controlling use. Every home can set audio or visual alarm that warns when high consumption rates are reached. It is also possible to link a group of houses to one item that signals when high consumption rates are achieved. There is a suggestion that will change the consumption capacity and save energy in the long run. Accordingly, if the city center is moved to the northern side, energy consumption will decrease, and the efficiency will remain the same. Switching places between housing and town centers will direct Al Falah's project towards the vision of smart cities and consider the consumption capacity, fig 6.9 shows.

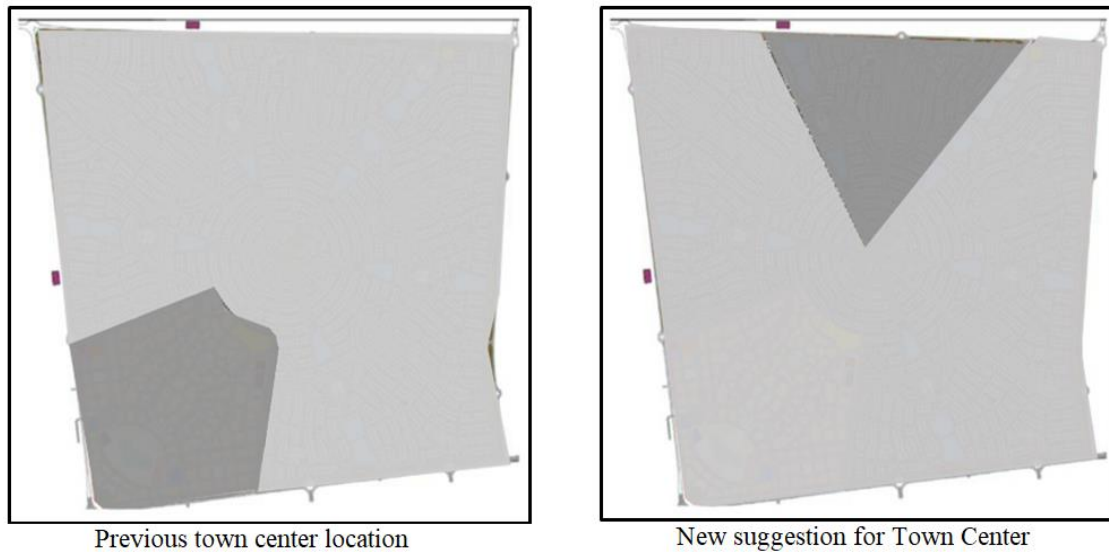


Figure 6.9: Town Center location in Al Falah City

6.4. ANALYZING HOUSING CONSTRUCTION

Smart cities, in general, are impressive and gorgeous for looking. Always smart cities contain groups of ideas that distinguish them from other cities. The Masdar city chose a strategic site exposed to a large amount of solar power and laid the design foundations in building the structure. The city's structure base helped to benefit from solar energy while protecting the residents from direct radiation exposure. There is harmony in the design of residential buildings and pedestrian streets. Chose wave-shaped residential buildings and installed them in harmony direction to save the pedestrian street below from sun heat. It created the idea of ornate facades for residential buildings, giving an aesthetic appearance and adding high efficiency. There are carved decorations openings in residential facades that allow air and sunlight to enter the house's interior space. This design is highly flexible, characterized as the best natural lighting entering the house in a hot and sunny climate. The carved design does not entirely block the sun's rays but refracts the incoming sunlight intensity by creating shadows shown in fig 6.10 and 6.11.



Figure 6.10: Main structure in Masdar city (Elgendy, K, 2010)



Figure 6.11: Shadows in the pedestrian path - masdar city (Digital, T, 2021)

Masdar City comprises buildings not exceeding seven floors, either residential or commercial. Shadow and geometry between wave's layers result from hermetic installation and design. Each wave is asymmetrically fixed above the other, which gives the building a feeling of moving. The windows do not open automatically on the street. The existing distance works to protect residents and prevent future accidents. Smart cities need a great diversity in the external shapes of housing, as happened in Al Falah Complex Housing between Andalusian, modern, and heritage and Masdar city between modern and Islamic design. There are many interior plans in Masdar City that include one, two, or three bedrooms. The method of the dwellings focused on balconies overlooking the project from various directions and did not depend on partition walls. In Al Falah City, there are single housing units with a large area approximately three times bigger than Masdar City homes. The houses' sizes varied between three to five bedrooms and adopted a clear privacy system figure 6.12 shows.



Figure 6.12: Al Falah City Housing (Abuimara, T, & Tabet Aoul, K , 2013,5)

Intelligent cities approve no specific system for the residential section. It needs a great diversity in the external housing shapes, as happened in Al Falah Complex Housing between Andalusian, modern, and heritage and Masdar city between modern and Islamic design. Furthermore, the essential requirement in any residential complex is diversity in the interior space and rooms distribution. The different style in the plan is due to the complex residential concept and the residents' choice. Smart cities are concerned with connecting the residential house with internal and external services to create an appropriate residential environment. A control panel connected to (HEMS) is a significant internal matter that can control home services and monitor consumption levels. The (HEMS) is present in both projects related to the sustainable system in the home. Al Falah Complex Housing chose to have a simple construction style free of complications while considering safety rules. Achieving external services in high standards is the reason for the success of intelligent residential environment projects.

6.5. APPARENT HOUSING COMPLEX ISSUES

Smart cities always deal with various factors, whether security, services, climate, or overpopulation. Separate single-unit housing and residential buildings have different data causing discomfort. Masdar City has dealt with increasing temperature in many ways due to its high efficiency and ability to work with issues. The facilities were distributed between dwellings, avoiding long walks under the sun. Masdar City benefited from the sun's intense rays by building solar panels center specialized in manufacturing and export abroad. After proving the success, it was made a starting point and exported to the world. It interacted with the data creatively and practically to serve the population. Masdar city chose waves-shaped residential buildings and installed them in harmony direction to save the pedestrian street below from sun heat. The solar panels are installed on the opposite buildings in new ways that create shade on the road and reduce the exhibition area with high temperatures. Provide a wind tower to improve air quality in the city squares. Masdar city builds massive structures that interact well with the sun and support the presence of ventilation and cool air. The structures

extend more than seven floors. Masdar city installed solar thermal collectors, PV panels, and solar thermal storage over the structures system shown in fig 6.13.

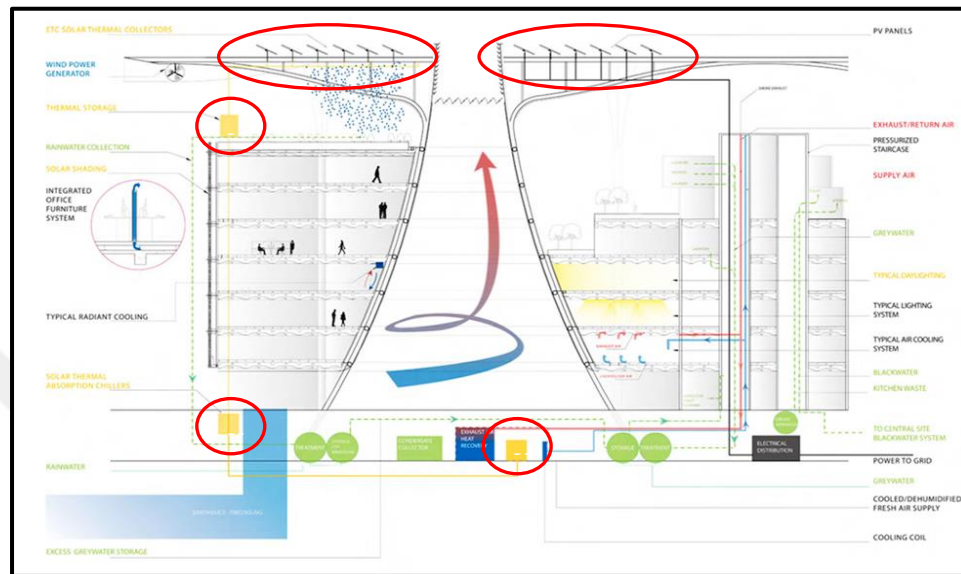


Figure 6.13: Structures in the Masdar Headquarters (Elgendy, K, 2010).

