NET ZERO CARBON SCENARIOS FOR THE ENERGY SECTOR IN WEST ASIA

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NET ZERO CARBON SCENARIOS FOR THE ENERGY SECTOR IN WEST ASIA

Foreword

Carbon neutrality is one of the greatest challenges of the climate action.

With the energy sector being the source of around three-quarters of greenhouse gas emissions today, it holds the key to averting the worst effects of climate change.

This is of particular concern for the countries in West Asia since a large share of oil and gas exports to the rest of the world is coming from this region, and the region plays an important role in global energy markets.

These countries are increasingly stepping up their efforts to ensure a net zero transition by introducing green growth strategies to reduce reliance on fossil fuels as well as economic diversification strategies and the current developments in energy prices might also influence this process.

In addition to the energy sector, other key sectors such as transport and industry play an important role to shape green growth pathways.

In this context, we are happy to introduce the "Net Zero Carbon Scenarios for Energy Sector in West Asia" report. This report analyses alternative mitigation pathways, including net-zero emissions scenarios by looking at what can the mitigation actions in Nationally Determined Contributions (NDCs), Economic Diversification Plans, and green growth strategies of countries in West Asia achieve comparing the business-as-usual scenarios. These mitigation pathways quantify the CO_2 mitigation potential for the energy sector of the 12 countries, Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen and Palestine.

The report lists important technologies to help mitigate CO_2 emissions within three key sectors namely, energy, transport and industry while measuring the contribution of each of these sectors. Furthermore, the report summarizes the impacts of mitigation actions in terms of employment and investments in the region and provides recommendations in this regard.

We wish this report will support and inspire countries in West Asia to further developing their ambitions towards climate action while developing green growth pathways.

This landmark report would not have been possible without the extraordinary dedication of the UNEP colleagues, from both the Climate Copenhagen Centre and the West Asia Office, and the Islamic Development Bank team, who have worked so tirelessly and rigorously on it.

The report on the Net Zero Carbon Scenarios for Energy Sector in West Asia is commissioned by the UN Environment Programme's West Asia Office and the Islamic Development Bank.

Sami Dimassi,
UNEP Representative and Regional Director for West Asia.

Foreword

In recent years, countries around the globe have continued to raise ambition to attain net-zero by mid-century. These efforts remain crucial to meet the goals outlined by countries in the Paris Agreement. The implementation of these national net zero targets can play a critical role in limiting global warming to 1.5˚C, which requires carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions to rapidly decrease to net zero around 2050 and 2070, respectively. Specifically, while it is encouraging to have countries including IsDB member countries that have developed and announced their net zero emission targets, actualizing the net-zero ambition of countries would entail multisectoral approaches including ambitious effort in critical sectors such as energy, transport, urban services, agriculture and food systems, water, and sanitization amongst others. In West Asia region, decarbonization of the energy, transport and industry sectors will be key to helping countries actualize the long-term low carbon and ultimately net-zero targets by mid-century.

As a first step, understanding the various plausible scenarios to actualize national and regional net zero targets seems like a good starting point to enable introduction of practical actions. This is what this report seeks to answer. This report provides critical insights on the Business as Usual (BaU) scenario, Current Policy Scenario (CPS), and The Enhanced Climate Action Scenario (ECAS) for the West Asia region. I have no doubt that the "Net Zero Carbon Scenarios for Energy Sector in West Asia" report jointly developed with our partners would offer insightful thoughts and thinking to better understand the various decarbonatization pathways countries can adopt towards net zero in the region. As a multilateral development bank, in light of the realigned strategic direction of the Bank aimed at driving green economic growth, this report offers vital information for us to assess and identify key sectors and industries with enormous emissions reduction potential in member countries within the region in both medium and long-term horizons. I am confident it will remain useful for stakeholders including public and private sectors actors in our member countries working in these important areas.

I am particularly pleased with the cordial partnership we have enjoyed working alongside our partners at the UN Environment Programme's West Asia Office and UNEP Copenhagen Climate Centre on this report. Special thanks to all IsDB and UNEP colleagues who worked tirelessly to making this a reality and for use of the wider public.

Together, we made this happen. Together, we can make net-zero by mid-century a reality.

Dr. Mansur Muhtar
Vice President, Operations, Islamic Development Bank

Abbreviations

ADB	Asian Development Bank
BAU	Business As Usual
BRT	Bus Rapid Transit
CAGR	Compounded Annual Growth Rate
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CH_4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CPS	Current Policy Scenario
CSP	Concentrated Solar Power
DNI	Daily Normal Irradiance
ECAS	Enhanced Climate Action Scenario
ESMAP	Energy Sector Management Assistance Program
EU	European Union
EWEC	Emirate Water and Energy Company
GACMO	Greenhouse Gas Abatement Cost Model
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHI	Global Horizontal Irradiation
GW	Giga Watt
GWh	Giga Watt Hour
GWP	Global Warming Potential
HFC	Hydro-Fluoro Carbon
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IMF	International Monetary Fund
IOMVM	International Organization of Motor Vehicle Manufacturers
IPCC	Intergovernmental Panel on Climate Change
ITS	Intelligent Transport System
LCOE	Levelized Cost of Electricity
LED	Light Emitting Diode
LPG	Liquified Petroleum Gas
MAC	Marginal Abatement Cost
MAR	Marginal Abatement Revenue
Mtoe	Million Tonnes of Oil Equivalent
N_20	Nitrous Oxide
NDC	Nationally Determined Contributions
PPP	Purchasing Power Parity
PV	Photovoltaics
TJ	Tera Joule
TWh	Tera Watt Hour
UAE	United Arab Emirates
UNDESA	United Nations Department of Economic and Social Affairs
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
USD	United States Dollar
Wh	Watt Hour
ZEV	Zero Emissions Vehicle

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Executive Summary

To limit global warming to 1.5°C, CO_2 emissions need to reach net zero around 2050. Achieving the net-zero emissions target as a global pathway entails a complete decarbonization of the energy sector by the middle of the century, implying that fossil fuels will play a limited role in future. Decarbonization of the energy sector to achieve clean energy solutions will also create transformational societal opportunities such as improved health-care, better education, new jobs and livelihoods, and sustainable economic value and thereby reduce poverty for both men and women. Currently, many West Asian countries export a large share of oil and gas, and therefore have high economic dependence on those exports. Countries in West Asia are thus trying to diversify away from fossil fuels. These countries' Nationally Determined Contributions (NDCs) and national strategies provide insights into the direction and scale of the mitigation options that could be used to achieve net zero for the energy sector in West Asia. This report covers twelve countries from West Asia, namely Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen and Palestine.

In this context, this publication tries to answer the following questions:

i) What can the mitigation actions defined in the Nationally Determined Contributions (NDCs), Economic Diversification Plans and green growth strategies of countries in West Asia achieve in terms of CO_2 emissions reductions from the business-as-usual scenario?

ii) What are the key technologies that will help mitigate CO_2 emissions within the three key sectors of energy, transport and industry, and how much can each sector contribute?

iii) What are the impacts of mitigation actions in terms of employment and investments in the region?

The report uses the Greenhouse Gas Abatement Cost Model (GACMO) to undertake the analysis. GACMO is an accounting model that has been used for mitigation analysis in a number of countries. The report uses the scenarios' modelling approach to answer these questions. The following three scenarios are analyzed in this report:

- The Business as Usual (BaU) scenario, in which current trends in economic growth and the demand for energy continue unabated. The energy mix remains same as the base year.

- The Current Policy Scenario (CPS) is linked to all the actions for the energy sector listed in the selected countries´ NDCs, as well as being included in their national economic diversification strategies.

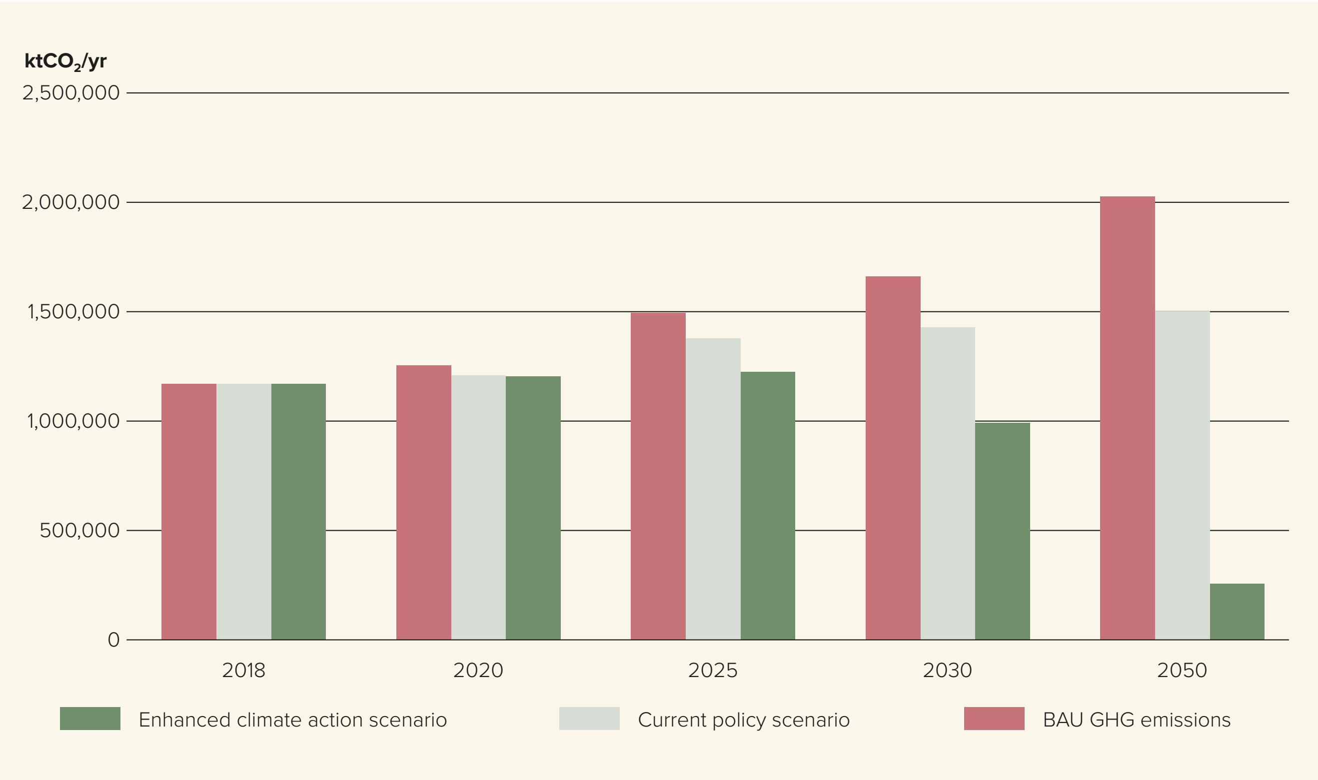
- The Enhanced Climate Action Scenario (ECAS), which is based on the *ambitious* deployment of mitigation technologies identified by the countries themselves within their NDCs, Economic Diversification Plans and additional mitigation technologies.

The study shows that with BAU scenario, CO_2 emissions from the energy sector in West Asia will double from 1,171 million tCO_2 in 2018 to 2,027 million tCO_2 in 2050. The policies and strategies announced and under implementation that were included within the CPS scenario can slow down the growth in emissions but won't be able to bring down CO_2 emissions from current levels (Figure ES1).

However, West Asia would be able to bring down its emissions to 250 million tCO_2 by 2050 under an ECAS by deploying technologies that are available today in the electricity, transport, industry, service and household sectors (Figure ES1).

The electricity sector is, and will remain, the largest sector in terms of CO_2 emissions in West Asia. With BAU scenario, this sector will account for 1,029 million tCO_2 by 2050. Although electricity production in 2018 was 99% based on fossil fuels (mainly gas and oil), a number of countries in West Asia have plans for diversifying electricity generation. The CPS scenario would result in a reduction of 349 million tCO_2 from the electricity sector. The main technologies that would deliver these reductions would be solar PV, nuclear and onshore wind. **In the ECAS sce-**

Figure ES 1. CO_2 Emissions from energy sector across scenarios

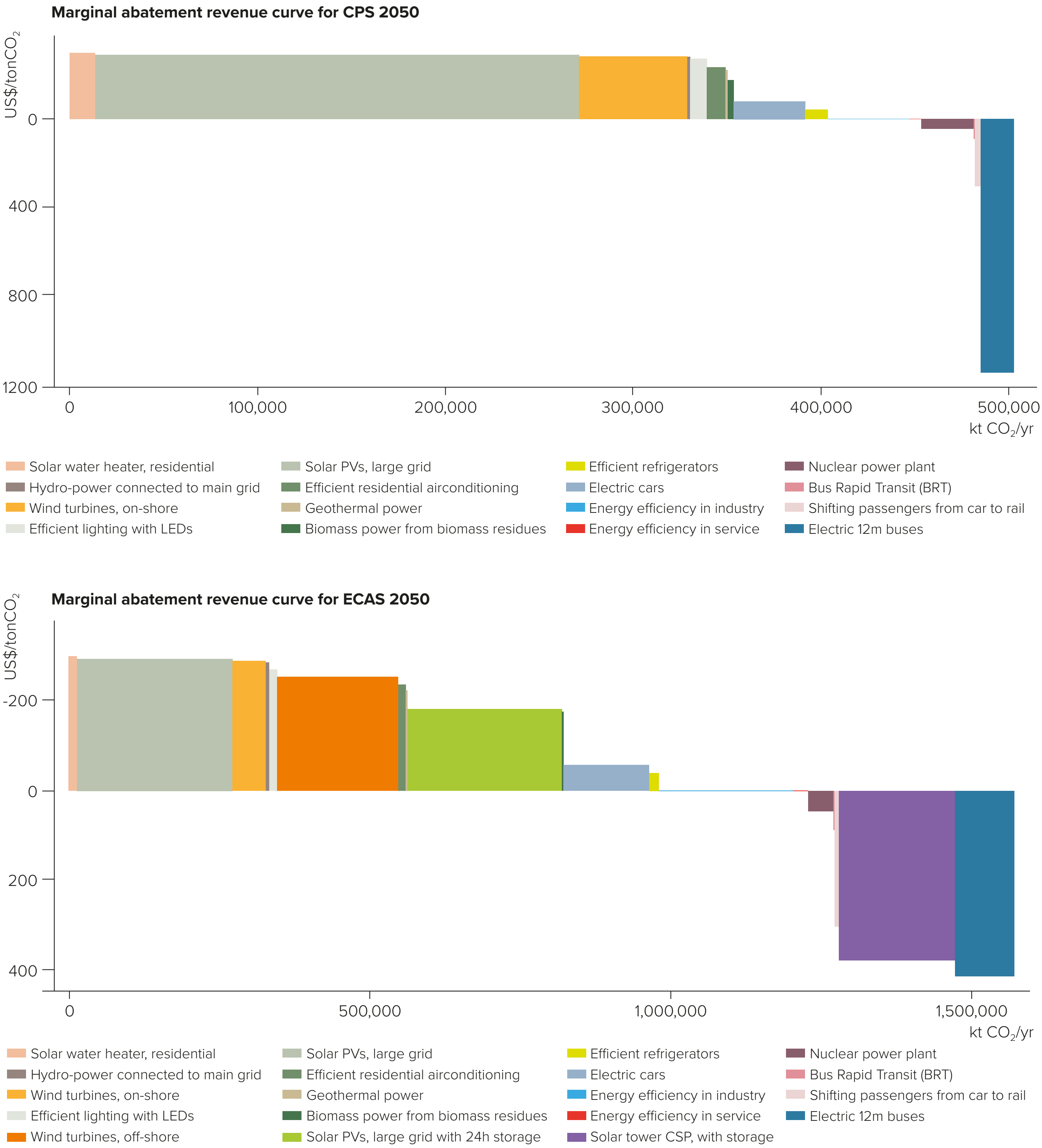


nario, the emissions from electricity production can be brought down to just 10 million tCO_2 by 2050. This would be achieved through the scaled-up implementation of the renewable technologies used in CPS, the strengthening of grids and the addition of storage, as well as by using additional technologies such as solar PV with battery storage and offshore wind.

However, large-scale implementation of renewables in the region would require a rethink about grid infrastructure. Currently, most grid infrastructure is located close to demand, as the transmission capacities to transfer electricity across countries in the region are limited. Electricity production using renewables would be more dispersed, closer to where the potential for production is, and not necessarily where the demand is. In addition, by their very nature, renewables provide power only intermittently without battery storage. These two features make it important to integrate the national grids so that power can be moved freely from where the demand is to where production is located. This will also require the creation of storage facilities in the grid.

In the BAU scenario, the transport sector will account for 453 million tCO_2 by 2050. The growth in the CO_2 emissions of the transport sector will mainly be due to the increasing number of personal vehicles. Vehicle ownership has shown a growing trend and is expected to increase from 143 vehicles per 1000 persons in 2015 to 506 in 2050. In general, the transport sector has been one of the most difficult sectors when it comes to reducing emissions since it requires not only technologies but a change in people's behavior. Countries in West Asia have a large proportion of their population living in urban areas, and this trend will continue in the future. Therefore, a key strategy for reducing transport-related emissions is to reduce the demand for transportation, shift demand to more sustainable modes, and adopt cleaner vehicles. Cities in West Asia are investing in metros and bus-based mass transit systems. In the CPS, due to the implementation of metros and bus-based

Figure ES 2. Abatement Costs and Marginal Abatement Revenue Curves for CPS and ECAS in 2050



transit systems, together with the electrification of vehicles, emissions would be reduced by 83 million tCO_2 by 2050. **In the ECAS the technology options remain the same as for CPS, though the high ambition to construct metro and bus-based transit systems and electric vehicles enhances the emissions reduction to 249 million tCO_2.** However, a large share of the reductions would be achieved through the electrification of vehicles, which would reduce emissions in ECAS by 163.3 million tCO_2 by 2050. Large-scale diffusion of electric vehicles would also create additional energy storage, which allows for the better integration of renewable energy.

West Asia exports a large share of oil and gas to the rest of the world. However, in a world that is trying to achieve net zero by midcentury, the demand for oil and gas must be just a fraction of what it was in 2020. This will mean an end to oil and gas exports to the rest of the world from West Asia by 2050. Consequently, CO_2eq emissions associated with production and processing would decline by 207 million tCO_2 in 2050. Finally, the ECAS scenario suggests that, in the services and household sectors, energy efficiency improvements in appliances (refrigerators and air conditioners) and lighting can deliver a further 26.1 million tCO_2 by 2050.

In the context of the scenarios described above, the publication looks at the costs of the different technologies it considers. A large number of mitigation technologies are currently available at negative abatement costs (Figure ES2). There has been a **large reduction in renewable costs, and many renewable technologies now have negative mitigation costs and can be implemented without grants and subsidies.** Energy efficiency measures also have negative abatement costs, as do electric cars due to a sharp reduction in battery costs. In fact, a large amount of mitigation can happen at negative abatement costs and can therefore be considered a revenue (Figure ES2).

Decarbonization of the energy sector will also create a large number of jobs in the green economy. For example, if the renewable energy ambitions of the ECAS scenario are achieved, then 17.7 million construction job-years and around 689,000 permanent jobs to operate and maintain the assets would be created. However, this also means that these necessary skills will have to be created in the countries concerned. While some jobs are expected to be created during this transition, others are expected to be eliminated, replaced, transformed and redefined. Low-carbon energy transitions need to include consideration of the social aspects of the transition in order to gain social approval for the changes that will be taking place, especially through the integration of the just transition concept. A just transition entails the adoption of gender-sensitive approaches in the advancement of knowledge, capacity-building and innovations in order to simultaneously reduce existing socio-economic inequalities in the energy sector.

This report shows that countries in West Asia can collectively achieve a net-zero scenario in the energy sector along with the diversification of their economies. This will lead to more sustainable and low-carbon economies in the region. Though the levelized costs of renewable energy technologies have come down to a level that it is possible to implement without subsidies and grants, large-scale investments will be needed in the different countries. As a next step, studies that define the net-zero pathways in terms of emissions pathways and mitigation options should be undertaken in each country, taking into account the specific national circumstances. Those country pathways could then be translated into implementable road maps at the sector level that define what needs to be done, at what scale, when, and by whom.

1. Introduction

1.1. International context

The Paris Agreement on climate change established a global framework to *"strengthen the global response to the threat of climate change in the context of sustainable development"*, taking into account the principle of Common but Differentiated Responsibilities and Respective Capabilities. By setting a long-term temperature goal – defined as *"Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels"* – the Agreement opens the door to ambitious mitigation actions to be undertaken by all the Parties.

Achieving the long-term temperature goals of the Paris Agreement requires short-term action, well before 2030. According to the Special Report 1.5 from IPCC, *"to be consistent with global emission pathways with no or limited overshoot of the 1.5°C goal, global net anthropogenic CO_2 emissions need to decline by about 45 per cent from the 2010 level by 2030, reaching net zero around 2050. For limiting global warming to below 2°C, CO_2 emissions need to decrease by about 25 per cent from the 2010 level by 2030 and reach net zero around 2070"* (United Nations Framework Convention on Climate Change [UNFCCC] 2021).

It should be noted that these net-zero target years are for global pathways and therefore need to be achieved collectively. *Setting net-zero targets for individual countries involves considerations of equity and fairness, which means that national net-zero targets do not necessarily have to coincide with the net-zero years and global pathways* (United Nations Environment Program [UNEP] 2021).

The focus of this report is on CO_2 emissions associated with use of fossil fuels: other greenhouse gases, such as CH_4, HFCs and N_2O, are therefore not covered. In the case of West Asia, CH_4 emissions from the oil and gas sector are significant due to the large oil and gas sector in this region. However, only Iraq and Oman practice significant gas-flaring (Collins et al. 2022). Therefore, methane emissions can be taken within country assessments, where CH_4 flaring is a significant contributor to GHG emissions.

Some Parties have already provided information on their respective long-term mitigation visions, strategies and targets up to and beyond 2050, sometimes referring to climate neutrality, carbon neutrality, GHG neutrality or net zero emissions. However, these Parties' contributions would only allow a reduction of 26 (23–29) per cent compared with the 2010 level (UNFCCC 2021). There is thus an urgent need to increase the level of ambition of NDCs significantly between now and 2030, as well as commitments beyond 2030, in order to attain the cost-optimal emissions levels suggested in many of the scenarios considered by the IPCC for keeping global warming well below 2°C or limiting it to 1.5°C. If emissions are not reduced by 2030, they will need to be substantially reduced thereafter to compensate for the slow start on the path to net-zero emissions.

By the end of 2021, 83 countries, representing 75% of global GHG emissions, were to have communicated net-zero emissions targets, including the world's two largest emitters, the United States and China (World Resources Institute [WRI] 2020). It is expected that the number of countries establishing net-zero emissions targets will continue to rise in the near future, as such targets are under discussion in many of them. The West Asia region counted for 3.2% of global GHG emissions in 2018 (International Energy Agency [IEA] 2020a). Some of the countries in the region are among the world's largest producers of fossil fuels and have some of the world's highest per capita CO_2 emissions . Yet as of November 2021, only the United Arab Emirates and Saudi Arabia in the West Asia region had announced plans for net-zero emissions by 2050.

