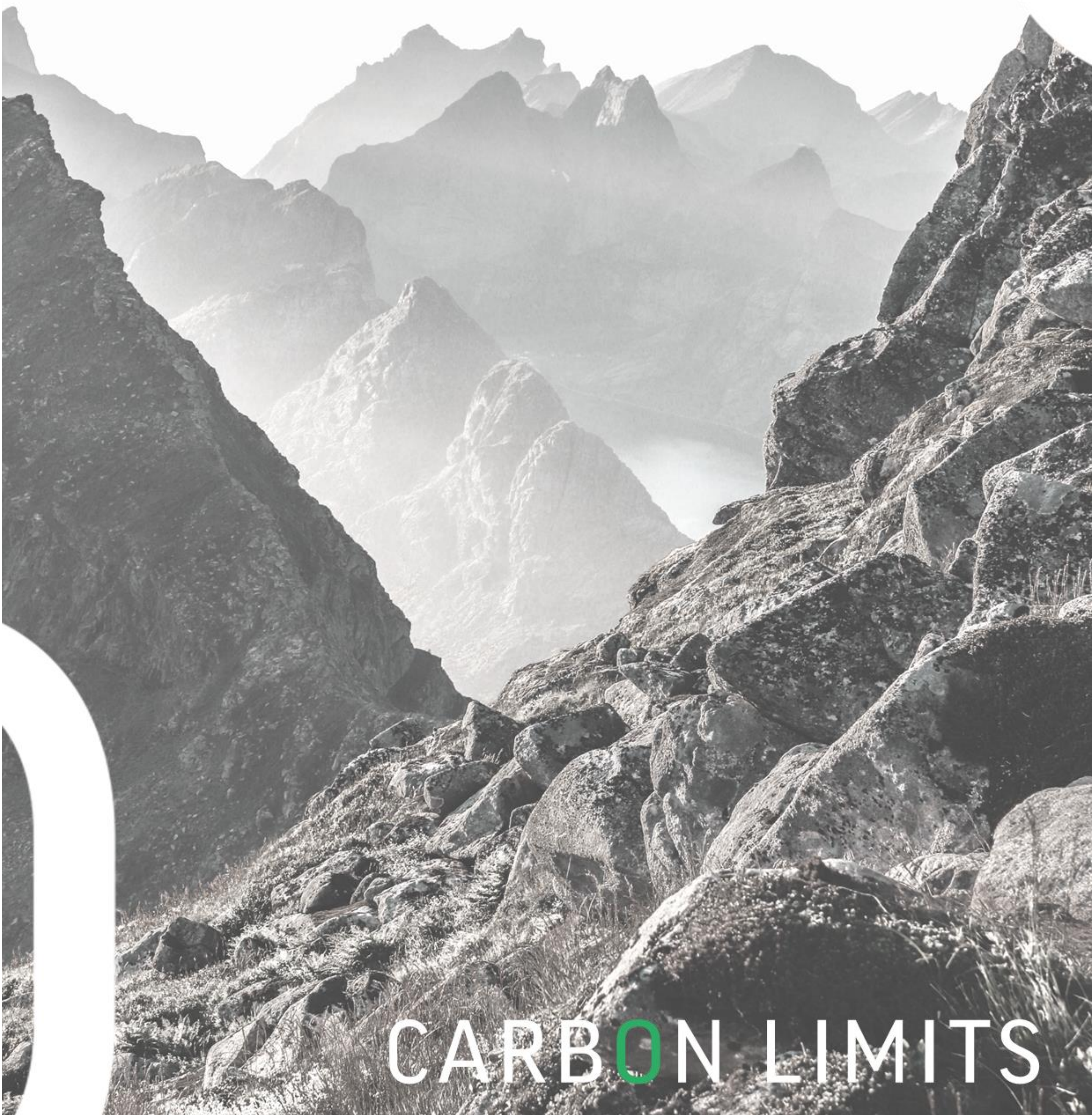
Iraq – Technology Needs Assessment report for mitigation and adaptation

2022



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Report title:

Iraq – Technology Needs Assessment report for mitigation and adaptation

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Carbon Limits works with public authorities, private companies, finance institutions and non-governmental organisations to reduce emissions of greenhouse gases from a range of sectors. Our team supports clients in the identification, development and financing of projects that mitigate climate change and generate economic value, in addition to providing advice in the design and implementation of climate and energy policies and regulations.