Al-Falah city faced the problem of the large area occupied by the construction compared to the service places. All services are gathered in one area that is difficult to access by all residents-see fig 6.14. Despite the far distances, Al-Falah city also depends on Petrol and diesel cars as transportation. Using cars is not ideal for short ranges also causes damage to the environment. Not apply solutions for high temperatures and create a suitable climate for walking around the city.



Figure 6.14 Al-Falah Complex Housing villages (Aston Consult, 2016)

A simple new idea develops the environment of Al-Falah Complex Housing and improves the quality of life. Al-Falah city owns five villages can evacuate two or three houses in each village and restructure and make it service places. When distributing services, places in each village meet the population's needs and relieve pressure on the town center. For ease of movement, small cars that run on solar energy can be diffused inside the city. This option helps reduce petrol and diesel emissions and supports the intelligent city system. High temperatures are difficult to control because most solutions require high cost and re-infrastructure preparation. Provide glazed cabins with insulation along the roads to cater to pedestrians for a period of sunlight shown in fig 6.15. Spreading trees and palms can also create shades and break the sun's intensity.

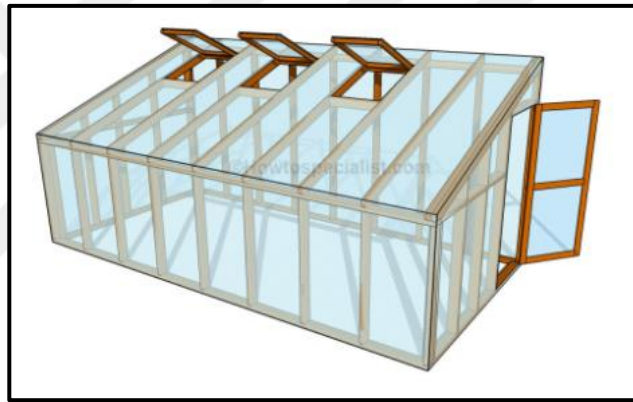


Figure 6.15: Example of glazed cabins (Sander, J, 2021)

6.6. MATERIALS STANDARD AND EMISSIONS

According to new data, sustainable materials create flexibility and ease of restructuring. Masdar City uses 60% of the building materials in the office section to enable a specific strategy. The office department is periodically rented to various companies, thus being able to restructure the department according to the company. The recycling materials used are more flexible than ordinary materials, which helped the diversity of services in the buildings. All materials used in buildings, whether residential, commercial, recreational, were done by calculating emissions.

The choices of Al Falah City for materials and construction methods are good but not innovative. The limitation design between three styles, Andalusian, Modern, and Heritage, helps not consume high emission materials see fig 6.16. Al-Falah city had a unique imprint in the use of pre-prepared cement slabs, which helped finish the project quickly. Effective insulation materials have been used that support the building and increase efficiency. Thus, Al Falah Complex housing and Masdar City were achieved using building materials that are environmentally friendly and moldable way.



Figure 6.16: The construction phase of Al Falah Complex Housing (Bande, L, et al., 2019, 4).

6.7. THE USE OF SOLAR SYSTEMS IN HOUSING COMPLEX

The Masdar city chose a strategic site exposed to a large amount of solar power and laid the design foundations in building the structure. Masdar City uses three systems to capture solar energy simple PV panels (CSP) and (ETC). The project functions two types of collectors, 26% of the (CSP) system by Heliostat field collectors (HFC) shown in figures 6.17 and 6.18 , 14% Evacuated tube collector. Concerning residential buildings and many facilities, simple photovoltaic panels were used, as they occupied 53% of the entire project. Thus, Masdar City uses solar energy by 93%, and the remaining 7% comes from recycling waste and turning it into energy. The city of Masdar has completely abandoned fossil fuels, gas, petroleum, and nuclear energy. It has employed solar power to operate buildings and facilities to meet the needs of residents and visitors through pipelines underground. In addition to institutes and solar panel factories, Masdar City supplies fresh water to its utilities through a desalination plant powered by solar energy.

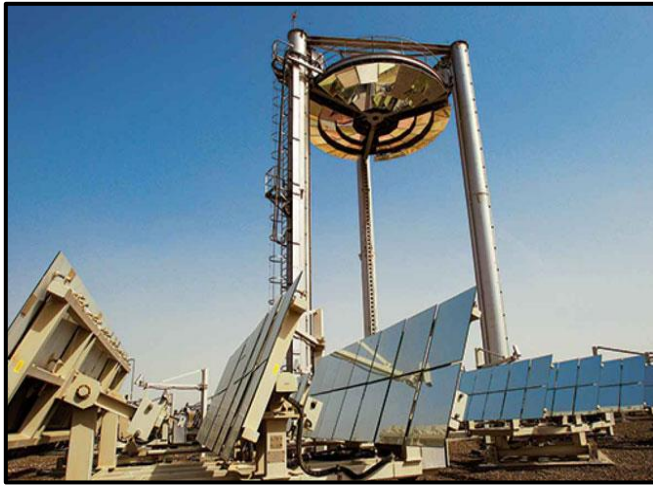


Figure 6.17: Solar plant in Masdar City (Lee, S, 2016)



Figure 6.18: Linear Fresnel field collectors in Masdar (Rooij, D. D, 2016).

Sensors and intelligent home energy management installed in homes helped alert residents when internal pipes were malfunctioning or any problem occurred in the house. It also controls water and energy consumption and implements systems to avoid extravagance. Through these systems in masdar city, water consumption has been reduced by around 54% compared to other regions in the UAE. Al Falah Complex Housing also has a home energy management system, but since it is not a smart city does not care about determining consumption rates. It doesn't depend on vast space for facilities. Housing is more than 75% while other facilities around 25%. The approved solar systems are elementary, maybe simple solar collectors or panels connected to each residential unit separately, figure 6.19 shown. Considering the development of Al-Falah Complex Housing to be an intelligent system

focused on solar energy, it needs to strengthen CSP, either Heliostat field collectors (HFC) or Linear Fresnel Collectors (LFC). Choosing one of the CSP systems that are environmentally friendly will give high energy to the place and support the high-efficiency operation for a long time. After Al-Falah Complex Housing obtains enough solar energy will prevent other harmful power in all areas, operation of facilities, transportation, etc.



Figure 6.19 : Solar collectors on the roofs in the Al-Falah city (Al Akayleh, A, 2011)

6.8. DEALING WITH ENVIRONMENTAL DATA

With the high temperature and direct sun rays falling on the UAE, there were solutions implemented by Masdar City. Masdar City implemented a distinctive design that supports the place's ventilation system and benefits from solar energy. Headquarters of masdar city perform 11 columns cone-shaped connected a wave plate from the top. The connected part between the columns absorbs the necessary energy from the sun to operate the project and stores the surplus. The interior space benefits from sunlight through the cone openings by taking simple

power and heating the place shown in figure 6.20. The system works entirely under negative pressure during the day. Ventilation and moving the wind in the covered part, the wind cones are pulled hot air up and pull cold air by the depths of the ground. The system works oppositely at night, and purpose cools the structure by taking cool air to the bottom. With this system, the city of Masdar employed the heat with the intense rays falling on the area as forces to create a new and practical idea..