Achieving the net-zero emissions target as a global pathway implies achieving complete decarbonization of the energy sector by the middle of the century (Intergovernmental Panel on Climate Change [IPCC] 2018). This is of particular concern for countries in West Asia, since a large share of oil and gas exports to the rest of the world happen from this region, and the region plays an important role in global energy markets. A number of countries in West Asia are therefore coming up with economic diversification and green growth strategies to reduce their reliance on fossil fuels. Some of these economic diversification strategies

Table 1. Trends and projections of population in West Asia (per 1000 persons)

Country	Household Size (2017)	2,010	2,020	2,025	2,030	2,050	CAGR 2020-30	CAGR 2030-50
Bahrain	5.9	1,241	1,702	1,865	2,013	2,316	1.7%	0.7%
Iraq	7.7	29,742	40,223	45,187	50,194	70,940	2.2%	1.7%
Jordan	4..8	7,262	10,203	10,340	10,655	12,932	0.4%	1.0%
Kuwait	5.8	2,992	4,271	4,518	4,747	5,393	1.1%	0.6%
Lebanon	4.3	4,953	6,825	6,397	6,195	6,528	-1.0%	0.3%
Oman	8.0	3,041	5,107	5,573	5,936	6,915	1.5%	0.8%
Qatar	5.3	1,856	2,881	3,122	3,327	3,851	1.4%	0.7%
Saudi Arabia	5.6	27,421	34,814	37,249	39,322	44,562	1.2%	0.6%
Palestine	5.9	4,056	5,101	5,718	6,342	8,816	2.2%	1.7%
Syrian Arab Republic	-	21,363	17,501	23,062	26,677	33,129	4.3%	0.2%
United Arab Emirates	-	8,550	9,890	10,324	10,661	10,425	0.8%	1.6%
Yemen	6.7	23,155	29,826	33,140	36,407	48,080	2.0%	1.8%
Grand Total		**135,632**	**168,343**	**186,495**	**202,476**	**253,890**		

Source: UNDESA 2019

and the commitments made by these countries within their NDCs should move their respective domestic energy sectors away from fossil fuels. Decarbonization of the energy sector to clean energy solutions will also create transformational societal opportunities such as improved health-care, better education, new jobs and livelihoods, and sustainable economic value, thus reducing poverty for both men and women (Bhattacharyya 2019).

The concept of economic diversification in the climate debate is nothing new. It was initiated under the United Nations Framework Convention on Climate Change (UNFCCC) in 2000, when the Parties began working on its various aspects as part of the Convention and the Kyoto Protocol. Several rounds of submissions and suggestions by the Parties followed in the intervening years, culminating in the Paris Agreement's recognition that *'mitigation co-benefits resulting from Parties' adaptation actions and/or economic diversification plans can contribute to mitigation outcomes* (Article 4, Para. 7)' and that *'building the resilience of socioeconomic and ecological systems, including through economic diversification and sustainable management of natural resources'*, is an option as a relevant plan, policy or contribution to the adaptation planning process (Article 7, Para. 9, (e)). The Parties also acknowledge that these actions and planning processes should adopt a gender-responsive, participatory and fully transparent approach, taking into consideration vulnerable groups, communities and ecosystems.

In this context, the publication analyses alternative mitigation pathways, including net-zero emissions pathways for the West Asia region. These mitigation pathways quantify the CO_2 mitigation potential for the energy sector of the twelve selected countries: Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen and Palestine.[1]

1.2. Population and GDP trends in the West Asia region

Population and GDP per capita are the two key drivers of energy consumption. The relationship between GDP per capita and energy consumption per capita is an inverted

[1] The definition of the West Asia region in this publication is the definition adopted by the United Nations Environment Programme, which groups the following twelve countries together: Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen and Palestine. In this publication, the terms "West Asia", "West Asia region" and "the 12 countries" are thus used interchangeably.

Table 2. Gross Domestic Product (billion International Dollars, PPP terms)

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	CAGR 2010-19
Bahrain	58	61	66	68	68	63	64	71	74	77	74	3.2%
Iraq	378	415	484	515	491	370	347	405	419	445	401	1.8%
Jordan	69	72	74	79	82	88	90	98	102	106	105	4.9%
Kuwait	221	248	277	275	259	181	177	206	214	219	203	-0.1%
Lebanon	74	76	82	89	94	98	104	109	109	104	79	3.9%
Oman	135	141	156	159	156	134	130	136	140	142	134	0.6%
Qatar	250	284	311	323	317	239	221	250	259	266	262	0.7%
Saudi Arabia	1,413	1,587	1,672	1,680	1,723	1,542	1,476	1,566	1,643	1,677	1,627	1.9%
Syrian Arab Republic	136											
United Arab Emirates	555	606	632	647	678	601	599	637	660	684	651	2.3%
Palestine	15	17	20	21	23	25	28	29	30	30	27	8.0%
Yemen	96	86	85	93	94	69	63	61	63	65	63	-4.2%
West Asia	3,401	3,592	3,859	3,949	3,986	3,409	3,297	3,568	3,713	3,815	3,627	1.3%

Source: International Monetary Fund [IMF] 2021

U-shaped curve, with energy consumption increasing up to around USD 40,000, thereafter plateauing and then decreasing as per capita GDP goes beyond USD 45,000 (Chang 2015).

The estimated population of West Asia was around 168 million people in 2020 and is expected to increase to 253 million by 2050 (Table 1). The share of West Asia in the global population is expected to increase from 2.2% in 2020 to around 2.6% in 2050. In most countries, the population is expected to grow rapidly till 2030, then face a population growth slowdown till 2050.

The GDP growth of the West Asia region has been tepid overall for the last decade, growing at a CAGR of 1.3% between 2010 and 2019. In addition, the COVID pandemic impacted negatively on all the countries in the region (Table 2), which saw their GDP fall in 2020 compared to the previous year. However, post-2020 economies are expected to revive, and overall the region will grow at a CAGR of 5.1% till 2026 (IMF 2021).

1.3. Historical trends in energy and GHG emissions in the West Asia region

As seen in Table 3, the growth in final energy demand for the West Asia region between 2010 and 2018 shows much stronger growth than the economic growth. The demand for fossil fuels grew at a CAGR of 2.75% for the period 2010-18, and the demand for electricity at a still stronger 4.44% for the same period. There have been shifts away from fossil fuels to electricity in the household (away from kerosene and LPG) and agriculture sectors (Table 3). However, the transport sector shows a high reliance on fossil fuels for the whole period. Electricity production also remains almost entirely dependent on fossil fuels (Table 3).

A deeper look at West Asia's energy sector in 2018 is provided in Table 4. It reveals an overwhelming dependence on oil and natural gas to meet primary energy needs. Nearly half (47%) of the oil produced is used within the transportation sector, 33% is used for power generation, and the remainder is used in the industry and household sectors. In addition, 66% of produced gas is used for power generation, the remainder going into the industry sector (Table 4).

Table 3. Historical trends in electricity production and final energy demand

	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	CAGR 2010-18
Electricity Production											
From Fossil Fuels	TWh	588.2	609	653.1	678.9	740.2	783.9	808.6	842.7	842.2	4.60%
From Renewables	TWh	8.3	7.6	8.9	9.2	5.9	4.2	6.3	6	7.2	-1.70%
Final Energy Demand											
Industry											
Industry – Fossil Fuels	PJ	3897	4021	4184	4261	4425	4636	4650	4677	4684	2.30%
Industry – Electricity	TWh	88	98	101	114	116	109	111	112	118	3.70%
Transport											
Transport – Fossil Fuels, road	PJ	3141	3383	3573	3661	3736	3721	3786	3915	3815	2.50%
Transport – Fossil Fuels, air	PJ	54	50	50	51	55	62	59	62	59	1.10%
Transport – Electricity	PJ	0	0	0	0	0	0	0	0	0	
Household											
Households – LPG	PJ	248	258	262	260	245	225	238	244	241	-0.40%
Households – Kerosene	PJ	109	114	117	113	85	85	88	100	96	-1.50%
Households – Electricity	TWh	234	229	245	257	267	283	287	296	296	3.00%
Services*											
Services – Fossil Fuels	Pj	669	763	907	933	1009	1074	1101	1122	1213	7.70%
Services – Electricity	TWh	158	171	200	208	228	241	247	256	264	6.70%
Agriculture											
Agriculture – Fossil Fuels	PJ	57	56	52	52	55	47	48	50	50	-1.50%
Agriculture – Electricity	TWh	6	6	7	7	8	9	9	9	10	5.80%
Total Final Energy Demand											
Total Demand Fossil fuels	PJ	8175	8645	9145	9331	9610	9850	9970	10170	10158	2.75%
Total Demand Electricity	TWh	486	504	553	586	619	642	654	673	688	4.44%

*In this publication, services are similar to the tertiary sector.

Source: GACMO analysis based on ENERDATA (Online database available at https://www.enerdata.net)

Table 4. Energy Consumption (in TJ) in West Asia for year 2018

Energy consumption: TJ in 2018	Fossil power plants	Industry	Transport	Households	Services	Agriculture & Fishery	Total
LPG	-	-	1,102	10,319	9,001	406	20,828
Gasoline	-	-	2,308,788	5,630	108	-	2,314,526
Jet Fuel	-	-	59,242	-	-	-	59,242
Diesel	682,573	282,358	1,520,469	-	-	-	2,485,401
Fuel oil	2,000,000	981,472	1,206	551	340	406	2,983,974
Total oil products	2,682,573	1,263,830	3,890,807	2,322	-	-	7,839,532
Coal	-	91,893	-	8,502	451	406	101,253
Lignite	-	-	-	549	1,568	-	2,117
Gas	6,236,706	3,161,227	-	1,224	-	-	9,399,157
Total energy (fossil)	8,919,279	4,516,950	3,890,807	432,039	376,853	17,009	18,152,937
% Share	49%	25%	21%	2%	2%	0%	

Source: GACMO analysis based on ENERDATA

Table 5. CO_2 emissions (in million tCO_2) from the energy sector for select West Asian countries

Sector	Qatar	Bahrain	Jordan	Saudi Arabia	Kuwait	Lebanon	Oman	UAE
	2007	2006	2012	2012	2016	2015	2015	2014
Energy Industries	38,122	4,905	11,263	198,842	56,953	8,338	16,776	100,943
Electricity & Heat	15,943			161,672	47,558			68,925
Fuel Production & Processing (Oil, Gas)	22,179			37,170	9,395			32,018
Transport	5,277	2,583	7,242	120,494	15,000	5,999	13,696	32,995
Industry	3,106	11,229	1,245	48,481	2,856	4,549	8,928	30,767
Others *	-		2,806	74,426	569	3,914	505	1,173

*Includes residential, commercial and agriculture
Source: Latest National Communications or Biennial Reports from the countries selected.

Using the data on fossil-fuel consumption in Table 4, total CO_2 emissions from the energy sector for the twelve countries in West Asia were around 1,171 million tCO_2 in 2018. Power generation accounting for 555,168 $ktCO_2$ (47%) of the emissions, followed by industry at 282,884 $ktCO_2$ (24%) and transport at 277,104 $ktCO_2$ (24%). On a per capita basis, this would be a little more than 7 tCO_2 per person in 2018 for the energy sector, compared to a world average of 4.31 tCO_2/person tCO_2 per person (ENERDATA).

The overall picture for CO_2 emissions is similar if we compare this information with GHG emissions reported by countries (Table 5). Though only Qatar, Kuwait, Saudi Arabia and the UAE provide the data for electricity production, Table 5 shows that the production and processing of oil and gas has a significant share of the energy industry-related emissions. Transport is the second biggest contributor to emissions.

1.4. Objective of the publication

This publication feeds into the UNFCCC discussion on achieving a global net-zero emissions pathway by the second half of this century. It aims to enhance the knowledge of policy-makers and decision-makers in West Asia countries by identifying the opportunities and explaining the impacts of achieving net-zero carbon scenarios for this region.

In doing so, the publication addresses three questions:

iv) What can the mitigation actions defined in the NDCs, Economic Diversification Plans and green growth strategies of countries in West Asia achieve in terms of CO_2 emissions reductions from the business-as-usual scenario?

v) What are the key technologies that will help mitigate CO_2 emissions within the three key sub-sectors of power generation, transport and industry, and how much can each sector contribute?

vi) What are the impacts of the mitigation actions in terms of employment and investments in the region?

To answer these questions, Chapter 2 introduces the different scenarios – the business as usual and mitigation scenarios – and the methodologies used to perform the analysis. Chapter 3 analyses the different scenarios, their respective mitigation impacts and their marginal abatement revenue curves. Chapters 4, 5 and 6 present the mitigation technologies for the three sub-sectors respectively: power generation, transport and industry. Finally, Chapter 7 presents how moving away from oil and gas can impact on jobs and investment.

2. Research framework

2.1. Scenario storylines

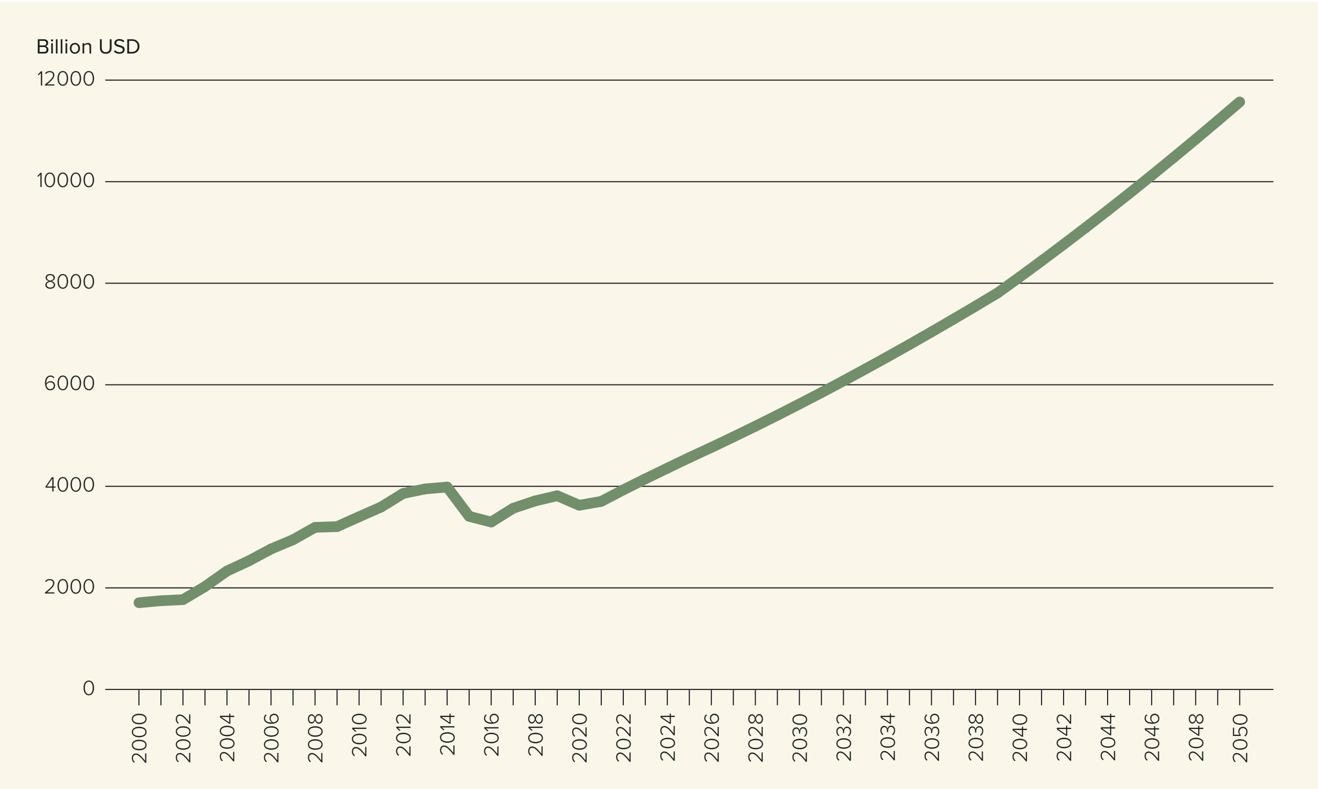
The energy sector is the largest source of greenhouse gas emissions in the West Asia region. This study looks at three future CO_2 emissions scenarios for this sector in the region: i) Business As Usual Scenario, ii) Current Policies Scenario (CPS) and iii) Enhanced Climate Action Scenario (ECAS). The analysis performed at the regional level has been made by compiling the data from the twelve selected countries in the region: Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen and Palestine.

In all the scenarios, the population for the countries in the region follows the medium growth projections of the UN's Population Division, which shows that the overall population for the twelve countries will reach 253 million by 2050 (Table 1).

Business as usual (BaU) scenario

The BaU scenario envisages a continuation of current growth trends in the economy and in energy use. GDP for the twelve countries grew at a CAGR of 1.3% between 2010 and 2018 (Figure 1). The COVID-19 pandemic contributed to a further decline in GDP in 2020. However, in the future, the region will most probably witness increased growth, and GDP is expected to increase from 3,627 billion USD (PPP) in 2020 to 4,565 billion USD (PPP) in 2025

Figure 1. GDP PPP: Historical trends and future projections



Source: historical trends and projections till 2025 based on the IMF's World Economic Database (IMF 2021). Beyond 2025, logistic projections are the authors'.

(IMF 2021). Beyond 2025, projections were made using a logistic function.[2] This indicates that GDP is expected to grow at around 3.9% for the period 2025-2050 and to reach around 12,000 billion USD (PPP) by 2050. Such a projection would increase the average GDP per capita for the region to around 46,800 USD (PPP) in 2050 as compared to 21,500 USD (PPP) in 2020.

The demand for fuel (specifically fossil fuels) from end-use sectors is expected to increase till 2025 in line with the energy growth witnessed in the last decade. In the period 2010 to 2018, the fuel demand from end-use sectors increased at a CAGR of 2.75% (Table 3). The BAU scenario considers continuous technological improvements and efficiency improvements which result in a strong decoupling between growth in GDP and energy demand. Therefore from 2025 to 2050 energy demand is expected to grow at a much slower rate of 1.3 % than the 3.9% GDP growth for the period 2025-2050. The BaU scenario considers no change in the fuel mix, and therefore the overall dependence on fossil fuels for the production of electricity will continue. In essence, the BaU scenario largely ignores the concern for climate, and therefore the energy sector grows so as to be largely dependent on fossil fuels.

Current policies scenario (CPS)

The CPS is linked to all the actions for the energy sector enumerated within the selected countries respective Nationally Determined Contributions. Actions for the energy sector included in the national economic diversification strategies, which aim to reduce the dependence on oil and gas exports of countries in the region, are also included in this scenario. Some of these actions are already being implements by the respective countries on their own, but others will require international financial assistance and technology support. A synthesis of the mitigation actions proposed by the different countries in West Asia is presented in Annex 1.

Enhanced Climate Action Scenario (ECAS)

The ECAS is based on the *ambitious* deployment of mitigation technologies identified by the countries themselves in their NDCs and Economic Diversification Plans, but in a way that is compatible with the Net Zero CO_2 Scenario for the energy sector. This scenario is in line with the global energy transition articulated in the IEA Net Zero Scenario, which achieves a zero-carbon energy sector by mid-century (IEA 2021). Since the region is heavily dependent on oil and gas, this scenario envisages some fossil-fuel use continuing in combination with carbon capture and storage (CCS). The region already has some CCS projects using depleted oil and gas wells in operation in Abu Dhabi, Qatar and Saudi Arabia with an annual CO_2 capture of 2 million tCO_2, as against a CCS storage potential of between 5 and 30 billion tCO_2 (Page et al. 2020). In combination with CCS capacities, the scenario assumes achievement of Net Zero by mid-century, though it should be emphasized that CCS as a technology is still at the demonstration stage and that the costs of CCS are still higher than US $ 50 per tCO_2. CCS therefore also imposes an energy penalty, which increases fuel consumption by between 13% and 44% (Leon Clarke et al. 2022).

2.2. Methodology for mitigation analysis

The report's analyses of greenhouse-gas scenarios and costs have been made using the Greenhouse gas Abatement Cost Model (GACMO).

GACMO is a modelling tool developed at UNEP DTU Partnership (UDP). The tool is based on Excel and can be freely downloaded onto an individual computer from the UDP website (https://unepdtu.org/publications/the-greenhouse-gas-abatement-cost-model-gacmo/). GACMO includes around forty spreadsheets built in such a way that the calculations and the generation of graphs are done automatically. The mitigation analysis is based on the methodologies developed under the Clean Development Mechanism (CDM), in which the mitigation potential is calculated in comparison to a base case technology. The model contains some default data related to mitigation, which is often based on information from the CDM projects. Finally, GACMO uses the IPCC database of emissions factors and Global Warming Potentials (GWP) provided by Intergovernmental Panel on Climate Change [IPCC] 2006.

The main data required to run GACMO are the energy balances, that is, data for the sectoral energy consumption of a country's fossil fuels and electricity. From these data, GACMO calculates greenhouse gas (GHG) emissions for a "start year", that is, for the year in which the data were collected (generally the most recent year for which the necessary data is available). Then, by applying growth factors for each sector, GACMO will project the energy and emissions

[2] A logistic function or logistic curve is an S-shaped curve which is used to make projections where there is fast growth in the middle and a slowing down with time. This kind of a curve is therefore used to make projections of GDP for developing countries where growth is fast as they start industrialization and then flattens out when they achieve a per capita GDP similar to developed countries.

Table 6. IPCC values for energy contents in GJ/ton for different fossil fuels

LPG	Gasoline	Bio-ethanol	Jet fuel	Diesel oil	Biodiesel	Fuel oil	Kerosene	Coal	Coke	Petro-leum coke	lignite	Natural gas
47.3	44.8	26.8	44.6	43.3	26.8	40.2	44.8	25.0	28.0	31.0	18.3	39.0

Source: IPCC 2006

Table 7. IPCC values for emission factors in Ton CO_2/TJ for different fossil fuels

LPG	Gasoline	Jet fuel	Diesel oil	Fuel oil	Kerosene	Coal	Coke	Petroleum coke	lignite	Natural gas
63.1	69.3	71.5	74.1	77.4	71.9	94.6	108.2	100.3	101.2	56.1

Source: IPCC 2006

for the business-as-usual scenario (BAU) towards the years 2025, 2030 and/or 2050.

Mitigation analysis is undertaken by GACMO using different mitigation technologies that are defined in the tool. The latest version includes 119 mitigation options. These mitigation options are organized into 24 categories of activity, such as agriculture, biomass energy, energy efficiency in homes and forestry, as well as geothermal, hydroelectric, solar and wind energy, among others. Once the mitigation options of interest have been selected and their scales of implementation decided for different horizon years in the chosen scenario, the tool calculates the emissions for the chosen scenario based on the previous growth factors and establishes a mitigation scenario towards the years 2025, 2030 and/or 2050. GACMO also calculates the GHG emissions reduction and provides an approximation of the investment, operating and maintenance costs that result from each selected mitigation action.

To make the assessments in the current report, a consolidated energy balance for all the countries in West Asia has been developed. Since country-specific data could not be found in the public domain, data from the ENERDATA[3] database have been used instead. The ENERDATA database includes data collected directly from specific countries and from the International Energy Agency (IEA).

Assumptions and default values

To estimate the greenhouse gas emissions, GACMO calculates the emissions in the base year from the energy data using default values for the fossil-fuel energy contents and for the fossil-fuel emissions factors. These default values are the values found in the IPCC methodologies (Tables 6 and 7).

To estimate the costs, GACMO uses 2020 global average cost values for the different fossil fuels (Table 8). These costs are global import/export average values before taxes.

Development of the business-as-usual scenario

The business-as-usual scenario in GACMO is built on greenhouse gas emissions in a base year multiplied by growth factors towards future years.

The first step in using GACMO is to establish the energy balance for West Asia for the base year in mass units (million tons and million cubic meters). This energy balance for the region is made by summing up the energy balances of all the countries considered in the study. The base year used in the study is 2018, as it was the most recent year for which data for all twelve countries could be found. The values for energy consumption are for all fossil fuels: LPG, gasoline, jet fuel, diesel, fuel oil, kerosene, coal, lignite and natural gas, that are consumed within the country and do not include bunker fuels used for international transport. The rows in the energy balance table provide data for energy consumption in twelve industrial sectors. Energy consumption in the transport sector includes road, rail, domestic air and navigation.