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Abbreviations

COP	Conference of the Parties
GHG	Greenhouse gas
GCF	Green Climate Fund
UNIDO	United Nations Industrial Development Organisation
BAEF	Barrier Analysis and Enabling Framework
TAP	Technology Action Plan
NDC	Nationally Determined Contributions
NAP	National Adaptation Plan
SDGs	Sustainable Development Goals
UNFCCC	UN Framework Convention on Climate Change
APG	Associated Petroleum Gas
VIIRS	Visible Infrared Imaging Radiometer Suite
NOAA	National Oceanic and Atmospheric Administration
bcm	Billion cubic metres (m^3)
MoE	Ministry of Environment
UNCCD	UN Framework Convention to Combat Desertification
UNDP	UN Development Programme
GHG	Global Environment Facility
UNEP	UN Environment Programme
NC 1	Initial National Communication
NDP	National Development Plan
NESAP	National Environmental Strategy and Action Plan
EFT	Environmentally Friendly Technology
NEFT	Non-Environmentally Friendly Technology
IWTP	Integrated Waste Treatment Plant
WWTP	Wastewater Treatment Plant
INDC	Intended Nationally Determined Contribution
BAU	Business as usual
NDC	Nationally Determined Contribution
bpd	Barrels per day
RCREEE	Regional Center for Renewable Energy and Energy Efficiency
PV	Photovoltaic
MCA	Multi-Criteria Analysis
CNG	Compressed Natural Gas
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
bcf	Billion cubic feet (ft^3)
scf	Standard cubic feet
CSP	Concentrating Solar Power
TES	Thermal Energy Storage
CSPP	Concentrating Solar Power Plant
OCGT	Open cycle gas turbine
LDAR	Leak detection and repair
VRU	Vapor recovery units

1 Introduction

1.1 About the TNA Project

The Technology Needs Assessment (TNA) process began in 2008, following the 14th Conference of the Parties (COP), supported by the Poznan strategic program on technology transfer. The program objective was to address the technology gap in developing countries by funding climate technological development and transfer. Subsequent COPs, as well as Article 10 of the Paris Agreement, have continued to highlight the importance of technological innovation for climate adaptation and mitigation.

TNA is a participatory process undertaken within the context of a specific country, to define and prioritise technology that both confronts the effects of climate change, through adaptation, and reduces greenhouse gas (GHG) emissions, through mitigation. The Republic of Iraq is regarded as one of the most vulnerable countries to the impacts of climate change in the Middle East and globally, particularly to decreased food and water availability. A recent increase in the frequency and intensity of extreme weather events, including drought, sand, and dust storms, have had a devastating impact on the agricultural sector and contributed to widespread desertification and environmental degradation. Other sectors – notably health, energy, and the economy – are also suffering the adverse effects of climate change.

In 2019, the Green Climate Fund (GCF) approved grant assistance to help Iraq develop a national readiness program. Within this program, appointed by the United Nations Industrial Development Organisation (UNIDO), a consultancy consortium led by Carbon Limits developed a comprehensive TNA. Discussions with officials preparing the technical assistance raised four key sectors to be covered within the assessment: two mitigation sectors, energy and industry; and two adaptation sectors, water and agriculture.

1.2 TNA objectives

The ultimate goal of the TNA is to scale-up climate technology transfer. A set of participatory activities define, select, and prioritise technologies, then prepare the roadmap for their diffusion. Different stakeholders (such as ministries, non-governmental institutions, and the private sector) are involved throughout the process to reflect each national context.

Three outcomes result from the assessment process: prioritized list of technologies, barrier Analysis and enabling framework, and Technology Action Plans (TAP). These deliverables each represent the key elements of the TNA:

- Identifying and prioritizing technologies for adaptation and mitigation
- Identifying and analyzing the barriers to developing these technologies and addressing them through an enabling framework
- Proposing an action plan to scale up the deployment of the selected technologies, and up scaling their diffusion within educational programs and institutional awareness, as well as their adoption for emissions reduction.

This analysis enables Iraq to begin addressing its climate technology needs and provide a reliable reference for further governmental processes and project planning. TNA findings are relevant for preparing national documents, including a Nationally Determined Contribution (NDC) and National Adaptation Plan (NAP), and support additional project proposals, funding, and implementation through knowledge of the local context.

Gender-based differences are considered throughout this project to reduce gendered imbalances around climate technology and ensure equal opportunity in the future activities outlined in the TAP.