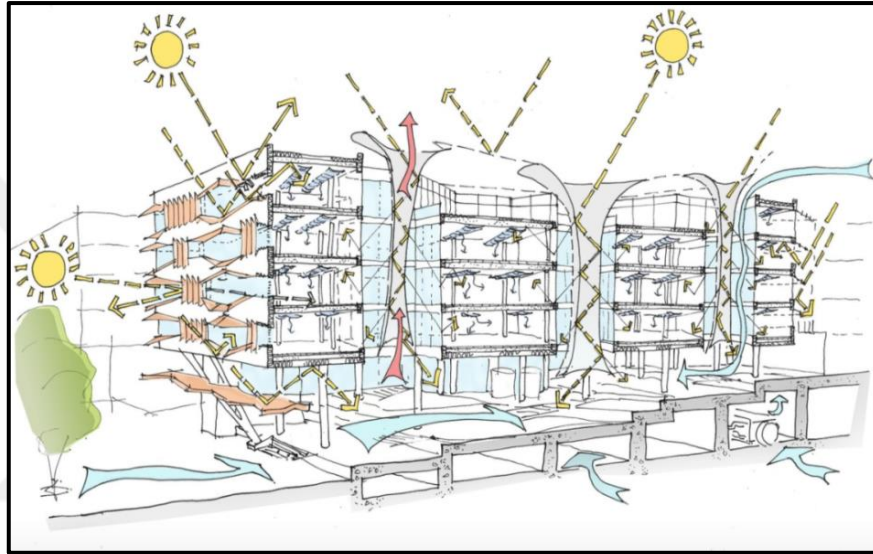


Figure 6.20 : Columns cone-shaped interacting (Elgendy, K, 2010).

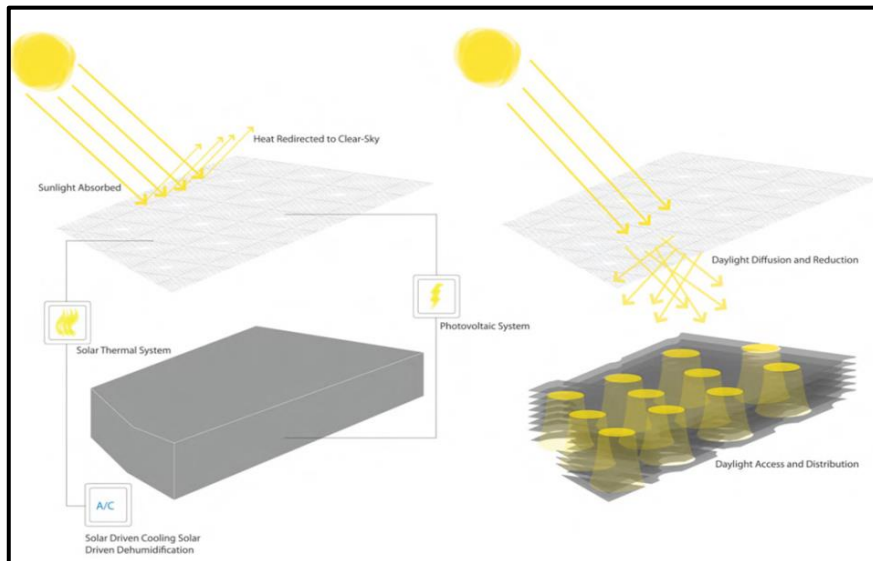


Figure 6.21: The structure reflects sunlight and absorbs energy (Elgendy, K, 2010).

Al-Falah city didn't originate new ideas that support housing communities in the gulf area but implemented a sustainable government project. It adopted the system of simple asphalt streets and single-unit dwellings with high privacy. The town center contains several service buildings: sports, restaurants, mosques, malls, and shops. The facilities in the project are far away from creative in constructive methods and ideas. Water fountains are huge open spaces that need ways to reduce the sun's rays and support a sustainable system see fig 6.22.



Figure 6.22 : The center town in Al-Falah project (Ferguson Brown, 2020)

There are some simple and inexpensive ideas compared to the Masdar City ideas, but they help serve Al-Falah City's population. A partially open glass roof supports the ventilation system and does not block sunlight completely. It keeps the cooling and heating for a longer time and adds an aesthetic look to the place. It can assume the existence of buildings with a high design around the project can block the sun's glare. Creating a shadow in the center of town will allow people to enjoy the place. Finally, it can generate a seating area covered with pergolas supported by plants to make an integrated environment with sustainable shading.

The results presented in the thesis are the findings of research and analysis on integrating solar energy with GCC houses in smart cities.

- a) Studies show that the highest consumption is for Gulf cities. The use of solar energy reduces consumption and supports meeting needs.
- b) The presence of standards that support normal construction shows the extent of continuing to evolve and introduce new technologies to homes.
- c) Development and upgrading didn't stop at a specific point only required several ideas and ways to implement them.
- d) Progress doesn't necessarily mean environmental harm. Within Masdar City, the best modern technologies are present and work on solar energy at 93%.
- e) Equality, the distance between all housing and services in the same residential complex is necessary, especially if no means of transportation support long distances.
- f) The strong infrastructure adds value and a strong foundation for the residential project, in addition to the abbreviation of areas land.
- g) Harmony and compatibility are not limited to the external form only. The sequence of tasks between the elements of the project is critical.
- h) Using two power generators in one project adds greater strength and capacity. The diversity in the use of collectors facilitates the process of energy absorption according to the characteristics of each collector.
- i) Investing in solar energy buildings is an inevitable success. New technologies and advanced materials help to restructure buildings according to needs.
- j) Measuring consumption and generation ratios are one of the pillars that add worth to Residential complexes and give them a high ranking.

7. CONCLUSION

Since there is an increasing demand for solar energy, this is evidence that energy technologies have reached a very high level of efficiency. Solar technology is the protection of the environment from risks, furthermore significantly improving the quality of life. It is estimated that renewable energies reached a vast expansion after adopting modern technology on the sun. It can reach this goal or more if there are short-term plans that are quick to achieve, and long-term plans can change the world vision. The programs are sequentially implemented to reach lofty goals and new prospects. There is also a suggestion on adding new prices that serve all cities in the utilization of endless energy and thus make solar energy an element that enters every building around the world, including remote countries. Investing in solar energy requires taking a risk that ends with profits exceeding the cost and benefit in the local economy and may reach the global economy.

One of the most critical challenges facing renewable energy systems is the high cost. The demand for technologies increases when their price is competitive with nuclear energy systems and fossil fuels systems. There is a problem in delivering marketing and explaining the advantages of solar energy to rural areas: lack of education and not keeping pace with the development in energy capabilities and customer reliability due to the close connection with the weather. Sometimes, some energy generation is low, and the effectiveness of the systems throughout the year cannot be predicted with accurate data, so a tank support system is added to conserve energy to achieve continuity of work with the same efficiency to avoid falling into this cavity. Control and management of large stations is a responsibility because the default in calculating concentrations or shed the beam wrong will cause significant disasters.

Solar energy has become a requirement for sustainable homes. The diversity in the techniques between PV and CSP enabled solar energy to enter into most advanced housing projects, whether simple or huge. Houses need solar collectors, and their types change according to the size of the house, the use of energy, percentage of consumption, and the capabilities of the building. There are stationary state collectors and sun-tracking concentrating systems.

Stationary states solar collectors are less efficient than tracking collectors causes of not having axes able to track the movement of the sun. The Performance varies according to the number of axes in the solar collector, and more axles mean more flexible movement. Solar panels are no longer a burden on the building from the outside. There are many types and methods in line with the modern design of homes. It enables advanced technologies to integrate the primary services in the house with solar energy without feeling inadequacy. Heating, water cooling, heating, ventilation, and optical lighting are perfectly compatible with solar energy. The well-being of sensors and services such as lighting, TV, laundry, and ovens are also directly linked with clean energy. The presence of the HEM system gives the house more incredible luxury and the ability to control even if it is remotely. The main link that connects solar collectors with comfort services in smart cities is strong internet lines in the city's infrastructure. Fewer errors and more accurate data are specifications for control centers located in developed intelligent cities.

The countries of the Gulf Cooperation Council own renewable energies, mainly solar and wind energy. The United Arab Emirates and Saudi Arabia stand out in the diversity of projects based on solar power. Recently, the investment is started in the solar field and integrating it into many residential projects, whether intelligent or not. The delay in entering massive solar energy projects by other Gulf countries to lack readiness and disparity marketing capacity varies between countries. There are two case studies of a residential project in the UAE, similar in sustainability and different in technology, Masdar City and Al Falah Complex Housing.

The reason for choosing Masdar City as a case study is because it proved a very successful example of the application of solar energy in the Gulf. Masdar City has received more than 15 awards between 2007 and 2015. The city of Masdar has adopted the basics in the architectural design of modern cities. Masdar City is a leading big name in renewable energy because of the diversity of solar energy applications in various methods and systems. It is a landmark of solar energy and owns the most important solar panels factories. Masdar City is very interested in

projects that use solar panels done by Masdar laboratory. These laboratories work to meet the needs of Masdar City and finance different projects.