[3] https://www.enerdata.net/

Table 8. Costs for the different fuels in 2020

	LPG	Gasoline	Bio-ethanol	Jet fuel	Diesel oil	Bio-diesel	Fuel oil	Kero-sene	Coal	Coke	Petro-leum coke	Natural gas
US$/GJ	11.1	13.1		12.3	10.4		6.4	12.3	2.0	2.0	2.0	3.1
US$/ liter			0.83			1.20						

Source: ENERDATA

Additional energy consumption data are also provided for households, services, agriculture and fisheries. Finally, the energy balance table includes a last row for energy consumption for non-energy chemical feedstocks.

The energy balance table expressed in mass units is then converted into an energy balance table expressed in energy unit Tera Joule (TJ) (Annex 2) by using the default values for the fossil fuels' energy contents, and then into an energy balance table expressed in kilotons of oil equivalent (ktoe) unit (Annex 2).

Finally, the energy balance table for the base year expressed in ktoe is converted into a greenhouse gas emissions balance expressed in kilotons equivalent CO_2 using the IPCC emission factor values of the different fossil fuels (Annex 2).

The second step in using GACMO is to project the greenhouse gas emissions established for the base year on to future years. GACMO estimates the emission projections using four intermediate years, 2020, 2025, 2030 and 2050. These projections are made by multiplying the data in the start year balances with growth factors estimated for energy consumption in the industrial sectors and transport sector, as well as for households, services, agriculture & fisheries, and non-energy chemical feedstock (Annex 2). The annual growth factors for the periods 2018-2020 and 2020-2025 are calculated using historical values taken from ENERDATA of the energy consumption increase in all the sectors in West Asia for the last ten years. The annual growth factors for the last two periods 2025-2030 and 2030-2050 were then assumed to be lower. The growth factor for the last period from 2030 to 2050 is lower due to the assumption that some energy efficiency measures have already been implemented in the business-as-usual scenario.

Development of the mitigation scenarios

GACMO has been set up for the West Asia region, which consists of the twelve countries already listed. The mitigation scenarios in GACMO are the results of greenhouse gas emissions reductions achieved through the implementation of specific mitigation actions. For this study, mitigation actions are considered for the transport sector, for the production of electricity and for the use of energy in households, industry and services. The technologies are identified taking into account the mitigation opportunities in the NDCs and the different countries' diversification strategies. For each technology, the number of units penetrating in 2025, 2030 and 2050 have been estimated for the CPS scenario and for the ECAS Scenario. GACMO then calculates the emission reductions by comparing the emissions linked to the mitigation technology with the emissions linked to the technology considered in the business-as-usual scenario.

2.3. Methodology for job analysis

Employment impact analysis is based on methodologies developed by Rutovitz et al. (2015), as updated by Ram et al. (2020). The methodology calculates only the direct jobs created in the primary sector and not indirect jobs or induced jobs. The primary sector is energy. Indirect jobs are jobs created in industries that supply goods and services to the primary sectors, e.g., jobs created in producing transformers and batteries, whereas induced jobs are created by the wages of workers involved in construction or the operation of the primary sector. Therefore, the jobs estimated using this approach are on the conservative side.

The jobs are estimated using the investment or capacity-installed numbers from the GACMO model. These numbers from the GACMO model are multiplied by the coefficients of jobs created per unit of capacity installed or invested. The coefficients used are derived from the literature and are described in Section 7.3.

3. Scenario assessments

This chapter looks at the different CO_2 emissions scenarios for the whole energy sector.

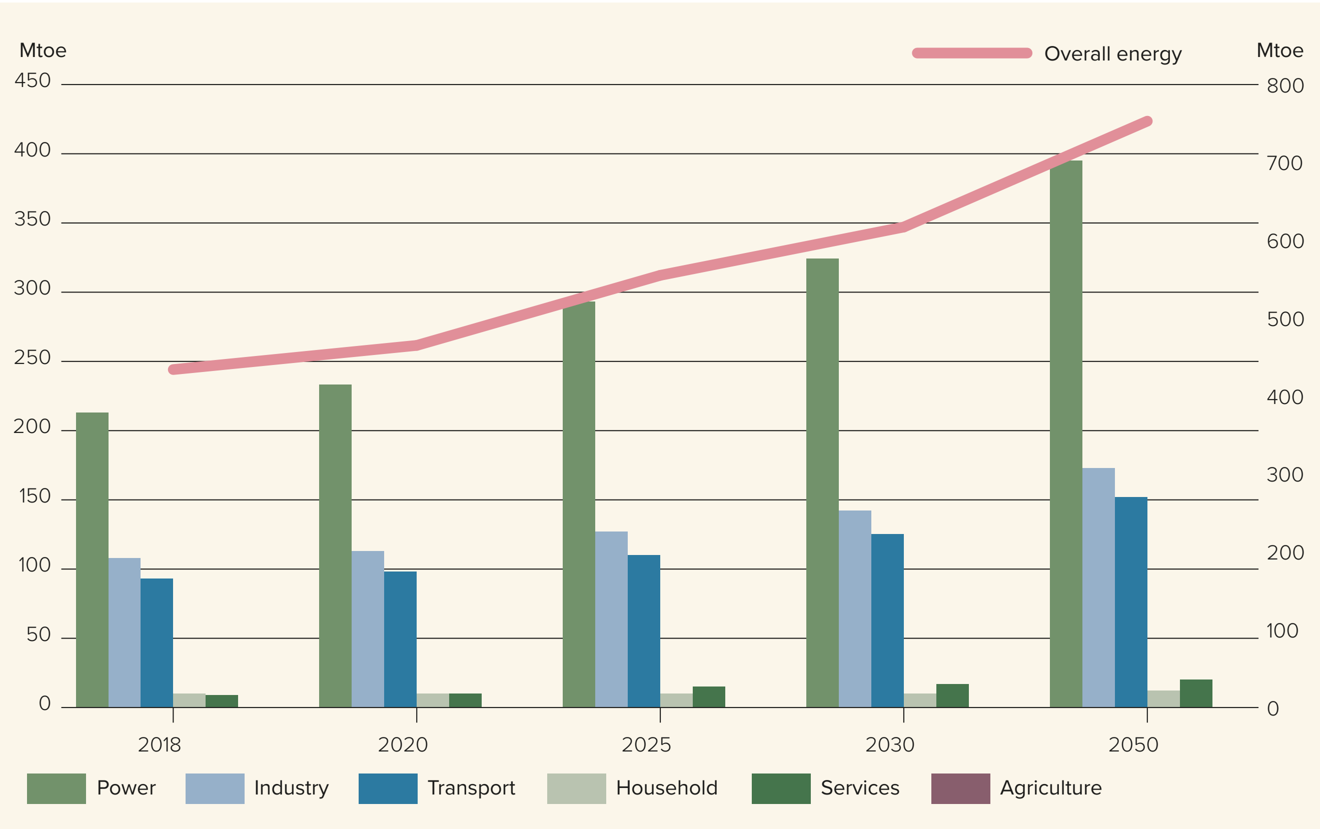
3.1. CO_2 emissions of the energy sector for West Asia

The demand for fossil fuel from end-use sectors (transport, agriculture, households, industry and services) in the BAU scenario is expected to increase in line with the growth in energy demand witnessed in the last decade for the respective sectors till 2025 (Figure 2). However, from 2025 till 2050 overall energy demand is projected to grow at a CAGR of 1.3% compared to the GDP CAGR of 3.9%. Most of the demand for fuels comes from industry and the transport sector (Figure 2). In the household sector, demand growth is slow owing to improvements in cooking devices due to a shift from kerosene to LPG. In the services sector demand has also been growing but on a low base.

In line with the growth in the demand for fossil fuel, the CO_2 emissions of the energy sector in BaU will increase across West Asia from 1.17 $GtCO_2$ to more than 2.02 $GtCO_2$ in 2050 (Figure 3).

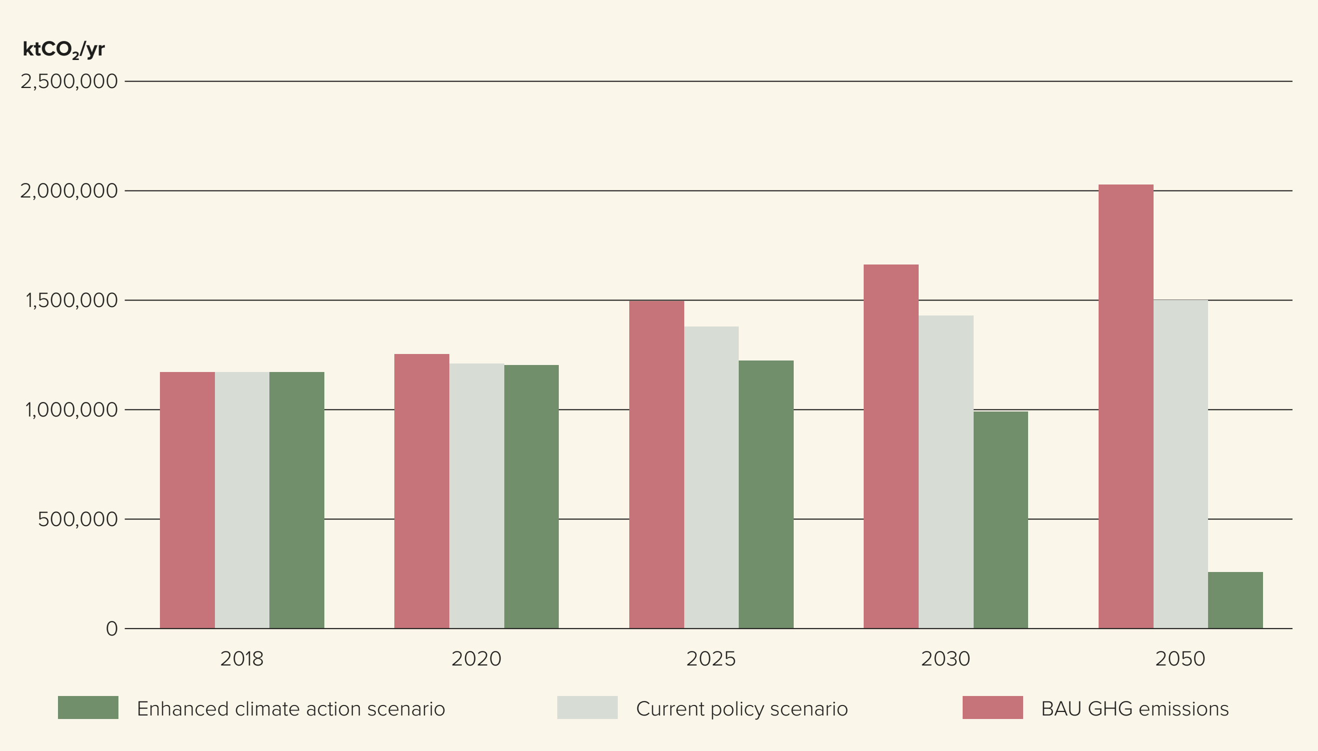
With the implementation of mitigation actions in the Current Policy Scenario (CPS), the total CO_2 emissions of the energy sector in West Asia in 2050 would be reduced by 26% from the BaU. Under this scenario, total CO_2 emissions for this sector would be 1.50 $GtCO_2$ in 2050 and therefore not consistent with a net-zero target.

Figure 2. Growth in the demand for fossil fuels from end-use sectors in the BaU scenario



Source: GACMO analysis

Figure 3. CO_2 Emissions from all sectors across the scenarios



Source: GACMO analysis

Table 9. Sub sectoral CO_2 emissions in BAU scenario

kt CO2/year	2018	2020	2025	2030	2050	CAGR 2018-2050
Total	1,171,309	1,254,010	1,495,700	1,662,104	2,027,806	1.7%
Electricity	555,168	607,355	763,938	843,449	1,029,168	1.9%
Industry *	282,884	296,047	331,695	371,635	453,465	1.5%
Transport	277,014	290,917	328,820	371,686	453,528	1.6%
Households	31,024	30,642	29,719	29,615	36,135	0.5%
Services	23,958	27,790	40,269	44,460	54,249	2.6%
Agriculture	1,260	1,260	1,260	1,260	1,260	0.0%

*Includes production- and processing-related emissions of oil and gas

With the implementation of mitigation actions in the Enhanced Climate Action Scenario (ECAS), total CO_2 emissions from the energy sector in West Asia in 2050 would be reduced by 88% from the BAU.[4] Under this scenario, total CO_2 emissions for this sector would be around 0.25 $GtCO_2$ in 2050.

3.2. CO_2 emissions from electricity and end-use sectors

The split in the BaU's CO_2 emissions for the energy sector shows that, in the West Asian countries, the power, industry and transport sub-sectors will remain the highest producers

[4] In this study, no CCS was considered in the mitigation scenarios (CPS & ECAS). However, the low CO_2 emissions which remain in 2050 under ECAS can be mitigated in combination with the use of CCS.

Table 10. Mitigation options used in CPS and ECAS

Sub-Sector	Mitigation options
Electricity	• Biomass power from biomass residues • Geothermal power • Hydro-power connected to the main grid • Nuclear power plants • Solar PV, large grid • Wind turbines onshore • Wind turbines offshore • Concentrated solar power
Transport	• Shift from cars to public transport • Bus Rapid Transit • Metros • Electric buses • Electric cars
Industry	• Energy efficiency in industry • Demand reductions for oil and gas
Services	• Energy efficiency in service
Households	• Efficient residential air-conditioning • Efficient lighting with LEDs • Efficient refrigerators • Solar water heaters, residential

Table 11. Current Policy Scenario CO_2 emissions: $ktCO_2$ in 2050

Sub-sector	BAU	CPS	Reduction
Electricity	1,029,168	680,555	348,613
Industry *	453,465	408,119	45,347
Transport	453,528	370,343	83,185
Households	36,135	9,932	26,203
Services	54,249	30,726	23,524
Agriculture & Fisheries	1,260	1,260	0
Total	**2,027,806**	**1,500,934**	**526,872**

*Includes production- and processing-related emissions of oil and gas

of GHG emissions up to 2050. Power, which is currently the largest contributor to CO_2 emissions, will grow the fastest at a CAGR of 1.9% till 2050. Transport and industry will grow at CAGRs of 1.6% and 1.5% respectively till 2050 (Table 9).

In the two mitigation scenarios, CPS and ECAS, the mitigation options that have been identified within the various countries' NDCs and economic diversification strategies were applied. These are summarized below in Table 10 and discussed in greater details in Chapters 4, 5 and 6.

In the CPS these mitigation options achieve 26% in CO_2 reductions in 2050 compared to BaU scenario (Table 11). The most significant reductions happen in the electricity sub-sector, followed by transport and industry.

Table 12. Enhanced Climate Action Scenario (ECAS) CO_2 emissions: $ktCO_2$ in 2050

	BAU	ECAS	Reduction
Power	1,029,168	10,718	1,018,450
Industry	453,465	19,733	433,733
Transport	453,528	204,823	248,705
Households	36,135	6,875	29,260
Services	54,249	7,420	46,829
Agriculture & Fisheries	1,260	1,260	0
Total	**2,027,806**	**250,828**	**1,776,977**

In the ECAS scenario, these mitigation options produce an 88% reduction in CO_2 emissions in 2050. The most significant reductions occur in the power sub-sector, followed by industry and transport (Table 12). The residual emissions can be mitigated through a combination of CCS in the fuel production for the transportation sector fuels.

3.3. Marginal abatement revenue of CO_2 emissions

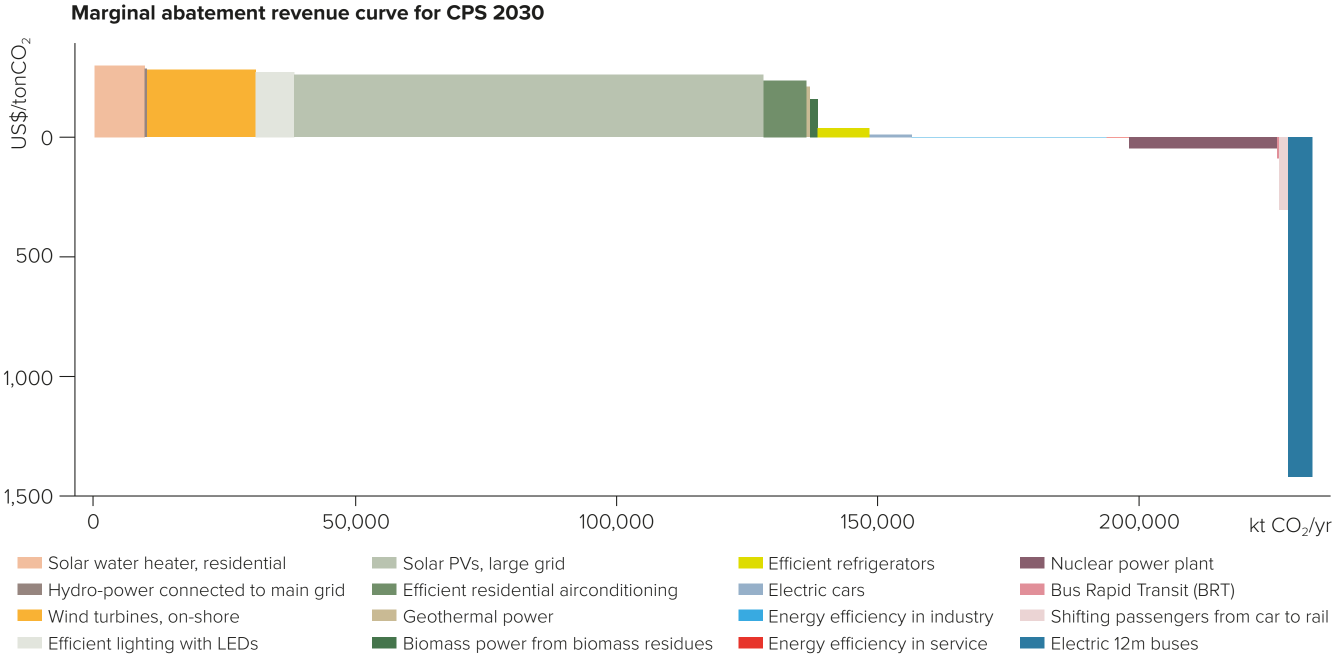
Marginal abatement cost (MAC) and marginal abatement revenue (MAR) curves are a commonly used policy tool for calculating the emissions abatement potential and associated abatement costs. They have been extensively used to assess a range of environmental issues in different countries and have increasingly been applied in climate-change policy-making (Kesicki 2011). MAC/MAR curves focus on the direct costs associated with emissions reductions. In the scenarios analyzed in this report, these costs include investment costs, operating and maintenance costs, and fuel costs for abatement measures. MAC/MAR curves are a useful policy tool providing a quick overview of what could be potential win-win mitigation options with regard to the abatement of both emissions and costs.

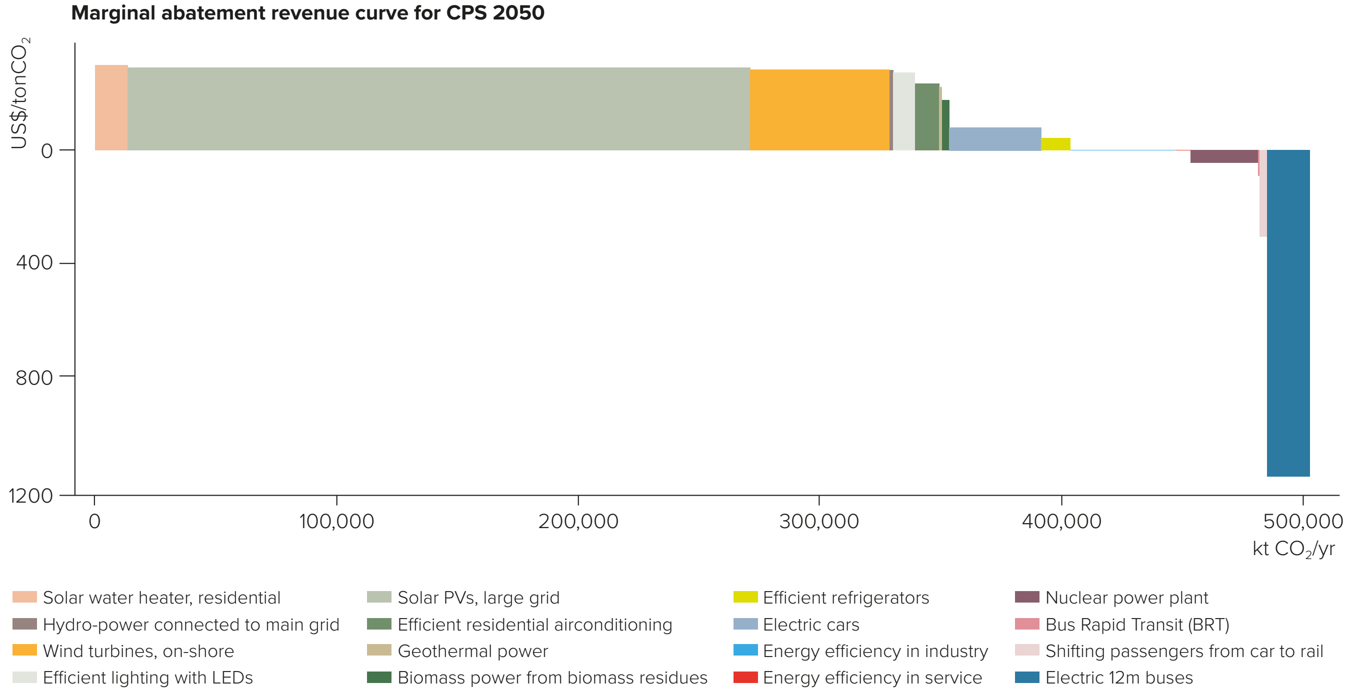
Figure 4 shows the MAR curve for years 2030 and 2050 for the CPS and ECAS scenario. All the options placed above the X-axes can be considered potential win-win mitigation options, that is, options which would allow CO_2 emissions to be reduced while achieving financial savings compared to the options considered in the BaU scenario. A large number of mitigation options can be implemented with negative abatement costs or positive revenues.

In the CPS scenario, by 2050 almost 403 million tCO_2 can be mitigated with positive MAR. Among the largest tools for mitigation with a positive MAR is solar PV. Electric cars emerge as the option with the highest MAR per unit in 2050 due to reductions in the cost of batteries.

In the ECAS scenario, by 2050 almost 980 million tCO_2 can be mitigated with positive MAR. The portfolio of mitigation options becomes diversified, and besides solar PV, wind offshore, solar PV with battery storage and electric cars deliver substantial reductions with a positive MAR. There are, however, a number of options with negative MAR that will need to achieve a zero-carbon energy sector by 2050. The major options with negative MAR are solar CSP and electric buses. The ECAS will also see a reduction of around 207 million tCO_2 due to the loss of oil and gas exports (See Section 6.1), though this is not counted as a mitigation option with the MAR curve.