1.3 Sector selection

Iraq's NDC and other national documents outlined measures for mitigation and adaptation across various sectors. To aid Iraq achieving these measures, this TNA prioritised four sectors for adaptation and mitigation. The goal is to contribute to the country's ongoing action program and develop an adequate project pipeline for financing proposals.

The extensive list of sectors was narrowed down according to Iraq's key ambitions and objectives. Despite the importance of oil and gas, this sector was not chosen to be considered independently, with respect to Iraq's commitment to diversify its economy in the long term and develop added value industries. The government also set a plan to cut 15% of emissions by 2035 and sought measures that would have the greatest contribution to climate mitigation through energy consumption. In regard to adaptation, conflicts within Iraq have heavily damaged the agriculture sector including water systems, irrigation facilities, and other infrastructure. Ongoing adaptation work in Iraq has focused on restoring water and agriculture systems, and on investments in climate resilient agriculture.

As part of a preparatory workshop for TNA technical assistance, discussions were held with ministry and agency representatives to define a revised list of sectors, determined by the context above. Two sectors with the greatest impacts were selected for both mitigation and adaptation, these being energy (including electricity and housing) and industry (including oil and gas), and water and agriculture, respectively. The selection also matches the prioritised sectors in Iraq's Initial National Communication document (NC 1, 2016, identified as having the greatest climate mitigation or adaptation potential.

1.4 GHG emissions and trends

Iraq is highly vulnerable to the impacts of climate change, threatening its progress towards meeting the Sustainable Development Goals (SDGs). However, Iraq is committed to reducing this vulnerability; in 2009, it ratified the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol as a Non-Annex I country. In 2016, Iraq signed the Paris Agreement. Since then, the country has worked to establish the national entities necessary to facilitate the implementation of the provisions of the UNFCCC (GCF, 2019).

According to the national GHG inventory of Iraq submitted to the UNFCCC in 2016 with emission estimates from 1997, the country's total emissions were about 73 million tonnes CO_{2e}. The energy sector was by far the main contributor to these emissions with 54.5 million tonnes CO_{2e}, constituting around 75% of total emissions. With 8 million tonnes CO_{2e} (11.1%), agriculture is the second largest contributor (NC 1, 2016)

Figure 1: GHG Emissions in Iraq – national estimates (based on Iraq's NC 1, 2016)

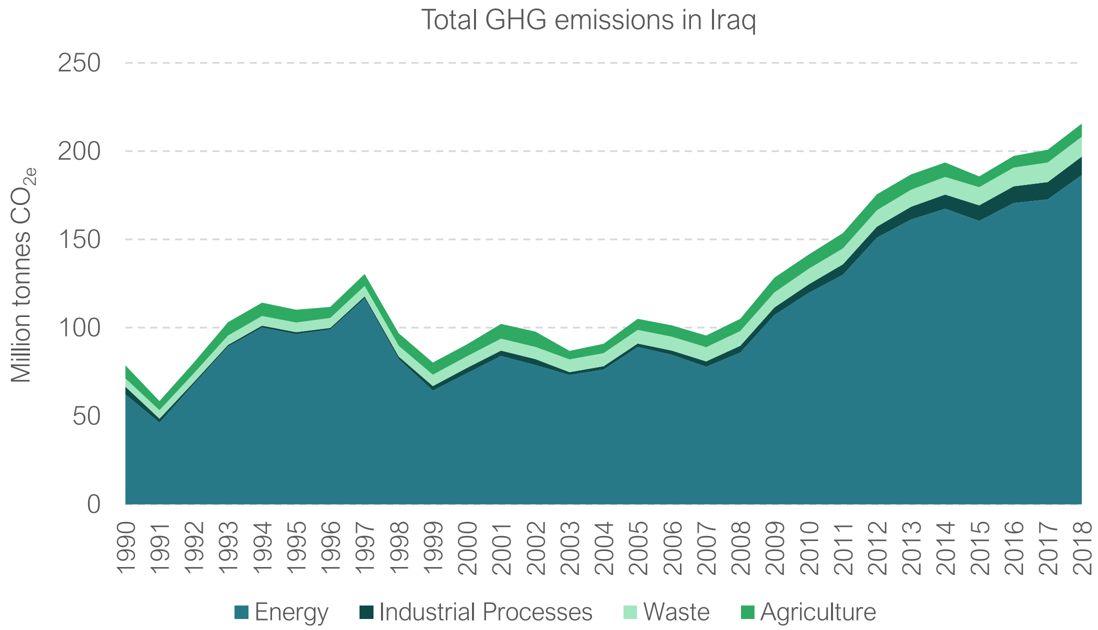
SHARE OF TOTAL GHG EMISSIONS	SECTOR	CURRENT STATE
75%	Energy	Includes gas flaring, combustion and fugitive methane from power generation, oil and gas operations, transport and other energy uses
9%	IPPU	Industrial Processes and Product Use include GHG emitted as by-products during industrial processes for manufacture of new products. This includes the manufacturing, cement, and chemical industries
11%	Agriculture	Covers Agriculture, Forestry and Other Land Use (AFOLU)
5%	Waste	GHG emissions from the waste sector result from the disposal of solid waste through landfilling, dumping, incineration, open burning and treatment of domestic and industrial liquid wastes