The second case study is Al Falah City, considered one of the successful sustainable housing projects. The vast project area and the administrative capacity made Al Falah City a project frequented by residents of Abu Dhabi. Al Falah City drew attention to individual housing units that provide privacy and two floors spaces in the design. The facilities and services gave the residents a particular advantage and provided most of the needs within a residential environment. Since Al Falah City is a sustainable city, the development and improvement of the environment are not impossible.

Every complex housing has a purpose and necessity, so there are different goals between Masdar city and Al Falah Complex Housing. According to the vision, the projects differ in construction, services, infrastructure, housing, etc. Masdar City aims to produce a smart city with zero carbon, with high advantages and luxury. Al Falah housing focuses on building five villas per day to complete government housing in a short period. As a result, the time element in Masdar City is a remarkable ability to come up with new ideas, accuracy in planning, and high quality. On the contrary, the speed of implementation in Al Falah Complex Housing by using pre-prepared items helps create housing for a more significant number of families but lacks ideas.

The city of Abu Dhabi has succeeded in highlighting the technological aspect of Masdar City. Intelligent systems have been introduced and adopted on a large scale in many smart home services. Case study analysis showed Masdar City uses two types of solar generators besides solar energy interaction systems. The storage of solar energy (TES), which depends on the use of power 24 hours, is installed on the rooftops of the structure and in the infrastructure. The city of Masdar applied three types of solar panels are Monocrystalline silicon panels, thin-film panels, and polycrystalline silicon panels. Al Falah Sustainable City is used solar collectors in the residential field only. In Al Falah City, every home has a solar collector, and the dwellings occupy about 85 % of the project area. Accordingly, the use of solar power constitutes 85 %. Table 7.1 shows the solar energy technology in Masdar City and Al-Falah.

Table 7.1: Comparison solar technology in Masdar and Falah City

The Comparison of the technologies used in case studies.		
Project name	Masdar City	Al Falah Complex Housing
Types of the solar energy generation system	PV+ CSP	PV
Percentage of use PV	used in collectors 40% + used separately 53%	used in collectors
Percentage of use the solar collectors	(CSP) Heliostat 26% +(ETC) Evacuated tube collector 14%	Home solar collectors 85%
Photovoltaic cells types	Monocrystalline silicon panels, thin-film panels, and polycrystalline silicon panels	unused
TES thermal storage	used	unused
Using HEMS	used	used
Solar-powered sensors	widely used	used on a small scale

The masdar city has a proven living in the high standard does not conflict with renewable energy production and calculating environmental damage. The Gulf countries have changed the world idea from undeveloped desert cities to cities with clear, well-planned visions and civilized. The city of Masdar and Al Falah complex housing participated In the clarity of the streets and the division of parts between housing and services.

The adopted technique in Al Falah housing is pre-prepared concrete, which aims to speed up the delivery process. Smart cities can use pre-prepared items provided that chosen low or no carbon materials. The use of pre-prepared materials supplies to construct houses following the

population's demand. In rental homes, the population changes over the years, so the possibility of restructuring the same place is more accessible and thus provides more comfort.

In my opinion, adequate awareness and successful planning for investment in solar energy projects provide job opportunities and open a future vision full of achievement. Small projects are wronged in the solar energy sector because of the lack of experience and information related to the labor market. Small projects resort to the employ untrained employees, despite a lack of obtaining information to support the project's services. The solution is to find low-cost loans to help small projects, financing, and training courses.

Construction is a large world that contains many details that can succeed or break the project. Based on the drawn plans, Masdar City and Al Falah City dealt with Abu Dhabi city and made the planning appropriate with the country. The mentioned reasons in the thesis are caused to the success of projects, such as providing a home energy management system, good residential services, facilities, and solar energy. There are reasons not mentioned, such as low-rise buildings, wide streets, open spaces in homes like balconies and gardens.

Finally, sustainable modernity is the frame for the inhabitants' future environment, giving comfort and high quality. Building a smart city that focuses on solar energy and preserves the rules of the environment, like a continuous loop, every road leads to the next. Design appropriate plan and distribute facilities throughout the city, it helps to walk and reduce the use of petrol cars. Advanced solar systems allow dependence on alternative energy and support development, and reduce consumption. Establishing a specific style that helps give a unique character and identity integrates the idea with design and implementation. Infrastructure is a basic rule that must be thought and studied over a long time to allow new ideas and prevent future problems. Small details add more excellent quality to the project, such as building materials, climate control, and multiple transportation options. Successful projects allow residents to pass the time within a particular space over a long period without having to get out of it. The presence of workplaces, housing, schools, hospitals, institutes, restaurants, places of entertainment is supported staying in the integrated environment.

REFERENCES

- Able Solar Ltd. (2017). Tile roof mounting system. Able Solar. Last Accessed, 13/1/2022. From <https://www.ablesolar.co.nz/shop/Solar+Panel+Array+Frame/Roof+Mounting+Frames/Tile+Roof+Mounting+System.html>.
- Abuimara, T, & Aoul, K, (2013), WINDOW THERMAL PERFORMANCE OPTIMIZATION IN GOVERNMENTAL HOUSING PROGRAM IN ABU DHABI, UAE, United Arab Emirates University, Pg., 1-12.
- ACHARYA, P, (2004) AN ADVANCED FUEL CELL SIMULATOR, M.S, thesis, (Unpublished Master dissertation) Texas A&M University, US.
- Afkhamiaghda, M. (2015). A Case Study of Masdar City: Feasibility of adapting Masdar city to Yazd, Iran, Published by Research Gate, pg1-23.
- Al Akayleh, A. (2011), Gulf precast achieves milestone at Al Falah Community Project. Gulf Precast, Retrieval date, January 14, 2022, from <http://www.gulfprecast.ae/gulf-precast-achieves-milestone-at-al-falah-community-project/>
- Al-Hader, M, Rodzi, A, Sharif, A, Ahmad, N, (2009), Smart City Components Architecture, Paper presented at IEEE International Conference on Computational Intelligence, Modelling and Simulation, <https://ieeexplore.ieee.org/abstract/document/5350055>.
- Almemari, I, Alhammadi, A, Alsalami, E, Hassan ,O, (2014), Evaluation Of Traffic Condition In Al Falah Community, Abu Dhabi, Retrieval date: 14/1/2022 , from <https://alfalahcommunity.weebly.com/site-description.html>
- AL Shugairi , A, 2020, Saudi Arabia Retrieval date: 19/1/2022 , from <https://www.youtube.com/watch?v=l0xmmKmGtQI&t=2429s>

Alternative Energy Tutorials, (2021, February 11). Integral collector storage or ICS for Solar Hot Water. Alternative Energy Tutorials. Retrieved January 12, 2022, from <https://www.alternative-energy-tutorials.com/solar-hot-water/integral-collector-storage.html>

Al-Waeli, A, Al-Asadi, K, Fazleena, M, (2017), The impact of Iraq climate condition on the use of solar energy applications in Iraq: A review. International Journal of Science and Engineering, 6(68), pg, 64-73.

ANDERSEN, A, (2017), THE POTENTIAL FOR IMPLEMENTING WIND INTO HYBRID RENEWABLE ENERGY SYSTEMS IN UNDP COUNTRY OFFICES A CASE STUDY, (Unpublished Master dissertation) UNIVERSITY OF COPENHAGEN Denmark.

Angelidou, M, (2017), the Role of Smart City Characteristics in the Plans of Fifteen Cities, Journal of Urban Technology, 24 (4), Pg., 1-27.