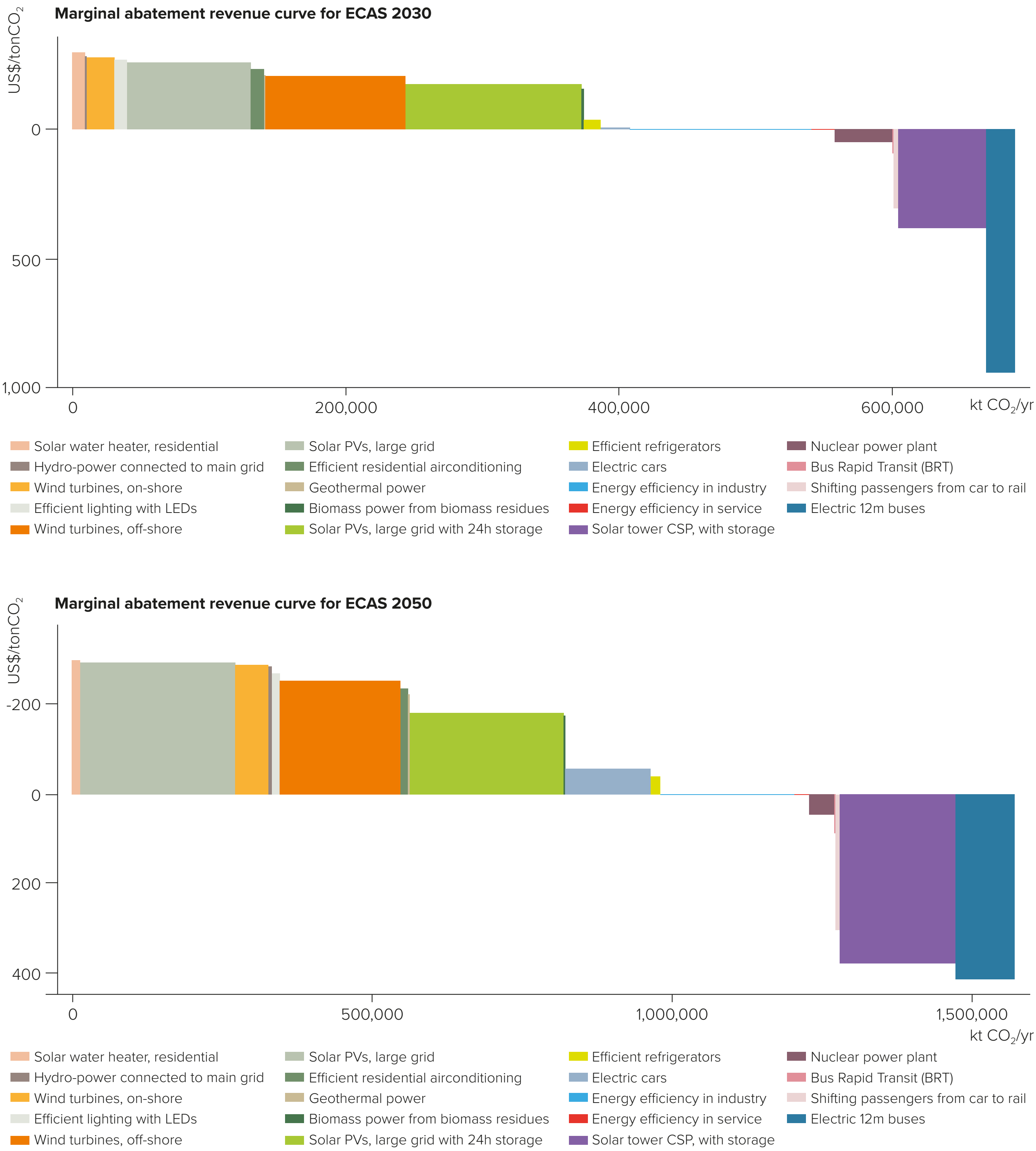
Figure 4-A. Marginal Abatement Revenue Curve across CPS





Source: GACMO Analysis

Figure 4-B. Marginal Abatement Revenue Curve across ECAS



Source: GACMO Analysis

4. Economics of decarbonizing the electricity sector

In 2018, the electricity sector was the largest emitter of CO_2 emissions in West Asia, and it is assumed that it will continue to remain the largest emitter of CO_2 emissions in the BAU (Table 9). This chapter looks more deeply into the electricity sector to understand how the demand for electricity would increase in future and how this sub-sector can be decarbonized.

4.1. Overall demand for and supply of electricity in BAU

The future demand for electricity within the different sectors in the BaU is expected to increase in line with historical trends to 2025. Beyond 2025, it is assumed that the demand for electricity will slow down due to a decoupling of the electricity growth from economic growth. This decoupling will be mainly due to the introduction of improved efficiencies of the different technologies. In 2020, households were the largest consumers of electricity, followed by services. However, this is expected to change in the future. Indeed, the service sector will emerge as the largest consumer of electricity (Table 13) due to the economic diversification strategies being pursued by different countries. Bahrain, for example, has heavily invested in banking and tourism, sectors that will become drivers of economic growth. Similarly, Jordan has opened up its economy, giving a boost to tourism, ICT and trading within the country. UAE is the second-largest economy in West Asia, having successfully diversified its economy away from oil (only 2% of GDP) into the finance and tourism sectors.

Total electricity production for West Asia in 2018 was 870,455 GWh (Table 14). However, total electricity demand in 2018 was 687,972 GWh, so electricity losses and own consumption accounted for 21% of its production.[5]

In 2018, 67.9% of the electricity was produced from natural gas, 31.3% from oil products and less than 1% from renewables (hydro, wind, solar, biomass). In the BaU scenario, in all future years the same mix for the production of electricity is assumed.

The BaU scenario considers that the supply side for electricity production would have a similar generating mix, electricity losses and own consumption. Accordingly, based on the demand projections provided in Table 13, the supply of electricity would increase to 1,322,453 Gwh in 2030 and 1,613,644 Gwh in 2050.

[5] This figure of 21% for electricity wastage and own consumption was kept constant for future years in the BaU scenario.

Table 13. Electricity demand in the BaU scenario (Gwh)

	2018	2020	2025	2030	2050	CAGR
Industry	118,057	126,955	152,245	168,091	205,103	1.7%
Transport	0	0	0	0	0	
Households	296,070	314,101	364,129	402,028	490,551	1.6%
Services	264,258	300,855	416,082	459,388	560,541	2.4%
Agriculture	9,586	10,731	14,225	15,706	19,164	2.2%
Total	687,972	752,641	946,681	1,045,213	1,275,358	1.9%

Table 14. Electricity Production in Base Year (2018)

	Electricity production(Gwh)	Share of production
Total	**870,455**	
Fossil fuels	**863,662**	**99.2%**
Lignite	-	0.0%
Coal	-	0.0%
Oil	272,634	31.3%
Natural Gas	591,028	67.9%
Nuclear	-	0.0%
Renewables	**6,793**	**0.8%**
Hydro	2,567	0.3%
Wind	748	0.1%
Solar	3,474	0.4%
Biomass	4	0.0%
Geothermal	-	0.0%

The decarbonization of electricity production can happen in two ways, by shifting to non-fossil sources of energy, or by using fossil fuels in conjunction with carbon capture and storage (CCS). In terms of non-fossil fuel sources, it could be by using renewables or nuclear. Since some countries in West Asia are pursuing nuclear power on the basis of ongoing plans, 5600 MW of nuclear power will be added in 2025 in CPS and further increased to 8400 MW in ECAS by 2050. However, the main strategy for decarbonizing the power sector is the transition to renewable energy.

4.2. Electricity imports and exports

West Asian countries have very limited electricity trade between them with the exception of Iraq (Figure 5). The overall trade in electricity is less than 5% of the demand of electricity and it is mostly because of Iraq, which imports mostly from Iran and is looking at diversifying its sources of supply.[6] This lack of trade is due to a lack of grid interconnections across the region that could enable electricity to be transferred. In the past, since most electricity production was based on fossil fuels, electricity production could be located close to the demand centers. However, with a shift to renewables, production will be located where there is potential, and output need not always be aligned with demand. Hence investments in grid interconnections would be needed.

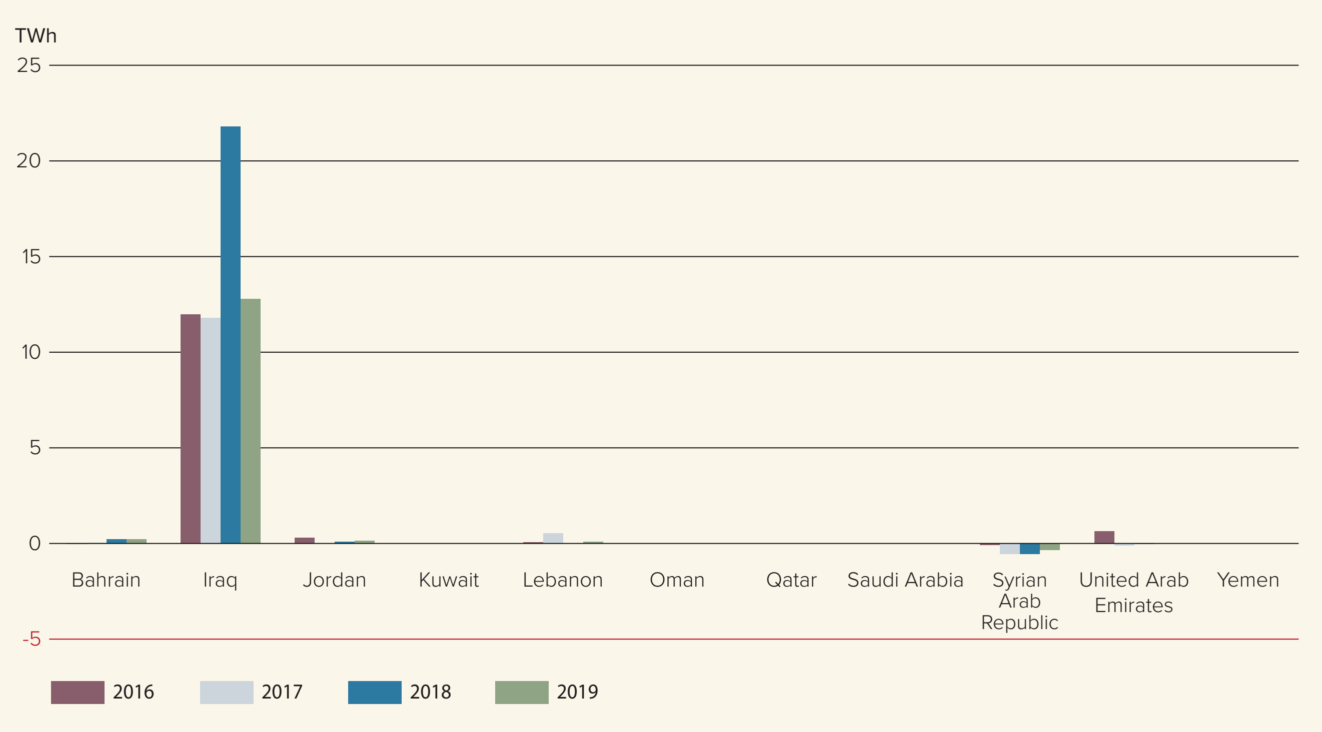
4.3. Deployment of renewable energy technologies in the CPS and ECAS

At the end of 2018, total power production in the West Asia region was around 870 TWh, of which only about 7 TWh, or 0.7 percent, was by renewables (Table 14), in contrast with the average of 25 percent of global electricity generation for the world in 2018. The year 2018 also saw the total renewable capacity in West Asia reach 6602 MW, with a large part being from hydro and solar.

The West Asia region shows great potential for many renewable sources, in particular solar, wind and to a lesser extend hydro and geothermal. All countries in the region have high average solar energy potential (Figure 6), with some of them, such as Yemen and Saudi Arabia, having among the highest potentials in the world. In Saudi Arabia, for example, the annual average daily global horizontal irradiation (GHI) ranged from about 5700 Wh/m^2 to 6700 Wh/m2, while the annual average daily daily normal irradiance (DNI) ranged from about 4400 Wh/m2 to over 7300 Wh/m2 (Zell et al.

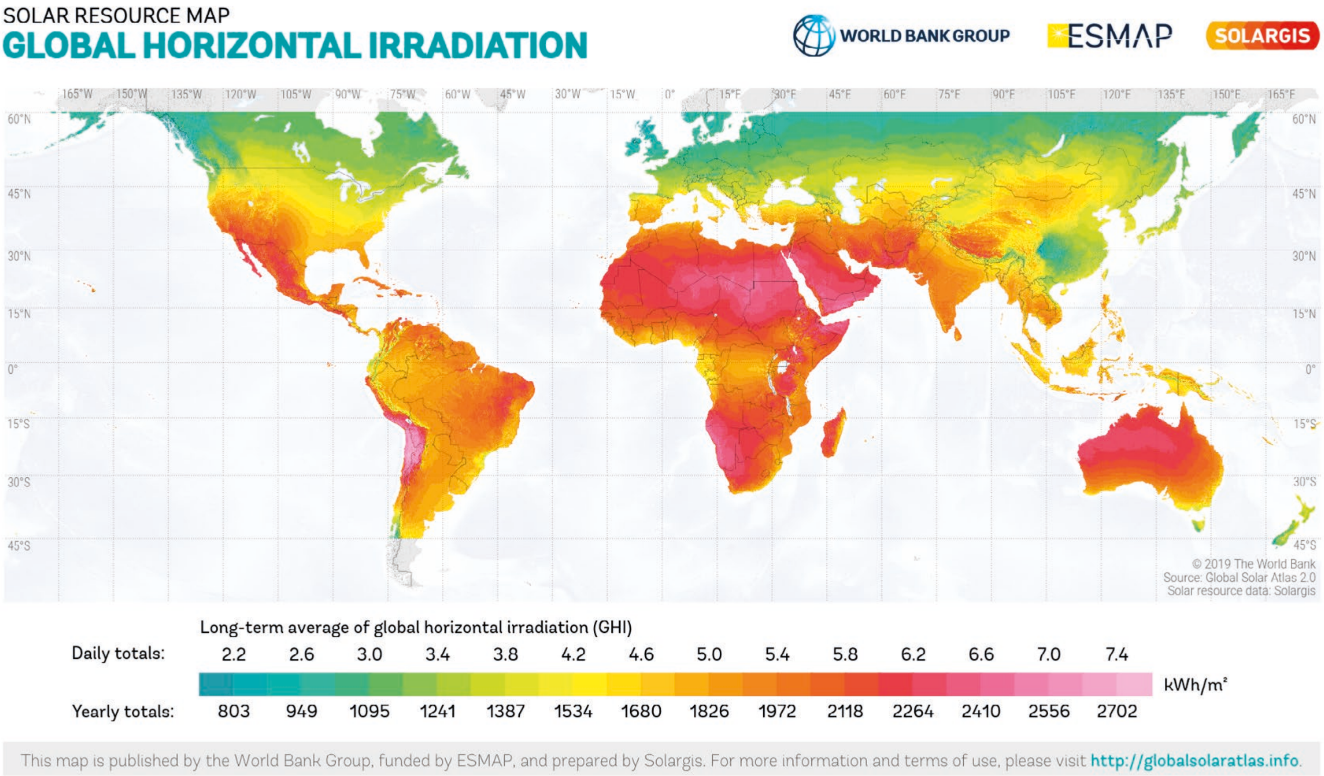
[6] Lizzie Porter in Iraq Oil Report, "Iraq seeks to diversify power imports as Iran tightens supply" 8 Dec 2021: https://www.iraqoilreport.com/news/iraq-seeks-to-diversify-power-imports-as-iran-tightens-supply-44273/

Figure 5. Net electricity imports



Source: GACMO analysis.

Figure 6. Solar Resource Potential



Source: Global Solar Atlas 2.0, World Bank Group (https://globalsolaratlas.info/download/world)

2015). This makes these countries perfectly suitable for producing photovoltaic (PV) power and generating concentrated solar power (CSP). Different studies have confirmed that the technical potential for both technologies is high in all twelve countries. In Saudi Arabia, for example, the technical potential for generation with CSP has been estimated at around 125260 TWh/yr, while in Oman and UAE it has been estimated at around 20611 TWh/yr and 5143 TWh/yr respectively (Alnaser et al. 2007).

In addition to solar, many countries in the West Asia region have significant wind potential, in particular for offshore wind. For example, the technical potentials for offshore wind energy in Oman, Yemen and Saudi Arabia are 179 GW, 158 GW and 106 GW respectively (Energy Sector Management Assistance Program [ESMAP] 2020).

In the past, the high cost of renewable energy technologies, such as solar panels and wind turbines, made them unattractive to investors. The economics of renewable energy, however, are changing. Dramatic reductions in the cost of renewable energy and rapid innovations in smart grids, storage and connectivity are driving large-scale clean energy investments (ESMAP 2020). In many cases, the price of wind and solar PV already competes with that of conventional energy resources, especially when subsidies for fossil fuels are taken into account.

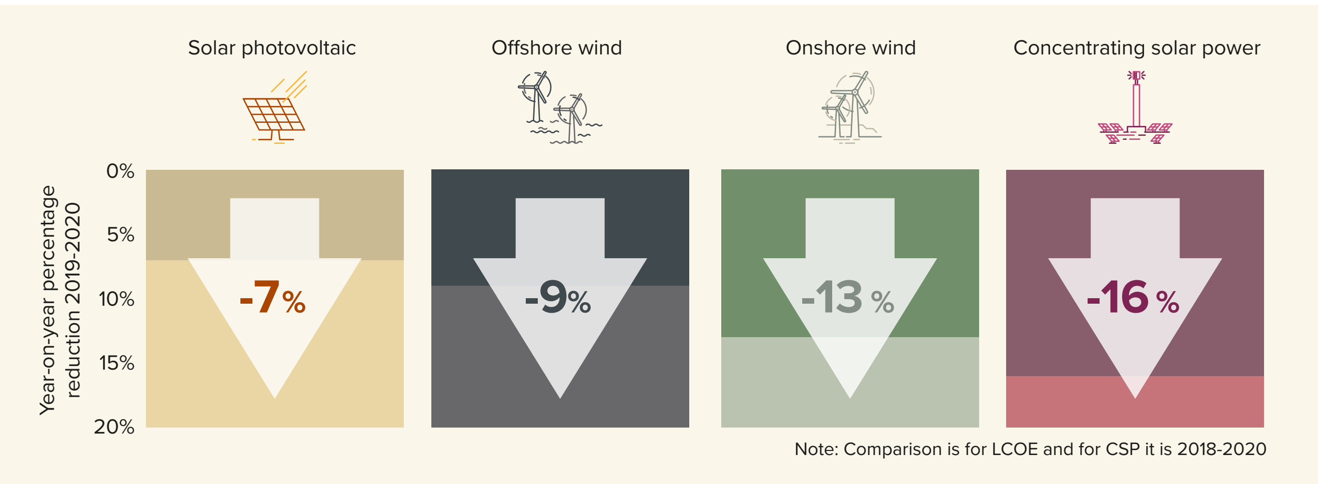
A look at global trends in the levelized cost of electricity generation (LCOEs) indicates that, on purely economic grounds, it will be increasingly difficult to justify investments in power generation using fossil fuels. In 2020, the global weighted-average LCOE from new capacity additions of offshore wind fell by 9% and that of utility-scale solar photovoltaics (PV) by 7% compared to 2019 (Figure 7).

The IRENA report on renewable power generation costs in 2020 (International Renewable Energy Agency [IRENA] 2021) shows that:

- The global weighted-average LCOE of utility-scale PV plants declined by 85% between 2010 and 2020, from USD 0.381/kWh to USD 0.057/kWh.
- The global weighted-average LCOE of newly commissioned CSP plants fell by 68% between 2010 and 2020, from USD 0.34/kWh in 2010 to USD 0.108/kWh.
- The global weighted-average LCOE of offshore wind fell 48% between 2010 and 2020, from USD 0.162/kWh to USD 0.084/kWh.

These global trends, showing a decline in the generating costs for renewable power, are also observed in the West Asia region. In April 2020, the Emirates Water and Electricity Company (EWEC) awarded a consortium of EDF and JinkoPower the contract for the world's largest solar power

Figure 7. Global weighted average LCOE of new utility-scale solar and wind projects



Source: IRENA 2021

Table 15. Renewable capacity in CPS

Reduction option	Sub-type unit	in 2020	in 2025	in 2030	in 2050
Biomass power from biomass residues	1 MW CHP plant	2	300	500	1,000
Geothermal power	1 MW		160	160	160
Hydro-power connected to main grid	1 MW			140	560
Solar water heater, residential	1,000 locations	3,800	4,236	4,722	6,700
Solar PVs, large grid	1 MW	10,400	29,800	70,000	200,000
Wind turbines, onshore	1 MW	1,200	7,125	13,000	36,000

Table 16. Renewable capacity in ECAS

Reduction option	Sub-type unit	in 2020	in 2025	in 2030	in 2050
Biomass power from biomass residues	1 MW CHP plant	2	300	500	1,000
Geothermal power	1 MW		160	160	160
Hydro-power connected to main grid	1 MW			140	560
Nuclear power plant	1,000 MW		5.6	8.4	8.4
Solar water heater, residential	1,000 locations	3,800	4,236	4,722	6,700
Solar PVs, large grid	1 MW	10,400	35,573	70,000	200,000
Solar PVs, large grid with 24h storage	1 MW		70,000	100,000	200,000
Solar tower CSP, with storage	1 MW		20,000	50,000	150,000
Wind turbines, onshore	1 MW	1,200	7,125	13,000	36,000
Wind turbines, offshore	1 MW		10,000	50,000	100,000

plant, producing 2 GW of solar PV at a levelized price of USD¢ 1.35/kWh for a 30-year contract.[7] Then, in April 2021, Saudi Arabia awarded a consortium a contract for the 600 MW Al Shuaiba PV project, with a levelized price of USD¢ 1.04/kWh for a 25-year contract.[8]

In the BaU scenario, since electricity demand is expected to grow at 1.9% over the period 2018-2050 (Table 13), and since the generating mix is assumed to remain the same in the future, the renewable capacity would reach 11,876 MW in 2050. In comparison, within the CPS and ECAS, substantial renewable capacity additions are assumed.

Current Policy Scenario (CPS)

The renewable capacity considered under the CPS to 2030 is based on the ambitions expressed in the NDCs and national economic diversification strategies of the selected countries. Beyond 2030, the historical trends in renewable capacity addition have been extrapolated ensuring that overall capacity additions do not exceed the demand for electricity. The renewable capacity additions assumed in the CPS are shown in Table 15.

Enhanced Climate Action Scenario (ECAS)

The ECAS has a more ambitious agenda for renewables (Table 16). This scenario assumes additional renewable capacity beyond what is stated in the NDCs and national economic diversification strategies of the selected countries.

7 https://www.ewec.ae/en/media/press-release/ewec-announces-partners-develop-worlds-largest-solar-power-plant
8 https://www.acwapower.com/annualreport2020/pdf/ACWA_AR20_full_en.pdf

Table 17. Mitigation measures for the electricity sector: costs and CO_2 reduction potentials (2030 & 2050)

a) CPS

Reduction option	US$/ton CO_2 2030	kt CO_2/yr 2030	US$/ton CO_2 2050	kt CO_2/yr 2050
Biomass power from biomass residues	- 160	1,607	- 176	3,214
Geothermal power	- 211	649	- 226	649
Hydro-power connected to main grid	- 286	356	- 286	1,426
Nuclear power plant	46	28,348	46	28,348
Solar water heater, residential	- 299	9,854	- 299	13,981
Solar PVs, large grid	- 261	89,993	- 294	257,123
Wind turbines, onshore	- 282	20,891	- 289	57,853

b) ECAS

Reduction option	US$/ton CO_2 2030	kt CO_2/yr 2030	US$/ton CO_2 2050	kt CO_2/yr 2050
Biomass power from biomass residues	- 160	1.607	- 176	3,214
Geothermal power	- 211	649	- 226	649
Hydro-power connected to main grid	- 286	356	- 286	1,426
Nuclear power plant	46	42,522	46	42,522
Solar water heater, residential	-299	9,854	- 299	13,981
Solar PVs, large grid	- 261	89,993	- 294	257,123
Solar PVs, large grid with 24h storage	- 178	128,562	- 182	257,123
Solar tower CSP, with storage	381	64,281	381	192,842
Wind turbines, onshore	- 282	20,891	- 289	57,853
Wind turbines, offshore	- 209	102,849	- 252	205,698

4.4. Costs of mitigation options and reduction potentials

The GACMO analysis is based on a pairwise comparison of a mitigation technology with a base case technology. Table 17 provides an overview of the mitigation costs and emissions reduction potentials by 2030 and 2050 respectively for each technology considered under the CPS and the ECAS.[9]

Table 17 shows that all renewable technology and most of the energy efficiency technology options have negative mitigation costs calculated on the basis of investment costs, operating and maintenance costs, and fuel costs. These options would then provide revenues if the associated barriers were removed and these technologies were implemented at scale. In terms of emission reduction potentials, energy efficiency in industry, solar PV and wind energy are the three options with the largest mitigation potentials.