Arabian Sunrise Properties, (2019), Oasis residences- Masdar City, Arabian Sunrise Properties. Retrieved January 14, 2022, from <https://www.arabiansp.ae/abu-dhabi/oasis-residences-masdar-city/>

ArchDaily, office buildings, (2014), Siemens HQ in Masdar City / Sheppard Robson, ArchDaily. Accessed 14 Jan 2022. From <https://www.archdaily.com/539213/siemens-hq-in-masdar-city-sheppard-robson>

Aston Consult, (2016). Al Falah community - Abu Dhabi, UAE, A CCI Company., Retrieval date January 14, 2022, from <https://www.astonconsult.net/projects/al-falah-community-abu-dhabi-uae/>

Awad, J, Hyder, A, Irfan, A, (2017), Development of Smart Cities from Fiction to Reality in Member States of the Gulf Cooperation Council, Russia, S, Pardalos, P (Eds), Smart City Networks Through the Internet of Things, (43-63), Switzerland, -Springer International Publishing. <https://link.springer.com/book/10.1007%2F978-3-319-61313-0>

Bande, L, Young, K, Adan, R, Khoukhi, M, Aldarmaki, A, Aldhaheeri, A, & Alneyadi, A, (2019), Housing programmes in UAE: case study analysis based on regional sustainable

standards and local microclimate. In Journal of Physics: Conference Series, 1343, (1), Pg., 1-6.

Bastianoni, S, Pulselli, F, Tiezzi, E, (2004), the problem of assigning responsibility for greenhouse gas emissions, Journal of Ecological economics 49(3), Pg. 253–257.

Batagan, L, (2011), Smart Cities and Sustainability Models, Journal of Informatica Economica, 15, (3), pg., 80-87.

Bellini, E, (2020), Flexible solar panel for bipv from Sunport. pv magazine International. Retrieved January 13, 2022, from <https://www.pv-magazine.com/2020/07/21/flexible-solar-panel-for-bipv-from-sunport/>

Bellos, E, Korres, D, Tzivanidis, C, Antonopoulos, K, (2016), Design, simulation and optimization of a compound parabolic collector, Journal of sustainable Energy Technologies and Assessments, 16(1), Pg53–63.

BERC, (2010), Biomass Energy at Work Case Studies of Community-Scale Systems in the US, Canada & Europe, Retrieved from, <https://forestry.msuextension.org/publications/fuels-biofuels/biomassenergyatwork.pdf>

Besenic, T, 2016, IMPLEMENTATION AND VALIDATION OF THE TWO-POTENTIAL ELECTROLYTE ASSEMBLY EQUATIONS IN THE COMPUTATIONAL FUEL CELL MODEL, Croatia: Zagreb Publishing.

BHATT, Y, (2021), Renewable Energy Deployment to Stimulate Energy Transition in the Gulf Cooperation Council, Janardhanan, N, Chaturvedi, V (Ed.), Renewable Energy Transition in Asia (1-292), New Delhi, India, <https://link.springer.com/book/10.1007/978-981-15-8905-8>

Brown, M, Soni, A, Lapsa, M, Southworth, K, (2020), Low-Income Energy Affordability: Conclusions from a Literature Review, Retrieved from <https://info.ornl.gov/sites/publications/Files/Pub124723.pdf>

- Chel, A, & Kaushik, G, (2018), Renewable energy technologies for sustainable development of energy-efficient building, Alexandria Engineering Journal, 57(2), Pg., 655-669.
- Cortés, C, (2021, February 21). *8 examples of wind powered architecture*. Arch Daily, [Online]. Last Accessed, January, 2022 <https://www.archdaily.com/956556/8-examples-of-wind-powered-architecture>
- Craciunescu, D, Fara, L, Dabija, M, Sterian, P, & Fara, S,(2019), Intelligent Approach for Improvement of BIPV Systems Performance: Case, Published by IOP Conference Series: Materials Science and Engineering Study, 471(11), Pg., 1-9 .
- Cristi, (2009), World's largest fuel cell town is built in Japan. The Green Optimistic. Retrieval date January 17, 2022, from <https://www.greenoptimistic.com/worlds-largest-fuel-cell-town-is-build-in-japan-20090209/>
- Daley, C. (2017), Masdar City - could be a sustainable - (green-print) - future-urbanism - (2030), Spatial Narratives. [Online]. Last Accessed, January, 2022 from <http://cody-daley.squarespace.com/blog/2017/1/8/masdar-city->
- DEMIRBAS, A, (2006), Hazardous Emissions, Global Climate Change and Environmental Precautions, Economics, Energy Sources, Part B: Economics, Planning, and Policy, University of Connecticut 1:1, pg. 75-84.
- D'Eramo, A, (2021). Masdar City: A Study of Energy, Infrastructure, and Technological Hope. SMU Journal of Undergraduate Research, 6(1), Pg.1-18.
- Devabhaktuni, V, Alam, M, Depuru, S, Robert, C, Green, II, Nims, D, Near, C, (2013), Solar energy: Trends and enabling technologies, Journal of Renewable and Sustainable Energy Reviews, 19(1), pg555–564.
- Digital, T. (2021). A 'greenprint' for sustainable urban development. Welcome to Masdar City. Retrieved January 14, 2022, from <https://masdarcity.ae/en>
- Dixit, A, Kumar, S , & Khanna, P, (2020), Adaptive Power Management Prototype Employing Intelligent Scheduling of Time and Solar Tracker, Procedia Computer Science Journal, 167 (1), Pg.1749-1760.

Dodds, P. E, Hawkes, A, (2014), the role of hydrogen and fuel cells in providing affordable, secure low-carbon heat. H2FC, SUPERGEN, London, UK.

Elgendy, K. (2010), Abu Dhabi's Masdar Headquarters: The first positive-energy building in the Middle East, Caroun Middle East sustainable cities. Retrieval date January 14, 2022, from <https://www.caroun.com/sustainable-design/masdar-headquarters-the-first-positive-energy-building-in-the-middle-east/>

Energy Information Administration (Ed.), (2012). Annual Energy Outlook 2012: With Projections to 2035, (US), Government Printing Office.
https://books.google.com.tr/books?hl=ar&lr=&id=w9B-U3NwUwoC&oi=fnd&pg=PA1&dq=Energy+information+administration%E2%80%8F+2020+gulf+countries&ots=mBwjZ6MBnm&sig=DQbR0RECa0eFW4KnTIAF8UTUMR4&redir_esc=y#v=onepage&q=Energy%20information%20administration%E2%80%8F%202020%20gulf%20countries&f=false

ESMAP, 2012, GEOTHERMAL HANDBOOK: PLANNING AND FINANCING POWER GENERATION, USA, Retrieved from, https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_Geothermal%20Handbook_TR002-12_Reduced.pdf

Eyre, J, Hart, R, Connolly, G, (2013), Optimising delivery solutions for social & affordable housing, Abu Dhabi, UAE, Al Falah Community Project – a social housing case study, El-Seif Engineering Contracting LLC, Pg., 1-11.

Ferguson Brown,(2020), Al Falah development Abu Dhabi, Retrieved January 14, 2022, from <https://ferguson-brown.com/portfolios/al-falah-development-abu-dhabi/>

Ferrari, G, Pezzuolo, A, Nizami, A, Marinello, F, (2020), Bibliometric Analysis of Trends in Biomass for Bioenergy Research, *Energies Journal* 13 (14) Pg., 1-21, Basel, Switzerland.

Ferreira, S., Moreira, N. A., & Monteiro, E. (2009). Bioenergy overview for Portugal. *Journal of Biomass and Bioenergy*, 33(11), Pg., 1567-1576.

Fuqiang, W, Ziming, C, Jianyu, T, Yuan, Y, Yong, S, Linhua, L, (2017), Progress in concentrated solar power technology with parabolic trough collector system: A

comprehensive review, *Journal of Renewable and Sustainable Energy Reviews*, 79 (1) pg. 1314–1328.

Gangopadhyay, U, Jana, S, Das, S, (2013), State of Art of Solar Photovoltaic Technology, *Conference Papers in Energy*, <http://dx.doi.org/10.1155/2013/764132>

Girvan, M, (2018). *Future Solar Energy Devices*, France: Springer Nature.

GreenMatch,(2021, September), Air To Water Heat Pumps: Working principles, GreenMatch, Last Accessed, January 2022,

<https://www.greenmatch.co.uk/blog/2014/08/air-to-water-heat-pumps-working-principles>

Griffiths, S, & Sovacool, B, (2020), rethinking the future low-carbon city: Carbon neutrality, green design, and sustainability tensions in the making of Masdar City. *Journal of Energy Research & Social Science*, 62(1), Pg., 1-9.