[9] All the technical data and cost data relative to each technology used to perform the calculation with GACMO can be obtained by writing to the authors.

5. Economics of decarbonizing of passenger transport sector

Transport is second biggest contributor to CO_2 emissions after the power sector (Table 5). The focus in this chapter will be on road transportation, since it accounts for bulk of the emissions.

5.1. Demand for transportation

The region has shown an overall growth from 16 million vehicles to 21 million vehicles at 6% CAGR between 2010 and 2015 in vehicles (Table 18). Data beyond 2015 were not available for all the selected countries, and the data that were obtained from Oman and Jordan were used to validate the data available from International Organization of Motor Vehicle Manufacturers [IOMVM] 2015. Vehicle ownership has increased from 119 per thousand to 143 per thousand (Table 18). It is assumed that this trend will continue and that vehicle ownership will increase at similar growth rates and converge by 2050 with the vehicle ownership figures of more than 500 per thousand observed currently in developed countries (IOMVM 2015).

Data available from IOMVM were also separately available for cars. These data show that the share of cars increased from 60% to 65% in the period 2010 to 2015. The data shared by Oman and Jordan showed that the shares of four-wheelers (sedans, SUVs, etc.) were 88% and 72% respectively (Table 19).

The growth in vehicle populations is projected based on two drivers: population, and vehicle ownership levels. Population growth is based on UN Population projections

Table 18. Vehicle Population Trends

Overall (number)	2010	2011	2012	2013	2014	2015
Bahrain	443,225	464,821	489,277	524,727	552,553	578,471
Iraq	2,690,000	3,065,483	3,340,562	3,502,000	3,670,000	3,900,000
Jordan	805,000	941,000	984,000	1,025,791	1,070,000	1,130,000
Kuwait	1,445,515	1,519,632	1,605,789	1,706,178	1,791,905	1,876,188
Lebanon	546,000	553,085	578,000	610,100	650,000	683,000
Oman	680,000	740,000	810,000	860,000	920,000	980,000
Palestine	221,000	264,000	307,000	340,030	385,000	405,000
Qatar	730,000	800,000	870,000	907,020	960,000	1,020,000
Saudi Arabia	4,870,000	5,280,000	5,702,889	5,950,000	6,240,000	6,600,000
Syrian Arab Republic*	1,559,465	1,530,195	1,501,475	1,473,293	1,445,640	1,418,507
UAE	1,439,508	1,563,142	1,681,000	1,827,000	1,960,000	2,140,000
Yemen	759,000	800,000	850,000	905,565	950,000	1,000,000
Total West Asia	**16,188,713**	**17,521,358**	**18,719,992**	**19,631,704**	**20,595,098**	**21,731,166**
Vehicle per 1000	**119**	**127**	**133**	**136**	**140**	**143**
% share of Cars	60%	61%	62%	63%	64%	65%

Source: IOMVM 2015 for all except Syrian Arab Republic. Syrian data has been estimated using a vehicle ownership of 73 vehicles per 1000 persons (http://mecometer.com/topic/vehicles-per-thousand-people/)

Table 19. Vehicle Mix in Countries

	Oman	Jordan
4 Wheelers	88%	72%
2 Wheelers	1%	0%
Bus	3%	2%
Trucks & Tankers	5%	23%
Miscellaneous	2%	4%

Source: vehicle registration data for Oman (Year 2015) and Jordan (2017).

(United Nations Department of Economic and Social Affairs [UNDESA] 2019), whereas the growth in vehicle ownership is different in the two scenarios. In the CPS, the growth in vehicle ownership follows the growth observed for the period 2010 to 2015, and by 2050 vehicle ownership reaches 506 vehicles per 1000 (Table 19). Vehicle ownership in 2050 is around the levels we can witness currently in the EU (IOMVM 2015). Based on these two drivers, in CPS the vehicle population will quadruple from 29 million in 2020 to around 128 million in 2050. A major contributor to the growth of the vehicle population would be private four-wheelers (sedans, SUVs, etc.), which will increase their share from 65% in 2020 to 85% in 2050 (Table 20).

A number of countries in West Asia as a part of their NDC and economic diversification strategies (Section 7.1) are trying to reduce dependence on cars and improve their public transportation systems (bus rapid transit, metro, etc.), along with improved city planning promoting walking and cycling. Additionally, undertaking gender analysis in infrastructure projects to improve understanding of the specific concerns for both women and men is crucial. In many parts of the world, women may not benefit fully from improved transport systems due to safety concerns and other cultural contexts, ultimately impacting on efforts to improve the use of public transportation systems (Asian Development Bank [ADB] 2019). The ECAS assumes ambitious implementation of public transportation projects along with better city planning, which will slow down the demand for private cars, arriving at 1% slower growth of vehicle ownership. As a result, vehicle ownership in 2050 would be around 255 per 1000 persons which is around half of the EU figure (IOMVM 2015). Based on growths in population and vehicle ownership, the vehicle population in ECAS will double from 29 million in 2020 to around 64 million in 2050. In addition, this scenario considers that the share of four-wheelers will also be a little lower than in the CPS. In contrast, the share of buses in the ECAS is considered higher than in the CPS (Table 20).

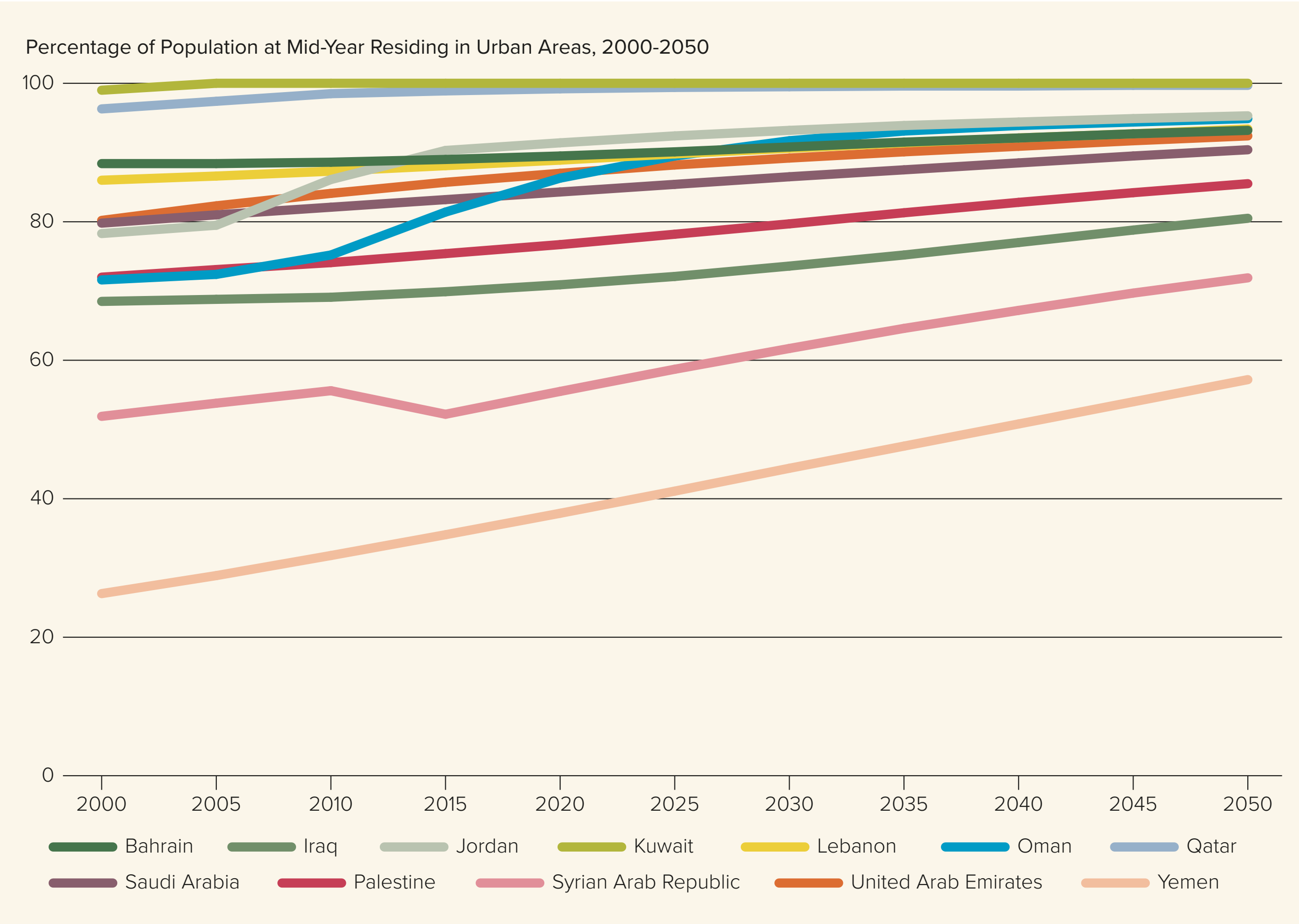
5.2. Mass Transit in the CPS and ECAS scenarios

In all the selected countries in West Asia with the exception of Yemen, a majority of population live in urban areas.

Table 20. Vehicle Population Projections

	Unit	2015	2020	2025	2030	2050
Population	000 person	151,987	168,343	186,495	202,476	253,890
Current Policy Scenario						
Vehicle ownership	Vehicles per 1000	143	171	205	246	506
Total vehicles	1'000 Vehicles	21,731	28,833	38,264	49,765	128,496
Share of four-wheelers	%	65%	70%	75%	80%	85%
Share of buses	%	3%	1%	3%	3%	3%
Enhanced Climate Action Scenario						
Vehicle ownership	Vehicles per 1000	143	171	195	223	255
Total vehicles (thousand)	000 Vehicles	21,731	28,833	36,454	45,168	64,636
Share of four-wheelers	%	65%	70%	74%	76%	80%
Share of buses	%	3%	1%	4%	5%	6%

Figure 8. Urbanization trends in West Asia



Source: UNDESA 2018

Future trends indicate that even more people will live in cities (Figure 8). Urban transport will therefore be a large component of transport-related emissions in these countries.

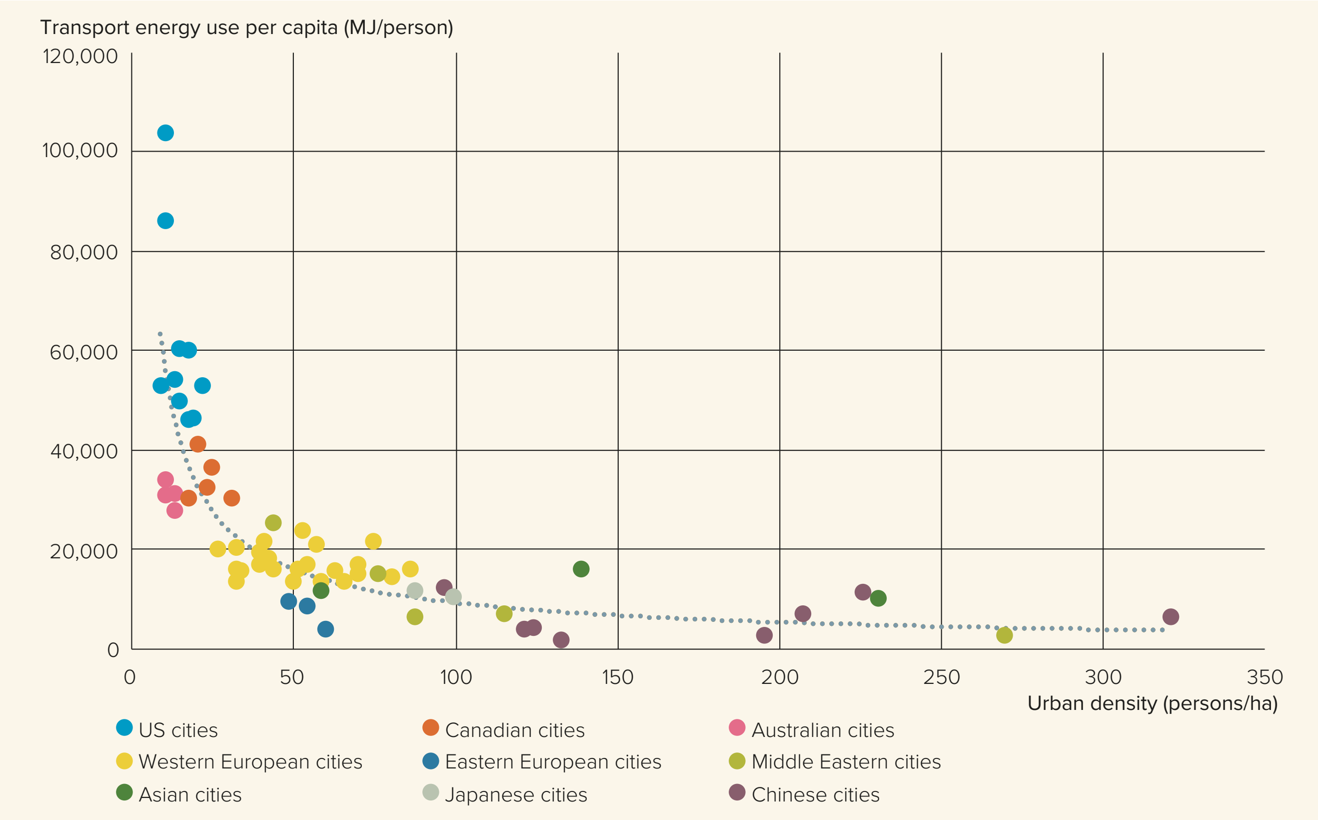
The data on vehicle ownership from Oman and Jordan (Table 19) shows that most vehicles are cars and fewer than 3% are buses. The data from IOMVM (2015) also shows that there was rapid growth in the share of private cars in the region between 2010 and 2015. Despite its large urban populations, West Asia only has a few mass-transit projects. There are two cities with functioning metro systems (Dubai and Riyadh) and only one city with a Bus Rapid Transit system. However, the potential for introducing mass-transit systems in West Asian cities is large, since, in terms of their urban densities, they are closer to cities in Europe than in North America (Figure 9). European cities are characterized by good mass-transit and bus services, with around 10% to 30% of motorized trips being taken with public transport, in comparison to cities in North America, where fewer than 10% of trips happen on public transport (Newman and Kenworthy 2011).

If those trips that take place using cars can be shifted on to buses (e.g., BRT) and rail-based public transport (e.g., Metro), substantial reductions in energy use can be achieved (Figure 10).

Current Policy Scenario

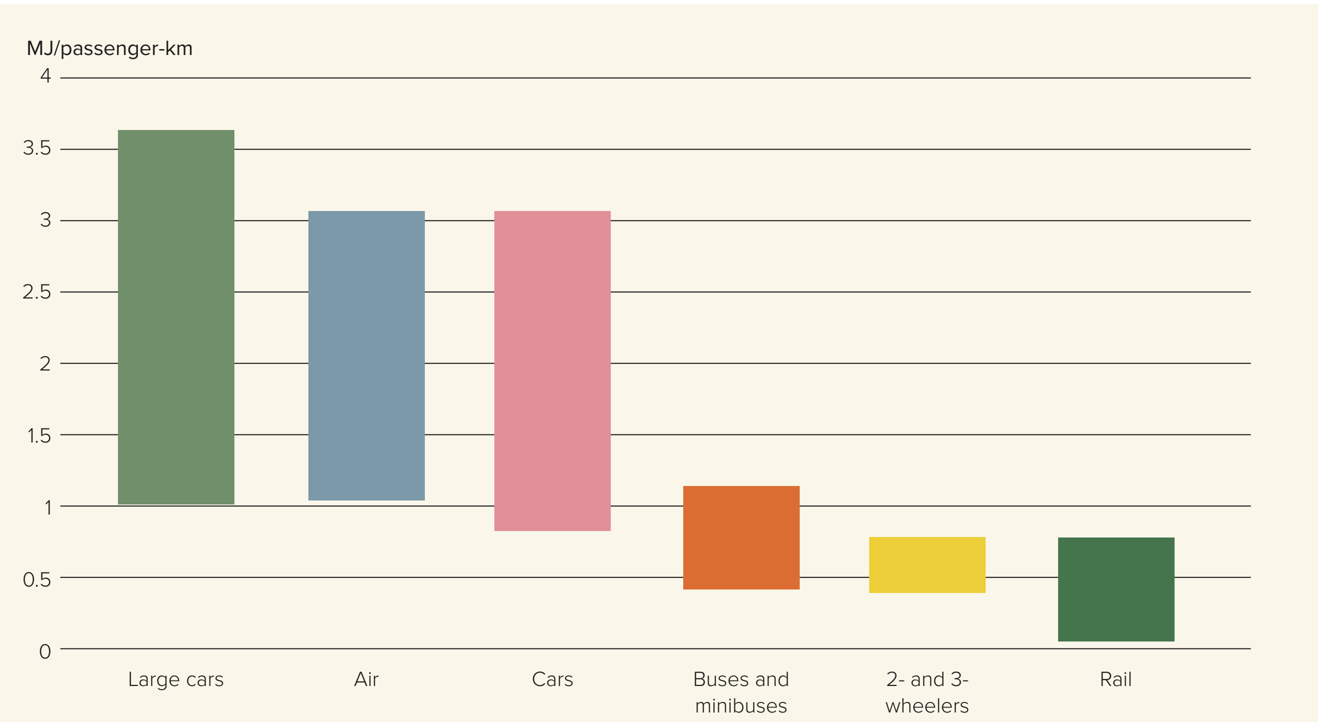
The CPS considers that countries in West Asia will follow a pattern similar to European countries. The share of private cars will increase to around 85%, and overall vehicle ownership will increase to around 500 vehicles per thousand by 2050, similar to European countries (IOMVM 2015). There will be investments in public transportation systems, in particular road-based systems, which will improve the efficiencies of public transportation systems. The CPS assumes that, besides the Amman BRT system, which is around 43 km

Figure 9. Transport energy use and urban density across cities in world



Source: Newman and Kenworthy 2011

Figure 10. Energy use per passenger km for different modes in passenger transportation



Source: Salvucci and Tattini 2019

Table 21. BRT and Metro length across scenarios beyond existing capacities

	2025	2030	2050
CPS			
BRT Length (kms)	43	90	215
Metro Length (kms)	250	500	900
ECAS			
BRT Length (kms)	43	180	430
Metro Length (kms)	250	1000	1800

long[10], five similar BRT systems will be implemented across West Asia with an overall length of 215 km by 2050 (Table 21). Similarly, there is currently a Metro in Dubai which is around 90 km long, and there are metros under construction in Riyadh and Mecca. The CPS scenario assumes that, besides Dubai, there will be metros in ten more cities by 2050, taking the overall metro length to 900 km by 2050 (Table 21).

[10] https://bit.ly/3yrekbV

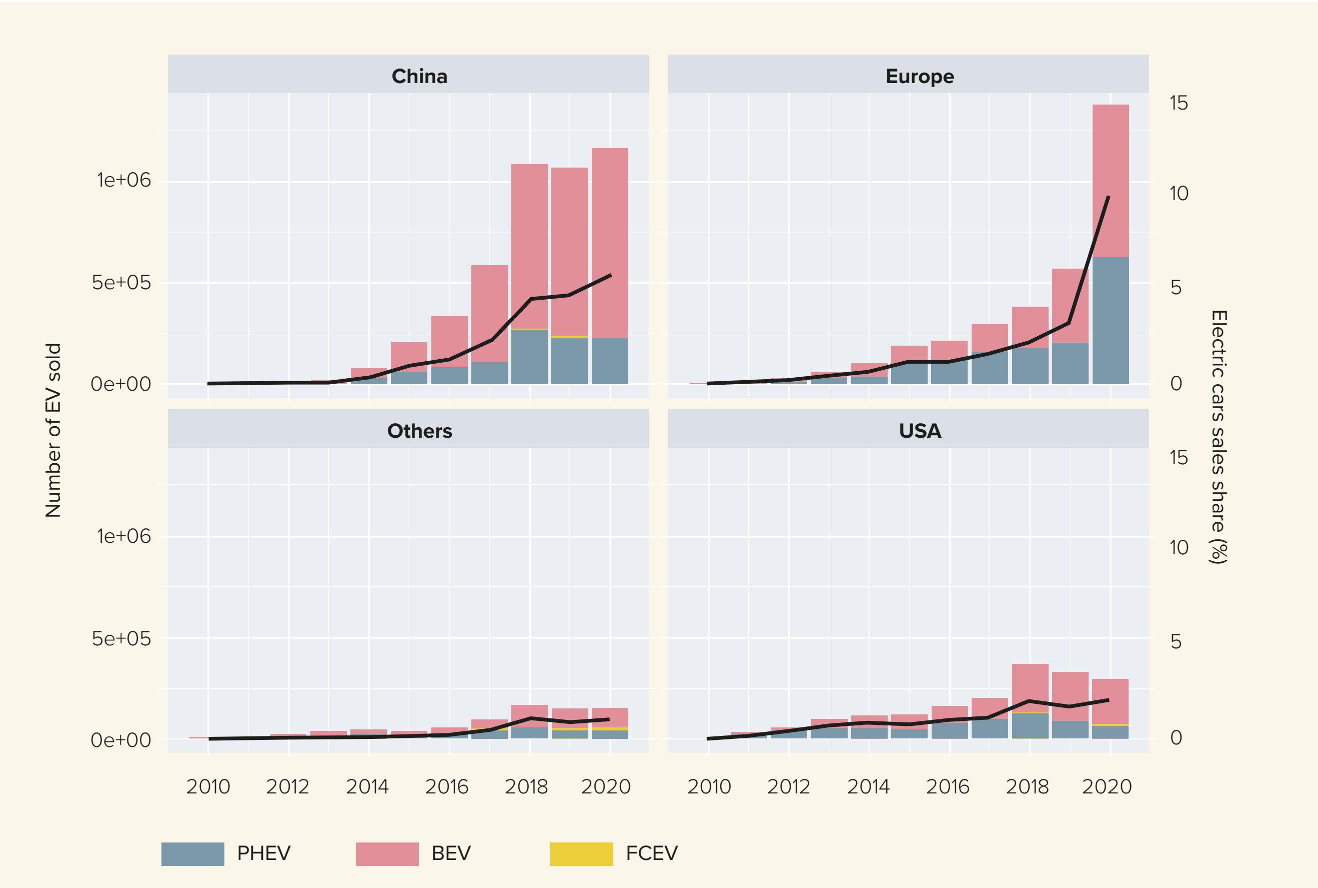
Enhanced Climate Action Scenario

In the ECAS, the ambition for BRT and Metro systems is double that in the CPS scenario (Table 21). The objective is not only to improve the efficiency of public transportation, but also to shift more people away from their cars. Therefore, the demand for vehicles will be much lower than in the CPS scenario, and the share of cars in the vehicle population will also be lower (Table 20).