Gwiazda, A, Banas,W, Sękala, A ,Sokol ,M ,Foit, K Monica, Z, (2018), Mechatronics function simulation of complex technical systems using advanced design environment, In *IOP Conference Series: Materials Science and Engineering*, 400(4), Pg., 2-8.

Hafez, A, Soliman, A, El-Metwally, K, Ismail, I, (2016), Solar parabolic dish Stirling engine system design, simulation, and thermal analysis, *Journal of Energy conversion and management*, 126 (1) pg.60-75.

Hantula, R, 2010, How Do Solar Panels Work?, Retrieved from

<http://www.energiazero.org/fotovoltaiico/How%20Do%20Solar%20Panels%20Work.pdf>

Hassan, A. M., Lee, H., & Yoo, U. (2016). From medieval Cairo to modern Masdar City: lessons learned through a comparative study. *Architectural Science Review*, 59(1), Pg., 39-52.

Heffron, R, Halbrügge, S, Korner, M, Obeng-Darko, N, Sumarno, T, Wagner, J, Weibelzahl, M, (2021), Justice in solar energy development, *Journal of Elsevier Ltd*, 218 (1) pg. 68–75.

Hira Industries, (2017), Al Falah community - Abu Dhabi , Activity report: 2022 January Aerofoam.NBR. Retrieved from <https://www.aerofoam.ae/wp-content/uploads/2017/06/Al-Falah-Community-Abu-Dhabi.pdf>

Hussaina, M, Ménézo, C, Kim, J, (2018), Advances in solar thermal harvesting technology based on surface solar absorption collectors: A review, Journal of Solar Energy Materials and Solar Cells, 187(1), pg., 123-139.

Hussain, B, (2017), DEVELOPMENT OF A PYTHON MODEL FOR ELECTRICITY RETAIL PRICES IN GERMANY UNDER PRESENT REGULATORY FRAMEWORK AND FUTURE EXPECTATIONS OF HIGH RE PENETRATIONS, (Unpublished doctoral dissertation), Cologne University of Applied Science, Germany.

HOHNE, P, (2017), OPTIMAL ENERGY MANAGEMENT OF A HYBRID SOLAR WATER HEATING SYSTEM WITH GRID CONNECTION UNDER TIME-BASED PRICING, (Unpublished Master dissertation), Central University of Technology, Free State, South Africa.

Ibrahim, I, (2016), Livable eco-architecture, Masdar City Arabian sustainable city, Urban Planning and Architecture Design for Sustainable Development, Procedia-Social and Behavioral Sciences ,216 ,(1), Pg., 46-55.

ICARES Becquerel Institute, (2018). Update on BIPV market and stakeholder analysis, BIPVBOOST, Retrieved from www.bipvboost.eu

IEA and UNEP, (2019). 2019 Global Status Report for Buildings and Construction: Towards a zero-emissions, efficient and resilient buildings and construction sector, UN Environment programme, Retrieved from <https://www.worldgbc.org/news-media/2019-global-status-report-buildings-and-construction>

Ignite Graphic Design, 2014, MOUNT TIMBER HOMES, Transportable Building Plans & Specifications, Last Accessed, January 2022

<http://www.mounttimberhomes.co.nz/plan/50m2-two-bedroom-plus-deck/>

İnce, A, Elma, O., Selamoğulları, U, & Vural, B, (2014), Data reliability and latency test for ZigBee-based smart home energy management systems. In 7th International Energy Symposium and Exhibition, Usak, Turkey (pp. 1-8).

IRENA, (2012), RENEWABLE ENERGY TECHNOLOGIES: COST ANALYSIS SERIES: Wind Power, Retrieved from <https://www.irena.org/Publications>

IRENA (2014), REmap 2030: A Renewable Energy Roadmap, IRENA, Abu Dhabi.
Retrieved from, www.irena.org/remap

IRENA, (2017), Geothermal Power: Technology Brief, International Renewable Energy Agency, Abu Dhabi, Retrieved from
<https://www.irena.org/publications/2017/Aug/Geothermal-power-Technology-brief>

IRENA, (2018), IRENA Work on Bioenergy for Sustainable Development: Accomplishments and Findings, Pg, 1-11, Abu Dhabi, UAE.

IRENA. (2018), New Estimates Show Rapid Growth in Off-Grid Renewables, IRENA International Renewable Energy Agency. Retrieved January 12, 2022,
<https://www.irena.org/newsroom/articles/2018/May/New-Estimates-Show-Rapid-Growth-in-Off-Grid-Renewables>

IRENA (2018), Solid biomass supply for heat and power: Technology brief, International Renewable Energy Agency, Abu Dhabi, Retrieved from, www.irena.org.

IRENA (2019), Future of Solar Photovoltaic: Deployment, investment, technology, grid integration and socio-economic aspects (A Global Energy Transformation: paper), International Renewable Energy Agency, Abu Dhabi, Retrieved from
www.irena.org/publications.

IRENA, (2019), ‘Renewable Energy Market Analysis: GCC 2019, Abu Dhabi, Retrieved from <https://www.irena.org/publications/2019/Jan/Renewable-Energy-Market-Analysis-GCC-2019>

IRENA and CPI (2020), Global Landscape of Renewable Energy Finance, 2020, international Renewable Energy Agency, Abu Dhabi, Retrieved from ISBN 978-92-9260-237-6.

Islam, M, Sumathy , K, Khan ,S ,(2013), Solar water heating systems and their market trends, Journal of Renewable and Sustainable Energy Reviews, 17(1), Pg. 1–25.

ISRA, (2019), Sustainable finance: Can Sukuk become a driver of solar and green energy growth? Retrieved from
<https://www2.deloitte.com/content/dam/Deloitte/xs/Documents/financial-services/Deloitte-solar-energy-report.pdf>

J.M.K.C. Donev et al. (2021). Energy Education - Renewable and sustainable energy [Online]. Last Accessed, January, 2022
https://energyeducation.ca/encyclopedia/Renewable_and_sustainable_energy

Johansson, B, (2013), Security aspects of future renewable energy systems: A short overview, Published by Elsevier Ltd, 61, Pg. 598-605.

Haidie, A, Hassani, S, Aqqal, A, El Hannani, A, (2016). the role of communication technology in building a future Smart City, Da Silva, I. N., & Flauzino, R. A. (Eds.), Smart Cities Technologies. BoD–Books on Demand.

Kalogirou, S, (2004), Solar thermal collectors and applications, Journal of Progress in energy and combustion science, 30(3), Pg., 231-295.

Kearney, P. (2017), why oil-rich Gulf countries need to invest in renewable energy, World Economic Forum. Retrieved January 13, 2022, from
<https://www.weforum.org/agenda/2017/05/why-oil-rich-gulf-countries-need-to-invest-in-renewable-energy/>

Khan, M, Asif, M, & Stach, E, (2017), Rooftop PV Potential in the Residential Sector of the Kingdom of Saudi Arabia, Buildings Journal, 7(2), Pg,1-20.

Kiss, G, Jansen, H, Castaldo, V, Orsi, L, (2015), The 2050 city, Published by Elsevier Ltd,Procedia engineering, 118 (1), Pg., 326 -355.

Kodis, M, (2011), Turn Me On: 100 Easy Ways to Use Solar Energy, Layton, library of congress cataloging.

Krietsch, B. (2020, May 19).The basics of Geothermal Heating Systems. House Method. Last Accessed, January 2022, <https://housemethod.com/maintenance/basics-of-geothermal-heating-systems/>

Ksenya, (2021). Solar Air Collectors. Solar Tribune. Last Accessed, January 2022 , from
<https://solartribune.com/solar-hot-air-panels/>

Kuzlu, M, Pipattanasomporn, M, & Rahman, S,(2015) , Review of Communication Technologies for Smart Homes/Building Applications, IEEE Innovative Smart Grid Technologies-Asia (ISGT ASIA), pg,1-6.