5.3. Electric Mobility in the CPS and ECAS scenarios

Electrification has been recognized as one of the primary means of the decarbonization of road transportation, especially with respect to light duty vehicles (Jaramillo et al.

Figure 11. Share of EV sold across regions



Source: Global EV Database https://www.iea.org/articles/global-ev-data-explorer

Table 22. Electric Vehicles in CPS and additional demand for electricity

	Unit	2015	2020	2025	2030	2050
Current Policy Scenario						
Four-wheelers						
Electricity consumption per unit	MWh/yr per 1000 electric cars		1,560	1,443	1,326	1,092
Share of EVs	%	0%	1%	10%	25%	50%
Total electric 4W	000 Vehicles	-	202	2,870	9,953	54,611
Electricity demand 4W	GWh		315	4,141	13,198	59,635
Buses						
MWh/yr per 1000 12m buses	MWh/yr per 1000 electric buses		32,000	29,405	27,200	25,600
Share of EVs	%	0%	5%	10%	25%	50%
Total electric (thousand)	000 Vehicles	-	14	115	373	1,927
Electricity demand, Buses	GWh		461	3,375	10,152	49,342
Electricity Demand CPS	**GWh**		**776**	**7,517**	**23,350**	**108,977**

Table 23. Electric vehicles in ECAS and additional demand for electricity

	Unit	2015	2020	2025	2030	2050
Enhanced Climate Action Scenario						
Four-wheelers						
Share of EVs	%		1%	25%	50%	100%
Total electric (thousand)	000 Vehicles		202	7,079	18,911	102,796
Electricity demand 4W	GWh		315	10,215	25,075	112,254
Buses						
Share of EVs	%		5%	25%	50%	100%
Total electric (thousand)	000 Vehicles		14	365	1,129	3,878
Electricity demand, Buses	GWh		461	10,719	30,714	99,282
Electricity Demand ECAS	**GWh**		**776**	**20,934**	**55,789**	**211,535**

Table 24. Mitigation measures for transport sector: costs and reduction potentials ('000 t/year)

a) CPS

Reduction option	US$/ton CO_2 2030	kt CO_2/yr 2030	US$/ton CO_2 2050	kt CO_2/yr 2050
Bus Rapid Transit (BRT)	89	179	89	426
Electric cars	- 11	8,278	- 83	51,051
Electric 12m buses	1,420	4,673	710	28,669
Shifting passengers from car to rail	305	1,688	305	3,038

b) ECAS

Reduction option	US$/ton CO_2 2030	kt CO_2/yr 2030	US$/ton CO_2 2050	kt CO_2/yr 2050
Bus Rapid Transit (BRT)	89	357	89	853
Electric cars	- 8	21,605	- 56	142,870
Electric 12m buses	941	21,339	414	98,906
Shifting passengers from car to rail	304	3,390	304	6,075

2022). Several developed countries and China have already achieved more than a 2% share in the sale of electric vehicles (EV) (Figure 11), and worldwide the share of EVs in new cars was 4% (IEA 2020b).

EVs can emerge as a significant mitigation option if electricity is decarbonized. Since increasing renewables is the main mitigation option in the electricity sector, especially with ECAS, EVs will become a strong mitigation option.

Current Policy Scenario

In the CPS the number of electric vehicles is assumed to increase gradually to 50% of total vehicles for both four-wheelers and buses by 2050. With this number of electric four-wheelers and buses, the extra demand for electricity in 2050 will be 109 TWh for the CPS (Table 22) and represent around 6.7% of the overall demand for electricity in 2050.

Enhanced Climate Action Scenario

In the ECAS the number of electric vehicles is assumed to increase to up to 100% of total vehicles by 2050. However, in the ECAS scenario the growth in the overall vehicle population (Table 20) will be lower, so the numbers do not double in comparison to CPS. With this number of electric four-wheelers and buses, the extra demand for electricity in 2050 will be 211 TWh for the ECAS (Table 23) and around 13.1% of the overall electricity demand in 2050.

5.4. Costs of mitigation options and reduction potentials

The GACMO analysis is based on a pairwise comparison of a mitigation technology with a base case technology. Table 24 provides an overview of the mitigation costs and emissions reduction potentials by 2030 and 2050 for each technology considered under the CPS and the ECAS.[11]

Table 24 shows that, except for electric cars, all the options have positive mitigation costs and therefore will need co-financing by the government and support from international climate finance. However, these options have multiple co-benefits for the selected countries, such as positive impacts on air quality, enhanced accessibility and reduced social and economic inequalities.

[11] All the technical data and cost data relative to each technology used to perform the calculation with GACMO can be obtained by writing to the authors.

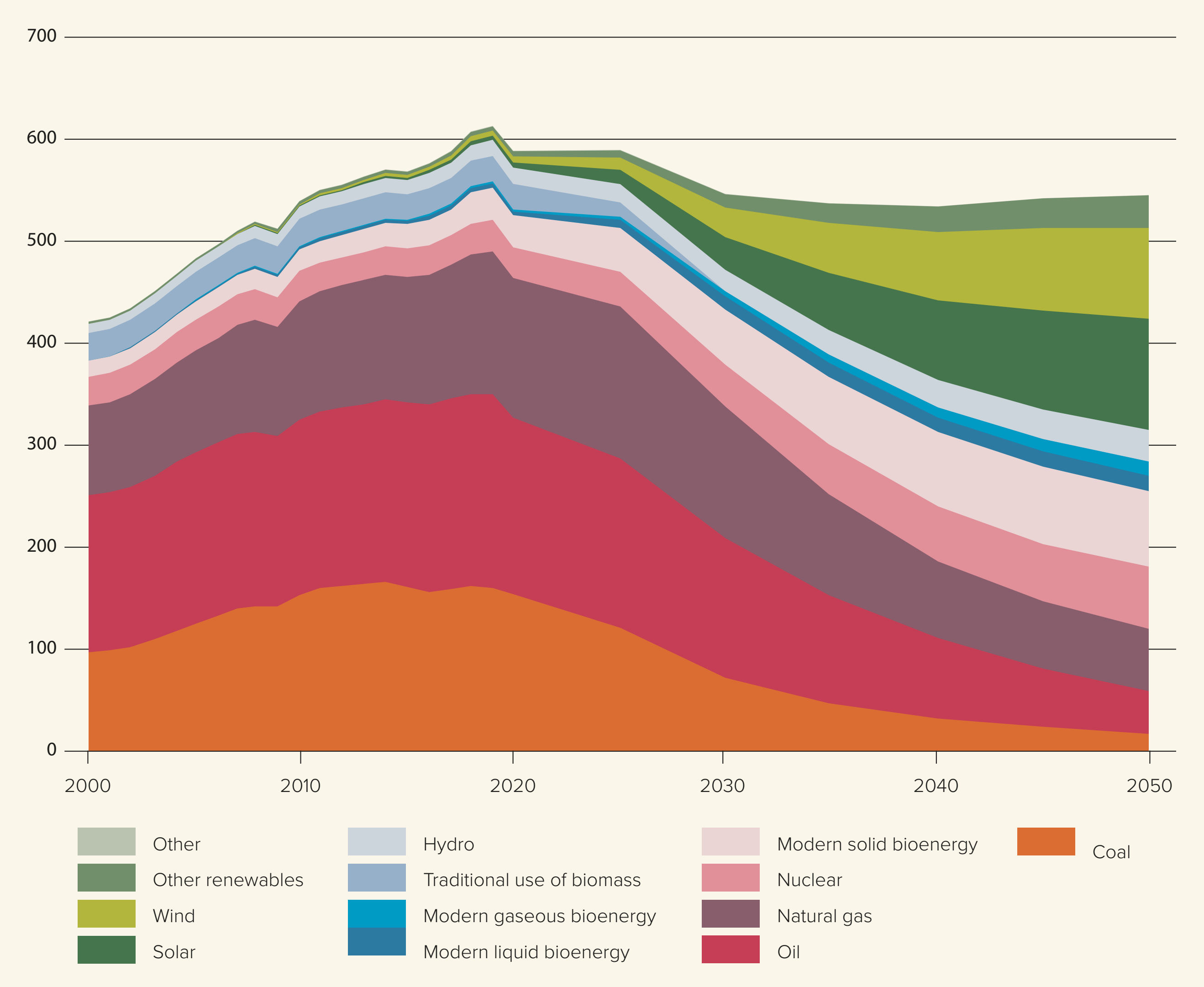
6. Economics of decarbonizing industry, services and households

Industry accounted for 25% of fossil-fuel consumption in West Asia in 2018 (Table 4), while services and households accounted for another 4% (Table 4). It is also clear from examining the national communications and BUR reports of countries that the production and processing of oil and gas have a large share of the energy sector's CO_2 emissions in several countries, ranging from 8% (Saudi Arabia) to 48% (Qatar) (Table 5). Therefore, this section looks at mitigation

Figure 12. Net oil and gas exports by countries

Source: data from ENERDATA

Figure 13. Global Demand for Primary Energy in Net Zero Scenario of IEA



Source: IEA 2021

in the oil and gas sector, followed by a discussion of what energy efficiency in industry, services and the household sector can deliver for West Asia.

6.1. Emissions reductions from oil and gas

Current Policy Scenario (CPS)

West Asia is a big exporter of oil to the world (Figure 12), with Saudi Arabia being one of the two largest exporters in the world. Other countries such as Iraq, Kuwait, Oman, Qatar and the UAE also have significant exports of oil. In addition, Oman and Qatar are large exporters of gas (Figure 12). Overall oil exports from West Asia stood at 41 EJ and gas exports at 4 EJ (ENERDATA). If we compare this with the global demand of 188 EJ for oil and 141 EJ for gas (IEA 2021), these figures work out at around 22% of oil demand and 3% of gas demand.

In the CPS we consider that West Asia continues to remain a source of fossil-fuel energy for the world and that exports of oil and gas continue at the current level of 45 EJ per annum.

Enhanced Climate Action Scenario (ECAS)

Meeting the long-term temperature goal established under the Paris Agreement requires achieving a global net-zero emissions pathway by 2050. The ECAS also envisages a net-zero scenario being achieved by the energy sector in West Asia and the world overall by the middle of the century. A

Table 25. Appliance ownership (in thousands) in BaU Scenario and efficient appliances in CPS and ECAS

Description	Assumption	2,020	2,025	2,030	2,050
Households (HH)*		31,353	34,734	37,711	47,286
		Ownership in BaU			
Refrigerators in BaU	1 per HH	31,353	34,734	37,711	47,286
Air conditioners in BaU	1 per HH	31,353	34,734	37,711	47,286
Light Bulbs in BaU	6 per HH	188,121	208,406	226,264	283,719
		Ownership of efficient appliances and LEDS			
		In CPS			
Refrigerators in CPS	20% of HH	6,271	6,947	7,542	9,457
ACs in CPS	20% of HH	6,271	6,947	7,542	9,457
LEDs in CPS	30% of HH	56,436	62,522	67,879	85,116
		In ECAS			
Refrigerators in ECAS	30% of HH	7,838	8,684	9,428	11,822
ACs in ECAS	30% of HH	7,838	8,684	9,428	11,822
LEDs in ECAS	40% of HH	75,248	83,362	90,506	113,487

* The number of households calculated using an average household size of 5.4, using data from the UN Population Division for 2018.

global transformation to net-zero scenarios for the energy sector will have a direct impact on the demand for oil and gas (Figure 13).

The global demand for oil and gas in 2050 will be one third of global demand in 2020 (Figure 13). All the oil and gas exports to the rest of the world from West Asia are thus assumed to stop by 2050. As a result, the production and processing of 41 EJ of oil and 4 EJ gas will come to an end by 2050. Assuming a loss of 6%[12] in the production and processing of oil and gas, around 2.6 EJ of oil and 0.26 EJ gas will be saved. This will deliver a reduction of 192.5 million tCO_2 from oil and 14.5 million tCO_2 from natural gas, or 207 million tCO_2 overall by in 2050.

6.2. Energy efficiency measures in the CPS and ECAS scenarios

Energy efficiency is one of the principal ways of reducing CO_2 emissions in the energy sector. Energy efficiency measures are typically described as least cost and quickest to implement (Shove 2018), and are sometimes referred to as 'no-regrets' options. However, despite their apparent benefits, households and professionals do not always take up energy efficiency measures, and due to rebound effects, they cannot lead to the expected energy savings (Shove 2018).

The CPS and ECAS include five mitigation options that will contribute towards reducing the demand for energy (Table 10). These are energy efficiency in industry, energy efficiency in services, efficient residential air-conditioning, efficient refrigerators, and efficient lighting with LEDs.

Current Policy Scenario (CPS)

Energy efficiency in the industry and service sector can be achieved through multiple technology and policy interventions (e.g., more efficient engines, improved control systems, improved metering, rationalized tariffs, etc.). The technical potential for the reduction of CO_2 emissions using energy efficiency from industry is estimated to be around 25% (Fischedick et al. 2014). Therefore, very conservatively, this study assumes that CO_2 emissions reductions of 10% can easily be achieved by the industry and service sector for West Asia in the CPS.

[12] The losses calculated as the difference between energy supply and final energy consumption, using global energy balances for 2010, 2019 and 2020 show a loss of around 6% for oil and around 10% for gas (IEA 2021).

Table 26. Mitigation measures for energy efficiency: abatement costs and reduction potentials ('000 t/year)

a) CPS

Reduction option	US$/ton CO_2	kt CO_2/yr	US$/ton CO_2	kt CO_2/yr
Efficient residential air-conditioning	- 237	8,021	- 237	10,057
Efficient lighting with LEDs	- 272	7,194	- 272	9,020
Efficient refrigerators	- 38	9,748	- 38	12,223
Energy efficiency in industry	1	37,164	1	45,347
Energy efficiency in services	1	4,446	1	4,446

b) ECAS

Reduction option	US$/ton CO_2	kt CO_2/yr	US$/ton CO_2	kt CO_2/yr
Efficient residential air-conditioning	- 462	5,145	- 462	6,452
Efficient lighting with LEDs	- 530	4,922	- 530	6,172
Efficient refrigerators	- 43	10,660	- 43	13,366
Energy efficiency in industry	1	133,789	1	226,733
Energy efficiency in services	1	16,006	1	22,230

High per-capita incomes and hot climatic conditions result in high levels of ownership of both refrigerators and air-conditioners. However, ownership rates for refrigerators and air-conditioners for the twelve countries in West Asia were not available. For this publication, an ownership rate of one refrigerator per household for the entire region was assumed, since developed countries have ownership rates of more than one per household (Cabeza et al. 2018). The air-conditioner ownership rate was fixed at a similar level.

The CPS envisages 20% of air-conditioners shifting from conventional air-conditioners with a Coefficient of Performance (COP) of 2.67 to ones with a COP of 4. In addition, this scenario envisages that there will be around 9.5 million efficient air-conditioners in use by 2050 (Table 25). The CPS also envisages 20% of refrigerators shifting from a conventional refrigerator with a power rating of 200 watts to ones with a power rating of 130 watts and that 9.5 million efficient refrigerators will be in use by 2050 (Table 25). In the case of light bulbs, the CPS assumes that inefficient light bulbs will be replaced in 30% of households and that 85 million LEDs will replace conventional bulbs by 2050 (Table 25).

Enhanced Climate Action Scenario (ECAS)

The ECAS assumes that energy consumption in industry and services will be reduced by 36% in 2030 (from 10% in CPS), as in the EU,[13] and to 50% in 2050 (from 10% in CPS).

The share of both efficient residential air-conditioners and refrigerators will be increased to 30% in the ECAS instead of to 20% in the CPS, so that 11.8 million units of each will be in use in 2050 (Table 16). In the case of light bulbs, ECAS assumes that inefficient light bulbs will be replaced in 40% of households and that 113 million LEDs will replace conventional bulbs by 2050 (Table 16).

6.3. Costs of mitigation options

The costs of all the energy efficiency options for lighting and cooling show negative mitigation costs and a high potential for mitigation (Table 26). Energy options for industry and the service sector are again low-cost and can therefore be implemented with limited climate financing, thus reducing the risks for the private sector and leveraging private capital.

[13] In the EU the target is to have a 32.5% reduction in energy compared to a baseline. https://ec.europa.eu/energy/topics/energy-efficiency/targets-directive-and-rules/eu-targets-energy-efficiency_da

7. Economic Diversification and Green Growth

Several countries in West Asia rely on revenues from fossil-fuel exports (Figure 11). Oil and gas demand and prices are expected to come down in future due to decarbonization strategies being pursued by countries across the world (IEA 2021). West Asian countries are cognizant of this reality and are pursuing economic diversification and green growth strategies.

Pursuing the decarbonization of power generation and transport provides an opportunity to invest in renewable energy, electric vehicles and clean technologies. These investments can create jobs, develop an industrial base and create skills in the region for the technologies of the future. Furthermore, taking into consideration the "Leave No One Behind" ambition of Agenda 2030, decarbonization and access to clean energy are key enablers and drivers of socially and economically inclusive, sustainable and resilient economic growth (Bhattacharyya 2019), which are integral for a just transition to a net zero-emissions energy system.

7.1. Synthesis of economic diversification strategies

Diversification strategies in the power sector

A synthesis of the NDCs, national plans and other national documents by the selected countries in West Asia[14] show that most countries have targets for renewable energy (Table 27) and that, even for those countries where no clear targets are provided, there are a number of renewable energy projects being implemented or planned (Annex 1). Renewable energy development is thus a high priority in the diversification plans of the West Asia region, which has a huge and obvious technical potential for renewable energy technologies, in particular solar energy (Figure 5).

Diversification strategies in the transport sector

Vehicle ownership shows wide variations across countries in West Asia (Table 18). Examination of data on the vehicle mix in a few countries shows that a large share of these are

[14] See Annex 1 for a list of projects identified across the different countries in West Asia.

Table 27. Targets for renewable and clean energy

Country	Share Targets	Capacity Targets
Bahrain	Planned national target of 5% renewable by 2025	255 MW
Iraq	Planned national target of 40% renewable by 2028	5000 MW Solar, 1000 MW Wind and 200 MW Bioenergy
Jordan	Planned national target of 31% renewable by 2030	3200 MW
Kuwait	Planned national target of 15% renewable by 2030	
Lebanon	Planned national target of 30% renewable by 2030	
Qatar	Planned national target of 20% renewable by 2030	
Saudi Arabia		Planned target of 58.7 GW renewable by 2030
United Arab Emirates	Planned target of increasing share of clean energy from 25% to 50% in 2050 (44% renewable and 6% nuclear)	

Table 28. Policy Actions in Transport Sector

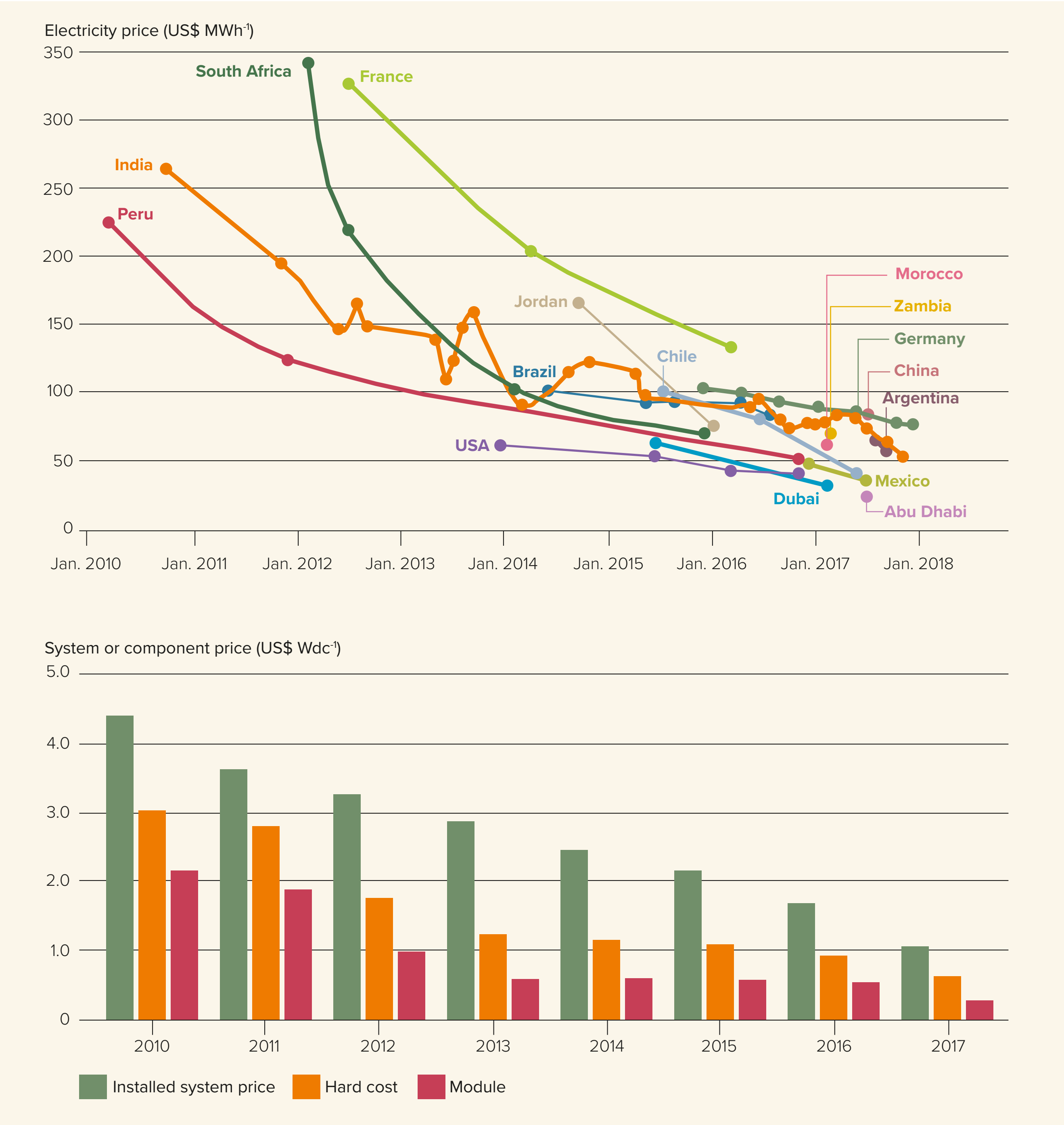
Country	Policy Actions	Projects
Bahrain	Reduce traffic time for vehicles	
	Create bus routes	
	Improve railways	GCC Railway Project
	Metro Light Rail	Bahrain Metro Project (Planned)
Iraq	Shifting to public transport from private transport	Increase buses to nearly 1500 in Baghdad
	Enacting and enforcing the Sustainable Transport Law,	
	Building modern railways alongside roads	
	Using planes with more efficient engines and operating systems in terms of fuel consumption	
	Using higher quality fuel with the least emission levels in vehicles	
	Increasing port terminals from 46 in 2018 to 83 in 2022	
Jordan	Increasing the total number of commuters using public transport as a percentage of the total number to 25% by 2025	
	Implement an intelligent transport system (ITS)	
	Introduction of the Zero Emission Electric Vehicle (ZEV) in Jordan (including public charging)	
	Reduce vehicle km	
	Implement BRT systems	BRT Amman
	Implement railway systems	
	Improve fleet efficiency	
	New infrastructure at Aqaba port	
Lebanon	Incentives to EVs	
	Fuel-efficient vehicles	
	Revive public transportation	
Qatar	Improve emissions standards for vehicles	
United Arab Emirates	Fuel-pricing policy in line with global standards	
	Freight rail network (across country and GCC)	
	Shift 25% of government fleet to CNG	
	Light rail and metro systems	Dubai Metro project
Saudi Arabia	Urban planning to promote mass transit	

four-wheelers (Table 19). A very small share of the vehicle population are commercial buses.[15] A few cities are now going for BRT systems (Amman) and metro systems (Doha, Dubai & Riyadh). Overall, there is limited public transportation, and this has meant a high dependence on cars for passenger transportation. Similarly, there is high reliance on trucks, tankers and trailers to transport goods. However, a large share of freight is in the transportation of oil (crude and refined oil) through a network of pipelines, which are of benefit in being an efficient means of transport.

With regard to the transport sector, the selected countries, as part of their NDCs and NDPs, have proposed a wide range of policy actions that can help shift the demand for passenger and freight transportation to less CO_2-intensive modes and improving the efficiency of the modes themselves. In addition, some countries have projects under active consideration (Table 28). However, in the case of transport sector – unlike the power sector, where a large number of projects

[15] Based on Vehicle Registration Data for Oman, Jordan (data awaited for other countries)

Figure 14. Evolution of PV system and electricity prices



Source: Apostoleris et al. 2018

that have been implemented or are planned for future are found – there are limited interventions ready for implementation.

7.2. How diversification strategies can lead to higher climate ambitions

The diversification strategies being pursued are at the core of the decarbonization that has been achieved thus far within the West Asia region, and rightly so.

The CPS is based on full implementation of economic diversification strategies within the energy sector. As shown in Figure 3, CPS can limit the growth of CO_2 emissions. However, a more ambitious implementation of mitigation options, as envisaged in the ECAS, is needed to achieve a net-zero energy sector.

The ongoing implementation of clean and renewable energy projects has resulted in price discovery for grid-scale renewable energy projects (Figure 14). With a price below US 3 cents per kWh, solar PV projects are now cost-competitive with gas- and coal-based power projects (Apostoleris et al. 2018).

Besides reductions in hardware costs over time (Figure 14), the low costs of electricity from solar projects in the UAE and Saudi Arabia are due to the implementation of projects on a large scale (through economies of scale), innovative contracting models (long terms for power purchase agreements), tax incentives, zero transmission costs (borne by utilities) and free land for projects (Apostoleris et al. 2018). It can be questioned whether all the incentives can be sustained for a scaled-up ambition. However, current prices give a lot of confidence that renewables can be scaled up to achieve a net-zero energy sector.

In the case of the transportation sector, only a few projects have been implemented. Therefore, it is difficult to conclude whether the experience of these projects will enhance the ambition for implementing similar projects in West Asia. The most prominent project among them is the Dubai Metro, which came into operation in 2009 and had a daily ridership of around 353,244 in 2017. The Metro had taken the share of public transport in Dubai to 16%[16] in 2017. The Riyadh Metro is the second metro project in West Asia, with a total system length of 176 km;[17] it is planned for completion in 2021. Bahrain is currently planning a metro system, the first phase being 29 km long.[18] The BRT system in Amman is another project that has attracted a lot of attention. It was announced in 2009 but has not yet been implemented. Once completely operational, it is expected to carry around 315,000 passengers per day.[19] It aims to improve the share of public transportation in Amman to about 40% by 2025.[20] Overall, the achievement of public transportation in the West Asia region is not great. However, growing congestion on the roads may push some of the larger cities in the region towards mass transit systems. This would definitively support increasing the climate ambition in the region and achieving a net-zero energy sector.

7.3. Impacts of mitigation options on jobs

It has been argued that investments in the transition to a low-emission, climate-resilient economy can help create jobs for both men and women, stimulate short-term demand and build the productive capacity for innovation-led growth in the medium to long term (Unsworth et al. 2020a). Given this argument, this publication considers the jobs that would be created in the CPS and ECAS scenarios.

For the power sector, Ram et al. (2020) analyze the job-years created per MW in the construction phase and the permanent jobs created in the operational phase of renewable energy projects. Using the numbers from this study, the results using GACMO for ECAS show that around 17 million job-years would be created within the construction phase until 2050, and 0.7 million permanent jobs would be created in the operational phase by 2050 (Table 29). It should be noted, however, that the participation of women in the engineering and technology sectors is low, as is true for both developed and developing countries (Strachan et al. 2018). Similarly, infrastructure-related projects, and in general the green economy, do not always benefit both women and men (ADB 2019). Therefore, it would be important to design policies that promote the skills development of women and promote their participation in jobs in these sectors. This would also be in line with the commitments made by countries at the United Nations Environment Assembly [UNEA] 2022.

16 https://gulfnews.com/uae/transport/one-billion-riders-used-dubai-metro-in-eight-years-1.2087164

17 Riyadh Metro http://riyadhmetro.com/

18 https://mtt.gov.bh/content/bahrain-metro

19 https://www.c40.org/case_studies/bus-rapid-transit-to-tackle-air-pollution-CO2-emissions-and-improve-mass-public-transportation

20 https://www.c40.org/case_studies/bus-rapid-transit-to-tackle-air-pollution-CO2-emissions-and-improve-mass-public-transportation

Table 29. Cumulative jobs created through investment in renewables

ECAS Scenario	Job-years/MW	Construction Jobs		Jobs/MW	Operation Jobs	
Reduction option		2030	2050		2030	2050
Biomass power from biomass residues	16.9	8,450	16,900	3.3	1,649	3,298
Geothermal power	10.70	1,712	1,712	0.40	64	64
Hydro-power connected to main grid	10.90	1,526	6,104	0.20	28	112
Nuclear power plant	13.1	110,040	110,040	0.6	5,040	5,040
Solar water heater, residential	9.72	45,901	65,124	0.00	0	0
Solar PVs, large grid	32.70	2,289,000	6,540,000	1.40	98,000	280,000
Solar PVs, large grid with 24h storage	32.70	3,270,000	6,540,000	1.40	140,000	280,000
Solar tower CSP, with storage	12.00	600,000	1,800,000	0.60	30,000	90,000
Wind turbines, onshore	7.9	102,700	284,400	0.3	3,900	10,800
Wind turbines, offshore	7.9	1,180,000	2,360,000	0.3	10,000	20,000
Total		**7,609,329**	**17,724,280**		**288,681**	**689,314**

Table 30. Cumulative jobs created through investment in energy efficiency

ECAS Scenario	Job-years/M$	Construction Jobs		Jobs/M$	Operation Jobs	
Reduction option		2030	2050		2030	2050
Energy efficiency in industry	4.6	6,154	10,430	3.1	4,147	7,029
Efficient residential air-conditioning	4.6	5,834	6,447	3.1	3,979	4,396
Efficient lighting with LEDs	4.6	4,154	5,209	3.1	2,833	3,552
Efficient refrigerators	4.6	11,642	12,864	3.1	7,939	8,772
Total energy efficiency		**27,785**	**34,949**		**18,898**	**23,749**

Investments in energy efficiency create more jobs than investments in fossil-fuel industries (Unsworth et al. 2020a). For example, data from the US show that an investment of USD 1 million in energy efficiency projects can generate 4.59 direct jobs and 3.13 indirect jobs (Unsworth et al. 2020a). Using the job creation values per unit investment, the results using GACMO show that, for the energy efficiency investments envisaged in the ECAS, 35,000 direct and 24,000 indirect jobs (Table 30) could be created within the economy of the West Asia region by 2050.

Electric vehicles can create jobs both on the manufacturing side and in creating and maintaining the charging infrastructure. For example, a study for the UK estimates that, for the approximately 41 million EVs sold in 2030, the jobs created in EV power trains will be about 19,000, and for approximately 53 million private and around 4 million public chargers the jobs created will be around 4,000 (Unsworth et al. 2020b). Based on this reference, the results using GACMO show that, for every million EVs sold, 460 jobs will be created in EV vehicle manufacturing and 60 jobs will be created per

Table 31. Cumulative jobs created through investment in EVs

ECAS Scenario	Job-years/M$	Construction Jobs		Jobs/M$	Operation Jobs	
Reduction option		2030	2050		2030	2050
Bus Rapid Transit (BRT)	4.6	2,666	6,369	3.1	1,818	4,343
Electric cars *	0.5	8,699	47,286	0.1	1,135	6,168
Electric 12m buses	4.6	647,764	1,263,801	3.1	441,721	861,808
Shifting passengers from car to rail	4.6	61,528	110,751	3.1	41,957	75,523
Total		**720,657**	**1,428,208**		**520,279**	**988,311**

*In the case of cars, job creation is per million cars and not per million $.

Table 32. Additional cumulative investments required for CPS (in million US $)

Reduction option	in 2020	in 2025	in 2030	in 2050
Biomass power from biomass residues	6	853	1,357	2,323
Efficient residential air-conditioning	815	903	980	1,229
Efficient lighting with LEDs	564	625	679	851
Efficient refrigerators	1,627	1,802	1,956	2,453
Energy efficiency in industry			372	453
Energy efficiency in services			44	44
Geothermal power		683	602	522
Hydro-power connected to main grid			159	637
Nuclear power plant		4,357	4,357	4,357
Solar water heater, residential	2	2	2	3
Solar PVs, large grid	15,600	29,800	56,000	80,000
Bus Rapid Transit (BRT)		139	290	694
Electric cars	2,666	9,471	8,958	27,256
Electric 12m buses	3,822	22,885	46,625	136,817
Shifting passengers from car to rail		3,351	6,702	12,064
Wind turbines, onshore	864	4,809	8,450	19,800
Wind turbines, onshore	**25,966**	**79,681**	**137,535**	**289,505**

Table 33. Additional cumulative investments required for ECAS (in million US $)

Reduction option	in 2020	in 2025	in 2030	in 2050
Biomass power from biomass residues	6	853	1,357	2,323
Efficient residential air-conditioning	1,019	1,129	1,226	1,537
Efficient lighting with LEDs	752	834	905	1,135
Efficient refrigerators	2,033	2,253	2,446	3,067
Energy efficiency in industry			1,338	2,267
Energy efficiency in services			160	222
Geothermal power		683	602	522
Hydro-power connected to main grid			159	637
Nuclear power plant		4,357	4,357	4,357
Solar water heater, residential	2	2	2	3
Solar PVs, large grid	15,600	35,573	56,000	80,000
Solar PVs, large grid with 24h storage		151,027	182,877	354,795
Solar tower CSP, with storage		180,000	450,000	1,350,000
Bus Rapid Transit (BRT)		139	581	1,388
Electric cars	2,666	23,361	17,020	51,398
Electric 12m buses		72,635	141,125	275,338
Shifting passengers from car to rail		3,351	13,405	24,129
Wind turbines, onshore	864	4,809	8,450	19,800
Wind turbines, onshore		25,000	110,000	140,000
Wind turbines, onshore	**22,943**	**506,006**	**992,009**	**2,312,917**

million chargers (public plus private). In the case of other transport options, i.e., BRT, Electric Buses and Shift to Rail, the job creation potential was considered similar to energy efficiency. Overall, in the ECAS, 1.4 million direct jobs and another 1 million indirect jobs would be created by 2050 (Table 31). However, the job potential is quite high in EVs and higher on the manufacturing side than charging infrastructure, suggesting that EV incentives should be such that they encourage local production.

Finally, in the transport sector in general, many additional jobs can be created by investing in infrastructure that promotes active transport (bicycling and walking). For example, a study by Unsworth et al. 2020a based in the US shows that the employment impacts of building and refurbishing bicycle-only infrastructure are the most labor-intensive option, generating 11.4 jobs per USD 1 million spent. A similar study by Unsworth et al. 2020a for the UK found that active transport can create 6.9 jobs per £1 million of investment.

7.4. Investments in the CPS and ECAS scenarios

Some investments will happen even in the BAU scenario. In this report we summarize the additional investments that will be needed to achieve the capacities for the different mitigation options that are considered in the CPS and ECAS scenarios. In some cases, we also have negative investments, which means that the mitigation option has lower investment costs than the BAU options: e.g., in the case of electric cars, due to the reduction in battery prices the investments will become negative. In the CPS scenario the cumulative investment that will be needed by 2050 will be around 290 billion US $ (Table 32). The largest share of these investments will be needed for electric buses and solar PVs.

In the ECAS scenario, the cumulative investment would need to be increased around eight times to 2,313 billion US $ (Table 33). The largest share of these investments will be for solar CSP, solar PV and electric buses.

8. Conclusions

To be consistent with global emissions pathways with no or limited overshoot of the 1.5°C goal, global net anthropogenic CO_2 emissions need to reach net zero around 2050. This publication aims to identify the opportunities and explain the impacts of achieving Net Zero Carbon Scenarios for the energy sector in West Asia.

The analysis has been built around three scenarios:

- The BaU scenario, which envisages a continuation of current trends of growth in the economy and energy usage.
- The CPS, which is based on all the actions for the energy sector enumerated within the Nationally Determined Contributions (NDCs) of the selected countries, as well as in their national economic diversification strategies.
- The ECAS, which is based on the *ambitious* deployment of mitigation technologies identified by the countries themselves within their NDCs and economic diversification plans.

The study shows that, under a BAU scenario, CO_2 emissions from the energy sector in West Asia will double from 1,171 million tCO_2 in 2018 to 2,027 million tCO_2 in 2050. However, the West Asia region would be able to bring down its emissions to 250 million tCO_2 by 2050 under ECAS by deploying technologies that are available today in electricity, transport, industry, services and households. The residual emissions mainly come from the transport sector and can be mitigated using synthetic fuels produced in a sustainable manner. The report did not look into synthetic fuels produced using low-carbon hydrogen with CCS since they need to be demonstrated at scale (Jaramillo et al. 2022).

The electricity sector is, and will remain, the largest sector in terms of CO_2 emissions. In the BAU scenario, this sector will account for 1,029 million tCO_2 in 2050. By implementing renewable technologies, strengthening grids and adding storage, these emissions can be brought down to just 10 million tCO_2 by 2050 in the ECAS scenario. West Asia has a minimal share (less than 1%) of renewables currently in electricity production but a huge potential, especially for solar power. There is also a good potential for offshore wind energy. Due to a significant reduction in renewable costs, many renewable technologies now have negative mitigation costs and can therefore be implemented without grants and subsidies. However, large-scale implementation of renewables in the region requires rethinking the grid infrastructure. Currently, most grid infrastructure is located close to demand, and there are limited transmission capacities to transfer electricity across countries in the region. Renewables would be more dispersed, closer to the production potential, and not necessarily where the demand is. In addition, by their very nature renewables are intermittent. These two features make it essential to integrate the national grids so that power can be moved freely from where the demand is to where production is located. This will also require the creation of storage in the grid.

The transport sector will be the second largest in terms of CO_2 emissions and will account for 453 million tCO_2 in 2050. The main driver for the growth of CO_2 emissions in the transport sector will be the increasing number of vehicles. Vehicle ownership is expected to go up from 143 per 1000 persons in 2015 to 506 vehicles per 1000 persons in 2050. In general, the transport sector has been one of the most difficult sectors for reducing emissions since it requires not only technologies but also a change in people's behavior. Countries in West Asia have a large part of their populations living in urban areas. This trend will continue in the future. Therefore, a key strategy for reducing transport-related emissions is to reduce the demand for transportation, shift the demand to more sustainable modes and adapt cleaner vehicles. Cities in West Asia are investing in metros and bus-based mass transit systems. More cities need to invest in these options and combine them with urban planning that reduces demand. This study shows that, in ECAS, the emissions could be reduced by 249 million tCO_2 in 2050 by implementing these options in West Asia. However, a large part of the reductions would be achieved through the electrification of vehicles, which would reduce emissions in ECAS by 163.3 million tCO_2 in 2050. A large-scale diffusion of electric vehicles would also create additional storage capacity in the grid and allow for better integration of renewable energy.

West Asia exports a large share of oil and gas to the rest of the world and is also the largest export for many countries in West Asia. However, in a world that is trying to achieve net zero by midcentury, the demand for oil and gas will be just a fraction of what it was in 2020. This will mean an end of oil and gas exports to the rest of the world from West Asia by 2050. Consequently, CO_2eq emissions associated with production and processing would decline by 207 million tCO_2 by 2050.

In addition, in the services and household sectors, energy efficiency improvements to appliances (refrigerators and air-conditioners) and lighting can remove 26.1 million tCO_2 by 2050 in ECAS. These will require implementing standards and labelling programmes within the different countries.

Decarbonization of the energy sector will also create a large number of jobs in the green economy. For example, if the renewable energy ambitions of the ECAS are achieved, then 17.7 million construction job-years and 689 thousand permanent jobs to operate and maintain the assets would be created. However, this also means that the necessary skills will have to be created in the selected countries. It is acknowledged that there is still a large gender gap across the technology, engineering and physical sciences disciplines. Therefore creating a more diverse and gender balanced workforce is important to meet the skills needs of the future through equal access to education, research and innovation opportunities. The number of jobs created can be even higher if West Asia can develop as a base for research, innovation and production of these technologies.

In conclusion, countries in West Asia can collectively realize a net-zero scenario in the energy sector along with the diversification of their economies, which has relied a lot on oil and gas exports. Implementing such a net zero scenario will lead to more sustainable and low-carbon economies in the region. An example of this is renewable energy, where the levelized costs have come down to a level that is possible to implement without subsidies and grants. Nonetheless, large-scale investments will be needed, especially for renewable energy and the electrification of transportation. The cumulative investment needed to achieve the CO_2 reductions envisaged in ECAS by 2050 will be around 2,312 billion US$. Since the abatement costs are negative, these investments will not require a large share of concessional finance.

A few countries in West Asia have announced target for net zero. However, to translate these net zero targets into reality would require studies at a country level that define the emissions pathways and mitigation options. Furthermore, these would need to be translated into implementable road-maps at the sector level that define what needs to be done, on what scale, when and by whom.

References

Alnaser, W.E., Trieb, F and Kries, G. (2007). The Potential of Concentrated Solar Power (CSP) in the GCC Countries. 3. pp 1843-1846. Proceedings of ISES World Congress 2007 (Vol. I – Vol. V) DOI: 10.1007/978-3-540-75997-3_376.

Apostoleris, H., Sgouridis, S., Stefancich, M., and Chiesa, M. (2018). Evaluating the factors that led to low-priced solar electricity projects in the Middle East. Nature Energy, 3(12): 1109-1114.

Asian Development Bank (2019) "Gender in Infrastructure: Lessons from Central and West Asia." https://www.adb.org/publications/gender-infrastructure-central-west-asia.

Bhattacharyya, S. C. (2019). "Energy Access." In Energy Economics, edited by Subhes C Bhattacharyya, 493–523. London: Springer London. https://doi.org/10.1007/978-1-4471-7468-4_17.

Cabeza, L. F., Urge-Vorsatz, D., Urge, D., Palacios, A., and Barreneche, C. (2018). Household appliances penetration and ownership trends in residential buildings. Renewable and Sustainable Energy Reviews, 98: 1-8.

Chang, S.-C. (2015). Effects of financial developments and income on energy consumption. International Review of Economics & Finance, 35: 28-44.

Clarke, L., Wei, Y. M., Navarro, A. de la V., Garg, A., Hahmann, A. N., Khennas, S., Azevedo, I. M.L., et al. (2022). "Energy." In Climate Change 2022: Mitigation of Climate Change. Working Group III Contribution to the IPCC Sixth Assessment Report.

Collins, W., Orbach, R., Bailey,M., Biraud, S., Coddington, I., DiCarlo, D., Peischl, J. et al. (2022). "Monitoring Methane Emissions from Oil and Gas Operations‡." Optics Express 30 (14): 24326–51. https://doi.org/10.1364/OE.464421.

Energy Sector Management Assistance Program (2020). Global Wind Atlas (version 3.0). Energy Sector Management Group, World Bank https://esmap.org/esmap_offshorewind_techpotential_analysis_maps

Fischedick M., Roy, J., Abdel-Aziz, A., Acquaye,A., Allwood, J.M. , Ceron, J.-P., Geng, Y. et al. (2014) "Industry". In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A. Baum, I. et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kesicki, Fabian, and Gabrial Anandarajah. (2011). "The Role of Energy-Service Demand Reduction in Global Climate Change Mitigation: Combining Energy Modelling and Decomposition Analysis." Energy Policy Energy Security 39 (11): 7224–33. http://www.sciencedirect.com/science/article/pii/S0301421511006409.

International Energy Agency (2020a). "World Energy Outlook 2020". Paris: International Energy Agency.

International Energy Agency (2020b) "Global EV Outlook 2020: Entering the decade of electric drive?" International Energy Agency (IEA).

International Energy Agency (2021). "Net Zero by 2050: A Roadmap for the Global Energy Sector" International Energy Agency (IEA)

International Organization of Motor Vehicle Manufacturers (2015). Motorisation Rate 2015- World-wide. https://www.oica.net/category/vehicles-in-use/: International Organization of Motor Vehicle Manufacturers (IOMVM).

International Monetary Fund (2021). "World Economic Outlook Database, April 2021"; 12 September, 2021. https://www.imf.org/en/Publications/WEO/weo-database/2021/April

Intergovernmental Panel on Climate Change (2006). IPCC Guidelines for National Greenhouse Gas Inventories,. Edited by Simon; Eggleston, Leanardo; Buendia, Kyoko; Miwa, Todd; Ngara, and Kiyoto; Tanabe. IGES, Japan.

Intergovernmental Panel on Climate Change (2018) . "Global Warming of 1.5 C. An IPCC Special Report.": Intergovernmental Panel on Climate Change (IPCC), 25 Aug 2021 at https://www.ipcc.ch/sr15 .

International Renewable Energy Agency (2021). "Renewable Power Generation Costs in 2020", International Renewable Energy Agency, Abu Dhabi.

Jaramillo, P., Ribeiro, S. K., Newman, P., Dhar, S., Diemuodeke, O., Kajino, T., Lee, D.S., et al. (2022). "Transport". In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of Intergovernmental Panel on Climate Change (IPCC)

Newman, P. and Kenworthy, J. (2011). "Evaluating the Transport Sector's Contribution to Greenhouse Gas Emissions and Energy Consumption". In R. Salter & S. Dhar & P. Newman (eds.), Technologies for Climate Change Mitigation: Transport Sector. Roskilde: UNEP Risoe Center.

Page, B., Turan, G., and Zapantis, A. (2020). "Global Status of CCS 2020". Melbourne: Global CCS Institute <https://www.globalccsinstitute.com/wp-content/uploads/2020/11/Global-Status-of-CCS-Report-2020_FINAL.pdf>.

Ram, M., Aghahosseini, A., and Breyer, C. (2020). Job creation during the global energy transition towards 100% renewable power system by 2050. Technological Forecasting and Social Change, 151: 119682.

Rutovitz, J., Dominish, E. and Downes, J. (2015). "Calculating global energy sector jobs: 2015 methodology". Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology Sydney

Salvucci, R. and Tattini, J. (2019). "DTU International Energy Report 2019: Transforming Urban Mobility". Technical University of Denmark.

Shove, E. (2018). What is wrong with energy efficiency? Building Research & Information null, 46(7): 779-789.

Strachan, R, A Peixoto, I Emembolu, and M T Restivo. (2018). "Women in Engineering: Addressing the Gender Gap, Exploring Trust and Our Unconscious Bias." In 2018 IEEE Global Engineering Education Conference (EDUCON), 2088–93. https://doi.org/10.1109/EDUCON.2018.8363497.

United Nations Department of Economic and Social Affairs (2018). "World Urbanization Prospects: The 2018 Revision, Online Edition": United Nations, Department of Economic and Social Affairs (UNDESA), Population Division <https://population.un.org/wup/Download/>.

United Nations Department of Economic and Social Affairs (2019). "World Population Prospects 2019, Online Edition. Rev. 1": United Nations, Department of Economic and Social Affairs (UNDESA), Population Division.

United Nations Environment Programme (2020). Emissions Gap Report 2020, United Nations Environment Programme, Nairobi.