LaMarche, J, Cheney, Roth, K, & Sachs, O, (2017), Home Energy Management: Products & Trends, eScholarship, University of California, Pg165-175.

Lee, S, (2016), RIM Creation/Flickr, CC BY-SA Welcome to Masdar City: the ultimate experiment in sustainable urban living, The Conversation. Retrieval date January 14, 2022, from <https://theconversation.com/welcome-to-masdar-city-the-ultimate-experiment-in-sustainable-urban-living-65575>

Li, F, Li, C, Sun, K, Zhang, J, Li, H, (2020), Capacity Configuration of Hybrid CSP/PV Plant for Economical Application of Solar Energy, Chinese Journal of Electrical Engineering, 6(2), pg19-29.

Li, Y, Nord, N, Huang, G, Li, X, (2020), Swimming pool heating technology: A state-of-the-art review, In Building Simulation 14, (1), Pg. 421–440, Tsinghua University Press.

Liu, B, Duan, S, & Cai, T, (2010), Photovoltaic DC-Building-Module-Based BIPV System—Concept and Design Considerations, Published by IEEE Transactions on Power Electronics, 26(5), Pg. 1418-1429.

Lobaccaro, G, Carlucci, S, & Lofstrom, E, (2016), A review of systems and technologies for smart homes and smart grids, Published by Energies journal, 9(5), Pg., 1-33.

Ma, D, & Xue, Y, (2013), Solar Energy and Residential Building Integration Technology and Application, International Journal of Clean Coal and Energy, 2(2), Pg. 8-12.

Machado, D, Rico, J, Andrade, G, (2019), A 2DOF THERMOSOLAR CONCENTRATOR PROPOSAL: SOLAR TRACKING AND DISTURBANCE REJECTION USING PROPORTIONAL DEFOCUS, Published by International Solar Energy Society, 1(1), Pg. 1-11.

Mal, N, (2019, May 2). Real-time activity recognition in a smart home using binary sensors. Medium. Retrieval date 13/1/ 2022, Web address <https://medium.com/@nickmal/real-time-activity-recognition-in-a-smart-home-using-binary-sensors-efd147ec694>

Masdar, Mauritania (2022). Mauritania Rural Electrification Programme. Masdar Clean Energy - Deploying Renewable Clean Energy Worldwide. Retrieved January 14, 2022,

from <https://masdar.ae/en/masdar-clean-energy/projects/mauritania-rural-electrification-programme>

Masdar, MBR, (2022). Mohammed bin Rashid Al Maktoum Solar Park, phase 3. Masdar Clean Energy - Deploying Renewable Clean Energy Worldwide. Retrieved January 14, 2022, from <https://www.masdar.ae/en/masdar-clean-energy/projects/mohammed-bin-rashid-al-maktoum-solar-park-phase-3>

Masdar, Siwa (2022). Siwa. Masdar Clean Energy - Deploying Renewable Clean Energy Worldwide. Retrieved January 14, 2022, from <https://masdar.ae/en/masdar-clean-energy/projects/siwa-solar-pv-plant>

Masdar City, (2018), Masdar City Master Plan existing project, Last Accessed January 13, 2022, [file:///C:/Users/gaida_000/Downloads/MasterPlan_21-12_English_V2%20\(2\).pdf](file:///C:/Users/gaida_000/Downloads/MasterPlan_21-12_English_V2%20(2).pdf)

Masdar (CSP), (2021). Solar energy - concentrated solar power (CSP). Solar Energy - Concentrated Solar Power (CSP) - Masdar Clean Energy Technologies, Retrieved January 13, 2022, from <https://masdar.ae/en/masdarcleanenergy/technologies/concentrated-solar-power>

Masdar (PV), (2021). Photovoltaic Power (PV) - masdar clean energy technologies. (PV) - Masdar Clean Energy Technologies. Retrieved January 13, 2022, from <https://masdar.ae/en/masdar-clean-energy/technologies/photovoltaic-power>

Masdar Institute. (2021), Futuristic university buildings in the first phase of a new sustainable city, AKT II, Retrieved January 14, 2022, from <https://www.akt-uk.com/projects/masdar-institute/>

Matungwa, B, (2014). An analysis of PV solar electrification on rural livelihood transformation: a case of Kisiju-Pwani in Mkuranga district, Tanzania, (Master's thesis), Published by Centre for Development and the Environment University of Oslo, Norway. Matuszewska-Janica, A, Zebrowska-Suchodolska, D, Mazur-Dudzinska, A, (2021), The Situation of Households on the Energy Market in the European Union: Consumption, Prices, and Renewable Energy, 14(19), pg.1-21.

Meister, C, & Beausoleil-Morrison, I, (2017), Experimental characterization of a solar combisystem with seasonal storage for a single-detached house, In Proceedings of ISES

Solar World Congress. doi:10.18086/swc.2017.29.08 Available at
<http://proceedings.ises.org>.

Mesloub, A, & Ghosh, A, (2020), Daylighting performance of light shelf photovoltaics (LSPV) for office buildings in hot desert-like regions. *Applied sciences*, 10(22), pg,1-24.

Milani, D, (2012), *Modelling Framework of Solar Assisted Dehumidification System to Generate Freshwater from Thin Air*, Australia, Published by the University of Sydney.

Miller, M. (2015). *The internet of things: How smart TVs, smart cars, smart homes, and smart cities are changing the world*, USA, Pearson Education

Moghbelli, H, Silva, C, Sabih, S, Ali, F, Mueller, M, (2009), *Investigation of Solar Cells for Households in Gulf Cooperation Council (GCC) Countries*, Doha, Qatar, Pg, 1-7.

Mohapatra, B, Kumar, M, & Mandal, S, (2019). Positioning of light shelves to enhance daylight illuminance in office rooms. *Indonesian Journal of Electrical Engineering and Computer Science*, 15(1), Pg,168-177.

Nagarajan, S, Barshilia, H (2010), *Review of sputter-deposited mid-to high-temperature solar selective coatings for Flat Plate/Evacuated tube collectors and solar thermal power generation applications*, Retrieved from
<https://www.researchgate.net/publication/277327602>

Najmi, H, (2018), *Selectivity of Porous Composite Materials for Multispecies mixtures: Application to Fuel Cells*. France: Centre-Val de Loire Publishing

Nambiar, S. (2011). Masdar Institute. *Architectural Record* RSS. Retrieved January 13, 2022, from <https://www.architecturalrecord.com/articles/7860-masdar-institute>

Noori, M, Kucukvar, M, & Tatari, O, 2015, Economic input-output based sustainability analysis of onshore and offshore wind energy systems. *International journal of green energy*, 12(9), Pg., 939-948.

Norton, B, (2011), *Solar Water Heaters: A Review of Systems Research and Design Innovation*, 1, (2), pg. 189-207.

Okedu, K, & AL Salmani, L, (2019), *Smart Grid Technologies in Gulf Cooperation Council Countries: Challenges and Opportunities*, *International Journal of Smart Grid*, 3(2), pg. 92-102.

Osborne, M, (2017), Midsummer offers complete bipv cigs thin-film metal roof systems. PV Tech. Retrieved January 13, 2022, from <https://www.pv-tech.org/midsummer-offers-complete-bipv-cigs-thin-film-metal-roof-systems/>

Palmer, R, (2011), 10 The Masdar Institute's GRC Residential Facade, Masdar Institute - Use of GRC in Sustainable Construction Paper presented GRC 2011 Congress Istanbul, <https://fibrettech.org/wp-content/uploads/2011/09/10-The-Masdar-Institute%E2%80%99s-GRC-Residential-Facade.pdf>

Pedranti, R. (2019). RPA: Richard Pedranti architect, what's a passive house, Retrieved January 13, 2022, from <https://richardpedranti.com/passivehouse/>

Peng, D, Zhang, X. Dong, H, Lv, K, (2010), Performance study of a novel solar air collector, Journal of Applied Thermal Engineering, 30(16), Pg. 2594-2601.