United Nations Environment Assembly (2022). "Ministerial Declaration of the United Nations Environment Assembly at Its Fifth Session UNEP/EA.5/HLS.1 - High-Level Segment." https://www.unep.org/environmentassembly/unea-5.2/proceedings-report-ministerial-declaration-resolutions-and-decisions-unea-5.2?%2Fproceedings-report-ministerial-declaration-resolutions-and-decisions-unea-5_2=.

United Nations Framework Convention on Climate Change (2021). "Nationally determined contributions under the Paris Agreement. Synthesis report by the secretariat (FCC/PA/CMA/2021/8)"

Unsworth, S., Andres, P., Cecchinato, G., Mealy, P., Taylor, C., and Valero, A. (2020a). "Jobs for a Strong and Sustainable Recovery from Covid-19": Centre for Economic Performance (CEP), Downloaded on 17 Sep 2021 <https://cep.lse.ac.uk/pubs/download/cepcovid-19-010.pdf>.

Unsworth, S., Valero, A., Martin, R., and Verhoeven, D. (2020b). "Seizing sustainable growth opportunities from zero emission passenger vehicles in the UK": Centre for Economic Performance (CEP), Downloaded on 17 Sep 2021 <https://cep.lse.ac.uk/pubs/download/special/cepsp37.pdf>.

World Resources Institute (2020). "Climate Watch Net-Zero Tracker", World Resources Institute. Washington, DC.

Zell, E., Gasim, S., Wilcox, S., Katamoura, S., Stoffel, T., Shibli, H., Engel-Cox, J., and Subie, M. A. (2015). Assessment of solar radiation resources in Saudi Arabia. Solar Energy, 119, 422-438.

Annexes

Annex 1. Current policies, programs and projects for clean energy in West Asian countries

Technology	Country	Description of Action (When, Where and Unit Size)	Overall Size	References
All Renewable	Bahrain	National renewable energy target: 5% of peak capacity by 2025 and 10% by 2035	255 MW by 2025, 710 MW by 2035	Supreme Council for Environment (SCE). 2020. Bahrain's Third National Communication. Kingdom of Bahrain. p.59 Available under: https://unfccc.int/sites/default/files/resource/9143680_Bahrain-NC3-2-SCE%20Third%20National%20Communication%20 2020.pdf
Wind	Bahrain	National Renewable Action Plan: 50 MW Onshore wind in 2025, 250 MW Onshore and 50 MW Offshore in 2035.	50 MW by 2025, 300 MW by 2035	Supreme Council for Environment (SCE). 2020. Bahrain's Third National Communication. Kingdom of Bahrain. p.59 Available under: https://unfccc.int/sites/default/files/resource/9143680_Bahrain-NC3-2-SCE%20Third%20National%20Communication%20 2020.pdf
Solar	Bahrain	National Renewable Action Plan: PV targets at 200 MW and 400 MW in 2025 and 2035	200 MW by 2025, 400 MW by 2035	Sustainable Energy Unit (SEU). 2017a. The Kingdom of Bahrain – National Renewable Energy Action Plan (NREAP). Available under: http://www.sea.gov.bh/wp-content/uploads/2018/04/02_NREAP-Full-Report.pdf
Bioenergy	Bahrain	National Renewable Action Plan: biogas targets at 5 MW and 10 MW in 2025 and 2035	5 MW by 2025, 10 MW by 2035	Sustainable Energy Unit (SEU). 2017a. The Kingdom of Bahrain – National Renewable Energy Action Plan (NREAP). Available under: http://www.sea.gov.bh/wp-content/uploads/2018/04/02_NREAP-Full-Report.pdf
All Renewable	Iraq	Long-term renewable target: 40% of Iraq's electricity mix by adopting wind, waste-to-energy, and geothermal technologies	not available	Iraq Energy Institute. 2020. Overview of Iraq's Renewable Energy Progress in 2019. Available under: https://iraqenergy.org/2020/02/20/overview-of-iraqs-renewable-energy-progress-in-2019/
Solar	Iraq	Federal Government Programme (2018-2022): procurement of seven PV power projects with a combined capacity of 755 MW, becoming operational by the end of 2021	755 MW by 2021	Iraq Energy Institute. 2020. Overview of Iraq's Renewable Energy Progress in 2019. Available under: https://iraqenergy.org/2020/02/20/overview-of-iraqs-renewable-energy-progress-in-2019/
Solar, Wind and Bioenergy	Iraq	Expected to have an installed capacity of over 5 GW of solar energy, about 1 GW of wind Energy and around 0.2 GW of Bioenergy by 2028	6,200 MW by 2028	REVE. 2018. Iraq is expected to have an installed capacity of five gigawatts of solar energy and one gigawatt of wind energy. Wind Energy and Electric Vehicle Magazine. Available under: https://www.evwind.es/2018/12/12/iraq-is-expected-to-have-an-installed-capacity-of-five-gigawatts-of-solar-energy-and-one-gigawatt-of-wind-energy/65470
Solar	Iraq	Pilot project: 8 MWp is to be developed as roof-top solar projects from government own buildings in two years	8 MW	Iraq Energy Institute. 2020. Overview of Iraq's Renewable Energy Progress in 2019. Available under: https://iraqenergy.org/2020/02/20/overview-of-iraqs-renewable-energy-progress-in-2019/
All Renewable	Jordan	Energy measures considered to achieve the NDC target: electricity generated from renewables to have a share of more 35% by the year 2030		Ministry of Environment of Jordan. 2021. Updated Submission of Jordan's 1st Nationally Determined Contribution (NDC). Available under: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Jordan%20First/UPDATED%20SUBMISSION%20 OF%20JORDANS.pdf

Technology	Country	Description of Action (When, Where and Unit Size)	Overall Size	References
All Renewable	Jordan	National Energy Strategy (2020-2030): increasing the share of renewable energy in the electricity mix to 31% by 2030 (3200 MW), up from 20% by 2020 (2400 MW)	3,200 MW by 2030	IRENA. 2021. Renewable Readiness Assessment: The Hashemite Kingdom of Jordan, International Renewable Energy Agency, Abu Dhabi. Available under: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Feb/IRENA_RRA_Jordan_2021.pdf
Solar and Wind	Jordan	By the end of 2021, 1600 MW of PV and 715 MW of wind energy are scheduled to be grid connected	2,300 MW by 2021	Ministry of Environment of Jordan. 2021. Updated Submission of Jordan's 1st Nationally Determined Contribution (NDC). Available under: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Jordan%20First/UPDATED%20SUBMISSION%20OF%20JORDANS.pdf
Solar and Wind	Jordan	250 MW of solar PV and 247 MW of wind projects are under construction as of January 2020	497 MW	IRENA. 2021. Renewable Readiness Assessment: The Hashemite Kingdom of Jordan, International Renewable Energy Agency, Abu Dhabi. Available under: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Feb/IRENA_RRA_Jordan_2021.pdf
Solar	Jordan	300 MW of CSP expected to be in operation by 2023	300 MW by 2023	The Hashemite Kingdom of Jordan. 2014. Jordan's Third National Communication on Climate Change. Available under: https://unfccc.int/resource/docs/natc/jornc3.pdf
Solar and Wind	Kuwait	national goal of 15% renewable energy generation by 2030, installing 4500 MW of solar and wind capacity by 2030	4500 MW by 2030	Oxford Business Group. 2016. New solar and wind capacity will move Kuwait closer to its 2030 renewable energy generation goals from The Report: Kuwait 2016. https://oxfordbusinessgroup.com/analysis/winds-change-new-solar-and-wind-capacity-will-move-country-closer-its-2030-renewable-generation
All Renewable	Lebanon	Target: 30% of total primary energy consumption (electricity and heating demand) from renewables by 2030. individual target capacities per technology (REmap analysis): 1000 MW wind, 601 MW hydro, 2500 MW centralized solar PV, 500 MW decentralized solar PV, 13 MW biogas	4614 MW by 2030	IRENA. 2020. Renewable Energy Outlook: Lebanon. International Renewable Energy Agency, Abu Dhabi. Available under: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Outlook_Lebanon_2020.pdf
Hydro-electricity	Lebanon	National Renewable Action Plan: hydroelectricity targets at 331.5 and 473 MW in 2020 and 2030.	331.5 MW by 2020, 473 MW by 2030	IRENA. 2020. Renewable Energy Outlook: Lebanon. International Renewable Energy Agency, Abu Dhabi. Available under: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Outlook_Lebanon_2020.pdf
Wind	Lebanon	National Renewable Action Plan: wind targets at 200 MW and 450 MW in 2020 and 2030	200 MW by 2020, 450 MW by 2030	IRENA. 2020. Renewable Energy Outlook: Lebanon. International Renewable Energy Agency, Abu Dhabi. Available under: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Outlook_Lebanon_2020.pdf

Technology	Country	Description of Action (When, Where and Unit Size)	Overall Size	References
Solar	Lebanon	National Renewable Action Plan: the solar large scale PV targets are 150 MWp and 300 MWp in 2020 and 2030. Distributed PV systems targets are 100 MWp and 150 MWp in in 2020 and 2030.	250 MW by 2020, 450 MW by 2030	IRENA. 2020. Renewable Energy Outlook: Lebanon. International Renewable Energy Agency, Abu Dhabi. Available under: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Outlook_Lebanon_2020.pdf
Wind	Oman	Projects planned: - 2023: 150 MW Dhofar II wind farm - 2x 200 MW 'Wind IPP 2023' and 'Wind IPP 2024', with likely locations Dhofar and Duqm	550 MW by 2024	Prabhu, C. 2018. Oman plans 6 new solar, wind projects. Oman Observer. Available under: https://www.omanobserver.om/article/57234/Business/oman-plans-6-new-solar-wind-power-projects
Solar	Oman	Projects planned: - 500 MW Ibri PV plant, commissioning expected in 2021 - 3x 500 MW 'Solar IPP 2022', 'Solar IPP 2023' and 'Solar IPP 2024'	2000 MW by 2024	NS Energy. N.d. Ibri II Solar Power Project. Available under: https://www.nsenergybusiness.com/projects/ibri-ii-solar-power-project/ Prabhu, C. 2018. Oman plans 6 new solar, wind projects. Oman Observer. Available under: https://www.omanobserver.om/article/57234/Business/oman-plans-6-new-solar-wind-power-projects
All Renewable	Oman	The Oman Power and Water Procurement Company (OPWP) is the sole off-taker of output from power generation and water desalination projects plans to procure at least 2,200 MW of renewables based electricity capacity by 2025 within the Main Interconnected System (MIS)	2200 MW by 2025	REVE. 2019. Wind energy in Oman: first wind farm comes online. Wind Energy and Electric Vehicle Magazine. Available under: https://www.evwind.es/2019/08/11/wind-energy-in-oman-first-wind-farm-comes-online/68398
All Renewable	Qatar	National Vision to achieve 20% non-gas energy by 2030 through investments in photovoltaic (PV) solar energy	not available	U.S. International Trade Administration. 2020. Qatar Solar Energy. Available under: https://www.trade.gov/market-intelligence/qatar-solar-energy
Solar	Qatar	Renewable energy target: Installing 2-4 gigawatts (GW) of Solar throughout the country by 2030	2,000-4,000 MW by 2030	US-Qatar Business Council. 2021. Qatar Sustainability Report: A Leader in Green Initiatives. Available under: https://usqbc.org/public/documents/upload/Qatar%20Sustainability%20Report%20-%20Final.pdf
Solar	Qatar	Al Kharsaah will be Qatar's first large-scale solar power plant and will be operational in 2021. It will start with a capacity of 350MW, and by April 2022, its operations will reach a full capacity of 800MW	800 MW by 2022	Power Technology. 2020. Al Kharsaah Solar Power Project. Available under: https://www.power-technology.com/projects/al-kharsaah-solar-power-project/
All Renewable	Saudi-Arabia	The National Renewable Energy Program (NREP) is a strategic initiative under Vision 2030 and the King Salman Renewable Energy Initiative. The aim is to have 27.3 GW in 2025 and 58.7 GW of renewable energy capacity by 2030, 40 GW of which will be in solar.	27,300 MW by 2025, 58,700 MW by 2030	Abdel-Baky, M. and Main Garcia, M. 2021. Renewable Energy Laws and Regulations - Saudi Arabia. The Law Firm of Wael A. Alissa in Association with Dentons & Co., Dentons. ICLG.com. Available under: https://iclg.com/practice-areas/renewable-energy-laws-and-regulations/saudi-arabia

Technology	Country	Description of Action (When, Where and Unit Size)	Overall Size	References
Solar	Syrian Arab Republic	The Ministry of Electricity Transmission Establishment issued two tenders for the construction of solar power plants, a 23 MW solar facility in Damascus and a 40 MW plant near Homs.	63 MW	Bellini, E. 2020. Syria launches tenders for 63 MW of solar. PV magazine. https://www.pv-magazine.com/2020/02/18/syria-launches-tenders-for-63-mw-of-solar/
All Renewable	United Arab Emirates	UAE Energy Strategy 2050: The strategy aims to increase the contribution of clean energy in the total energy mix from 25% to 50% (44% renewable and 6% nuclear) by 2050.	not available	United Arab Emirates. 2021. UAE Energy Strategy 2050. Available under: https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/federal-governments-strategies-and-plans/uae-energy-strategy-2050
Wind	United Arab Emirates	Masdar and Abu Dhabi's Tourism Development and Investment Company (TDIC) aim to develop an onshore wind farm on Sir Bani Yas Island with a capacity of up to 30 MW.	30 MW	United Arab Emirates. 2020. Wind energy. Available under: https://u.ae/en/information-and-services/environment-and-energy/water-and-energy/types-of-energy-sources/wind-energy
Solar	United Arab Emirates	Al Dhafra Solar PV project: 2 GW PV plant, fully operational by 2022, increasing Abu Dhabi's solar power capacity to approximately 3.2 GW.	3,200 MW by 2022	United Arab Emirates. 2020. Solar energy. Available under: https://u.ae/en/information-and-services/environment-and-energy/water-and-energy/types-of-energy-sources/solar-energy
Solar	United Arab Emirates	Dubai Clean Energy Strategy 2050: increase the share of clean energy in Dubai's total power output to 7% by 2020, 25% by 2030 and 75% by 2050. Solar projects in Dubai: The largest Concentrated Solar Power (CSP) project on a single site in the world will generate 1,000 MW of power by 2030. The Mohammed bin Rashid Al Maktoum Solar Park in Seih Al Dahal (Dubai) will generate 1,000 MW by 2020 and 5,000 MW by 2030.	6,000 MW by 2030	United Arab Emirates. 2020. Solar energy. Available under: https://u.ae/en/information-and-services/environment-and-energy/water-and-energy/types-of-energy-sources/solar-energy
Hydro-electricity	United Arab Emirates	Hatta's 250 MW hydroelectric power station to be commissioned in 2024.	250 MW by 2024	Arabian Business. 2021. Hatta's hydroelectric power station set to be commissioned in 2024. Available under: https://www.arabianbusiness.com/industries/energy/456888-hattas-hydroelectric-power-station-set-to-be-commissioned-in-2024
Waste	United Arab Emirates	60 MW Waste-to-energy project Al Ain will be finished in 2025.	60 MW by 2025	Power Technology. 2021. Al Ain Waste To Energy Project, United Arab Emirates. Available under: https://www.power-technology.com/marketdata/al-ain-waste-to-energy-project-united-arab-emirates/

Annex 2. Methodology for Mitigation

Table a) Energy balance table expressed in energy unit Tera Joule (TJ) for 2018

TJ units	LPG	Gasoline	Jet Fuel	Diesel	HFO	Kerosene and other	Total oil products	Coal	Lignite	Natural Gas	Coke	Petrocoke	Total energy (fossil)
Unit	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ
Total	241,358	2,308,788	59,242	2,539,693	2,982,805	97,207	8,229,093.2	180,533	51,264	9,692,047			18,152,937
Fossil power plants				682,573	2,000,000		2,682,573.2			6,236,706			8,919,279
FINAL CONSUMPTION	241,358	2,308,788	59,242	1,857,120	982,805	97,207	5,546,520.1	180,533	51,264	3,455,341			9,233,658
Industry – steel													
Industry – chemical													
Industry – non metallic mineral													
Industry – food processing and beverage													
Industry – construction													
Industry – mining													
Industry – machinery													
Industry – non ferrous metals													
Industry – paper and pulp													
Industry – transport equipment													
Industry – textile and leather													
Industry – miscellaneous				282,358	981,472		1,263,830.3	91,893		3,161,227			4,516,950
Transport – road	1,102	2,308,788		1,514,420			3,824,310.3						3,824,310
Transport – rail				6,049			6,048.9						6,049
Transport – domestic air			59,242				59,242.3						59,242
Transport – navigation					1,206		1,205.7						1,206
Households	235,714			23,062		97,206	355,981.7	23,001	51,264	1,793			432,039
Services	4,542			14,226	128	1	18,896.9	65,635		292,321			376,853
Agriculture & Fishery				17,004			17,004.0	5					17,009
Non energy – chemical feedstocs													

Table b) Energy balance table expressed in kilotonnes of oil equivalent (ktoe)

Unit : ktoe	Total	LPG	Gasoline	Jet Fuel	Diesel	HFO	Kerosene and other	Total oil products	Coal	Lignite	Natural Gas	Coke	Petro-coke	Electricity consumption Gwh		Electricity production Gwh	Share of production	Efficiency
ktoe per TJ		0.0239	0.0239	0.0239	0.0239	0.0239	0.0239	0.0239	0.0239	0.0239	0.0239	0.0239	0.0239					
Total	433,575	5,765	55,144	1,415	60,660	71,243	2,322	196,549	4,312	1,224	231,491				Total	870,455		
Fossil power plants	213,033				16,303	47,769		64,072			148,961				Losses	182,483	21.0%	
FINAL CONSUMPTION	220,542	5,765	55,144	1,415	44,357	23,474	2,322	132,476	4,312	1,224	82,529			687,972	Fossil	863,662	99.2%	
Industry – steel															Lignite		0.0%	0%
Industry – chemical															Coal		0.0%	0%
Industry – non metallic mineral															Oil	272,634	31.3%	37%
Industry – food processing and beverage															Natural Gas	591,028	67.9%	34%
Industry – construction															Nuclear		0,0%	
Industry – mining															Net import		0,0%	
Industry – machinery																		
Industry – non ferrous metals																		
Industry – paper and pulp																		
Industry – transport equipment																		
Industry – textile and leather																		
Industry – miscellaneous	107,885				6,744	23,442		30,186	2,195		75,505			118,057				
Transport – road	91,342	26	55,144		36,171			91,342										
Transport – rail	144				144			144										
Transport – domestic air	1,415			1,415				1,415							Renewables	6,793	0.8%	
Transport – navigation	29					29		29							Hydro	2,567	0.3%	
Households	10,319	5,630			551		2,322	8,502	549	1,224	43			296,070	Wind	748	0.1%	
Services	9,001	108			340	3		451	1,568		6,982			264,258	Solar	3,474	0.4%	
Agriculture & Fishery	406				406			406						9,586	Biomass	4	0.0%	
Non energy – chemical feedstocs															Geo-thermal		0.0%	

Table c) Greenhouse gas emissions balance expressed in kilotonnes equivalent CO_2 (ktoe)

Ton CO2/Toe (IPCC):		2.64	2.90	2.99	3.10	3.24	3.01		3.96	4.24	2.35	4.53	4.20
Unit : $ktCO_2$-e	Total	LPG	Gasoline	Jet Fuel	Diesel	HFO	Kerosene and other	Total oil products	Coal	Lignite	Natural Gas	Coke	Petrocoke
Total	1,171,309	15,222	159,999	4,236	188,107	230,770	6,986	605,319	17,078	5,188	543,724		
Fossil power plants	555,168				50,556	154,733		205,289			349,879		
FINAL CONSUMPTION	616,140	15,222	159,999	4,236	137,551	76,036	6,986	400,029	17,078	5,88	193,845		
Industry – steel													
Industry – chemical													
Industry – non metallic mineral													
Industry – food processing and beverage													
Industry – construction													
Industry – mining													
Industry – machinery													
Industry – non ferrous metals													
Industry – paper and pulp													
Industry – transport equipment													
Industry – textile and leather													
Industry – miscellaneous	282,884				20,913	75,933		96,847	8,693		177,345		
Transport – road	272,237	70	159,999		112,168			272,237					
Transport – rail	448				448			448					
Transport – domestic air	4,236			4,236				4,236					
Transport – navigation	93					93		93					
Households	31,024	14,866			1,708		6,986	23,560	2,176	5,188	101		
Services	23,958	286			1,054	10		1,350	6,209		16,399		
Agriculture & Fishery	1.260				1.259			1.259					
Non energy – chemical feedstocs													

Table d) Growth factors estimated for energy consumption in the different sectors

Growth from the start year	Annual % increase in the period				% increase from start year values			
Growth and multiplication factors	2018 to 2020	2020 to 2025	2025 to 2030	2030 to 2050	2020	2025	2030	2050
Population growth	0.83%	0.83%	0.83%	0.50%	2%	6%	10%	22%
GDP growth	-1.00%	4.71%	4.48%	3.58%	-2%	23%	54%	210%
Industry – fuel in steel	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – fuel in chemical	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – fuel in non metallic mineral	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – fuel in food and beverage	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – fuel in construction	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – fuel in mining	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – fuel in machinery	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – fuel in non ferrous metals	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – fuel in paper and pulp	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – fuel in transport equipment	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – fuel in textile and leather	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – fuel in miscellaneous	2.3%	2.3%	2.3%	1.0%	5%	17%	31%	60%
Industry – electricity consumption	3.7%	3.7%	2.0%	1.0%	8%	29%	42%	74%
Transport – fuel in road	2.5%	2.5%	2.5%	1.0%	5%	19%	34%	64%
Transport – fuel in rail	2.5%	2.5%	2.5%	1.0%	5%	19%	34%	64%
Transport – fuel in air	1.1%	1.1%	1.1%	1.0%	2%	8%	14%	39%
Transport – fuel in navigation	2.5%	2.5%	2.5%	1.0%	5%	19%	34%	64%
Transport – electricity consumption	2.5%	2.5%	2.0%	1.0%	5%	19%	31%	60%
Households – LPG	-0.4%	-0.4%	-0.4%	1.0%	-1%	-3%	-4%	17%
Households – Kerosene	-1.5%	-1.5%	1.0%	1.0%	-3%	-10%	-5%	15%
Households – electricity consumption	3.0%	3.0%	2.0%	1.0%	6%	23%	36%	66%
Services – fuel	7.7%	7.7%	2.0%	1.0%	16%	68%	86%	126%
Services – electricity consumption	6.7%	6.7%	2.0%	1.0%	14%	57%	74%	112%
Agriculture – fuel	0.0%	0.0%	0.0%	0.0%	0%	0%	0%	0%
Agriculture – electricity consumption	5.8%	5.8%	2.0%	1.0%	12%	48%	64%	100%
Non energy – fuel in chemical feedstocs	2.3%	2.3%	2.3%	2.0%	5%	17%	31%	95%
Livestock emissions	0.0%	0.0%	0.0%	1.0%	0%	0%	0%	22%
Rice emissions	0.0%	0.0%	0.0%	1.0%	0%	0%	0%	22%
N_2O from agricultural soils	0.0%	0.0%	0.0%	1.0%	0%	0%	0%	22%
Biomass burning	0.0%	0.0%	0.0%	1.0%	0%	0%	0%	22%
Forestry emission	0.0%	0.0%	0.0%	0.0%	0%	0%	0%	0%
Solid waste emissions	0.0%	0.0%	0.0%	0.0%	0%	0%	0%	0%
Liquid waste emissions	0.0%	0.0%	0.0%	0.0%	0%	0%	0%	0%
Industrial processes	0.0%	0.0%	0.0%	0.0%	0%	0%	0%	0%