Peregrine Energy Group PEG, and Clean Energy Group CEG, (2006), Clean Energy State Program Guide: Strategies to Foster Solar Energy & Advanced Efficiency In Affordable Multi-family Housing, Retrieved from <https://www.cesa.org/resource-library/resource/strategies-to-foster-solar-energy-advanced-efficiency-housing-in-affordable-multi-family-homes/>

Pickerel, K, 2015, An alternative to typical solar installations: Building-integrated photovoltaics, Solar Power World. Last Accessed, 13/1/2022. from <https://www.solarpowerworldonline.com/2015/07/an-alternative-to-typical-solar-installations-building-integrated-photovoltaics/>

Poerschke, U, Srebric, J, Stewart, S, Woollen, M, Murtha, T,(2011) WIND TURBINE INTEGRATION IN ARCHITECTURE AND THE BUILT ENVIRONMENT, ISBN 978-0-615-54244-7

Poullikkas, A, Hadjipaschalis, I, Kourtis, G, (2013), A comparative overview of wet and dry cooling systems for Rankine cycle based CSP plants, Published by Trends in Heat & Mass Transfer, 13(1), pg. 27–50.

Praveen, R, Keloth, V, Abo-Khalil, A, Alghamdi, A, Eltamaly, A, Tlili, I, (2020), an insight to the energy policy of GCC countries to meet renewable energy targets of 2030, Journal of Energy Policy, 147(1), Pg. 1-7.

- Prinsloo, G, & Dobson, R. (2015). Solar Tracking: High precision solar position algorithms, programs, software and source-code for computing the solar vector, solar coordinates & sun angles in Microprocessor, PLC, Arduino, PIC and PC-based sun tracking devices or dynamic sun following hardware, South Africa, Stellenbosch: SolarBooks.
- Proskuryakova, L, (2018), Updating energy security and environmental policy: Energy security theories revisited, *Journal of Environmental Management*, 223(1), Pg. 203–214.
- Racharla, S, & Rajan, K, (2017), solar tracking system – a review, *International Journal of Sustainable Engineering*, 10(2), Pg. 72-81.
- REN21. 2020, Renewables 2020 Global Status Report, Paris: REN21 Secretariat, Retrieved from ISBN 978-3-948393-00-7
- RETScreen ,(2005), SOLAR AIR HEATING PROJECT ANALYSIS CHAPTER, Canada, Retrieved from https://unfccc.int/resource/cd_roms/na1/mitigation/Module_5/Module_5_1/b_tools/RETScreen/Manuals/Solar_Air_Heating.pdf
- Reynders, G, Nuytten, T, Saelens, D, (2013), Potential of structural thermal mass for demand-side management in dwellings, *Journal of Building and Environment*, 64,(1), pg187-199.
- Rooij, D. D, (2016), Masdar City Guide: 7 solar and clean-tech sights you can't miss, Retrieval date January 14, 2022, from <https://sinovoltaics.com/technology/masdar-city-guide-7-solar-and-clean-tech-sights-you-cant-miss/>
- Russell, I, (2008), the Sustainability Principle in Sustainable Energy, *Tulsa Law Review*, 44, (1) Pg., 121-146, US.
- Sander, J. (2021), How to build a lean to greenhouse: HowtoSpecialist - how to build, step by step DIY plans, HowToSpecialist, Retrieval date January 14, 2022, from <https://howtospecialist.com/garden/greenhouse/how-to-build-a-lean-to-greenhouse/>
- Sankaran, V, & Chopra, A, (2020), Creating Global Sustainable Smart Cities (A Case Study of Masdar City). In *Journal of Physics: Conference Series*, IOP Publishing, 1706(1), Pg., 1 -14.

Santamouris, M, & Cartalis, C, (2017), Energy Consumption of the Building Sector: Incorporating Urbanization, Local Climate Change, and Energy Poverty, Russia, S, Pardalos, P (Eds), Smart City Networks Through the Internet of Things, (129-149), Switzerland, -Springer International Publishing.

<https://link.springer.com/book/10.1007%2F978-3-319-61313-0>

Sapia, C, (2013). Daylighting in buildings: Developments of sunlight addressing by optical fiber, Journal of Solar Energy, 89 (1), Pg., 113-121.

Sealing technology, (2020) GARAGES AS HYDROGEN CAR FUELING STATIONS, Freudenberg FST, [Online]. Last Accessed, January 2022

<https://www.fst.com/corporate/magazine/e-mobility/garages-as-hydrogen-filling-stations/>

Shams, S, Mahmud, K, & Al-Amin, M, 2011, A comparative analysis of building materials for sustainable construction with emphasis on CO2 reduction, International Journal of environment and sustainable development, 10(4), Pg., 364-374.

Siemens HQ in Masdar City / Sheppard Robson,(2014), ArchDaily. Accessed 14 Jan 2022. <https://www.archdaily.com/539213/siemens-hq-in-masdar-city-sheppard-robson>

Singh, A, Agrawal, M, (2007), Acid rain and its ecological consequences, Journal of Environmental Biology, 29(1), Pg15-24.

Solouser. (2020). Active vs passive solar water heating system: Know the difference, Solostar solar water heater,[Online], Last Accessed, January 2022

<https://www.solostar.in/blog/active-vs-passive-solar-water-heating-system-know-the-difference/>

SRNE. (2021), the differences between BIPV and BAPV. SRNE Solar, Retrieved January 13, 2022, from <https://www.srnesolar.com/blog/free-guides/the-differences-between-bipv-and-bapv>

- Strong, S. (2016). Building Integrated Photovoltaics (BIPV) WBDG. Retrieved January 13, 2022, from <https://www.wbdg.org/resources/building-integrated-photovoltaics-bipv>
- SUPSI, (2020), Building Integrated Photovoltaics: A practical handbook for solar buildings' stakeholders, Switzerland, Retrieved from <https://repository.supsi.ch/12186/>
- Suzuki, L, (2017), Smart Cities IoT: Enablers and Technology Road Map, Russia, S, Pardalos, P (Eds), Smart City Networks Through the Internet of Things, (167-190), Switzerland, -Springer International Publishing.
<https://link.springer.com/book/10.1007%2F978-3-319-61313-0>
- Techno Smartm, (2018), Al Falah Community Development, Retrieved January 14, 2022, from <https://www.technosmart.ae/projects/al-falah-community-development/>
- TRNSYS 18, 2021, TRNSYS 18 a transient system Simulation program. TRNSYS - Official Website. Last Accessed, January 2022
<https://sel.me.wisc.edu/trnsys/features/features.html>
- Tsoutsos, T, Mugnier, D, Heunemann, F, Korma, E, Piteru, L, Delorme, M, Quinette , J, Wiemken, E, Dallo. G, Lopez, J, Six, R, Richler, N, Henning, H, Fragnito, P, Enciso, Y, (2004), SOLAR AIR CONDITIONING, Retrieved from
https://www.researchgate.net/publication/259870784_SOLAR_AIR_CONDITIONING
- Tzivanidis, C. & Bellos, E, (2019), Solar Energy Utilization in Buildings, Journal of the Research Gate, pg. 1-54.
- Umar, T, & Wamuziri, S, (2016), Briefing: Conventional, wind and solar energy resources in Oman published by Institute of civil engineering, 16(1), pg., 1-5.

UNEP, (2015), Solar water heating in the tourism industry with a focus on the Caribbean region, Retrieved from https://www.solarthermalworld.org/sites/default/files/story/2015-10-29/unep_solar_water_heating_in_caribbean_tourism_final_231015_1.pdf

United Nations Environment Programme (UN), (2020).2020 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector, Nairobi, UN, Environment programme, Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/34572/GSR_ES.pdf.

Wang, W, Liu, Y, Wu, X, Xu, Y, Yu, W, Zhao, C, & Zhong, Y, (2016), Environmental assessments and economic performance of BAPV and BIPV systems in Shanghai, journal of Energy and Buildings,130, Pg., 98-106.

World Energy Council, (2013), World Energy Resources 2013 Survey, London, Retrieved from, www.worldenergy.org.

Zhu, G, Wendelin, T, Wagner, M, Kutscher, C,(2014), History, current state, and future of linear Fresnel concentrating solar collectors, Journal of Solar Energy,103(1), pg., 639–652.