Given that Iraq's national emissions estimates date back more than 20 years, more recent data can be found from international assessments of the country's GHG emissions. It should be noted that international assessments are more uncertain, as the organisations compiling the data have limited access to local data and often rely on international emissions factors and activity data.

The re-assessment of GHGs emissions in Iraq through conducting studies and research, as well as defining the contributions of the producing sectors of GHGs, especially CO2 and methane, is important to remove uncertainties related to the GHG inventories available.

Figure 2 illustrates historical development of emissions in Iraq based on an assessment from the World Resource Institute. GHG emissions more than doubled in the last decade with emissions from the energy sector accounting for over 85% of total national emissions in 2018.

Figure 2: International assessment of GHG emissions in Iraq (Climate Watch 2022)



Emissions from the energy sector consist predominantly of fossil fuel combustion across the entire economy, as well as direct fugitive emissions in the oil and gas sector (emitted mostly in the form of methane—a potent greenhouse gas with strong climate impacts). The largest growth in energy sector emissions comes from those associated with electricity and heat generation, in addition to fugitive emissions from oil and gas. The following sections investigate these two key emission categories within the energy sector.

Figure 3: International assessment of energy-related emissions in Iraq (Climate Watch 2022)

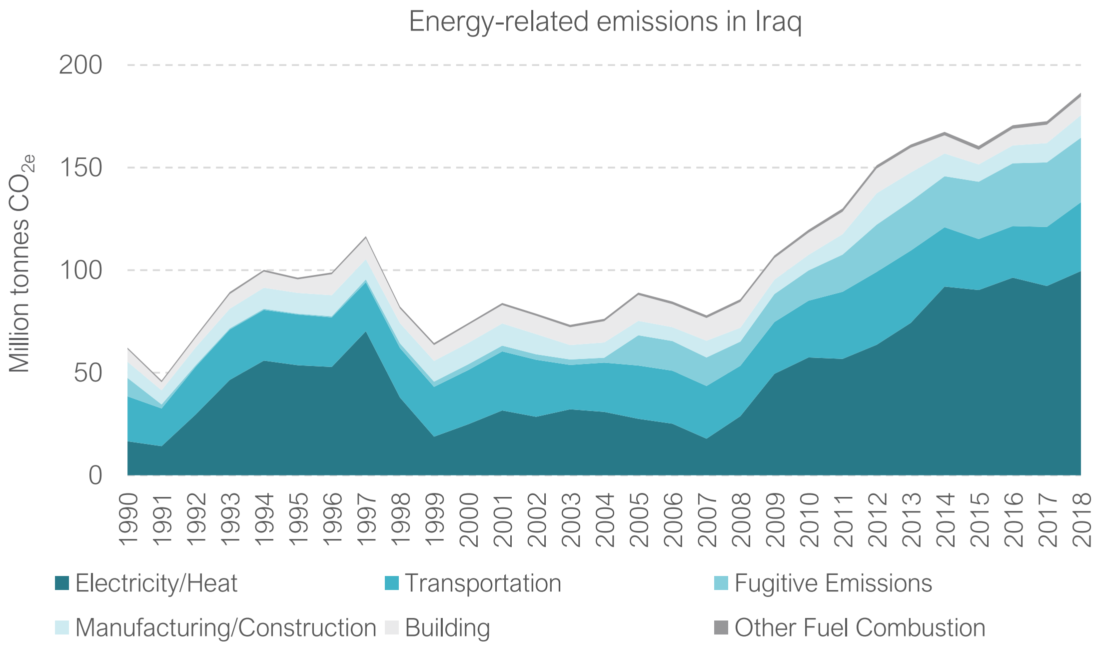
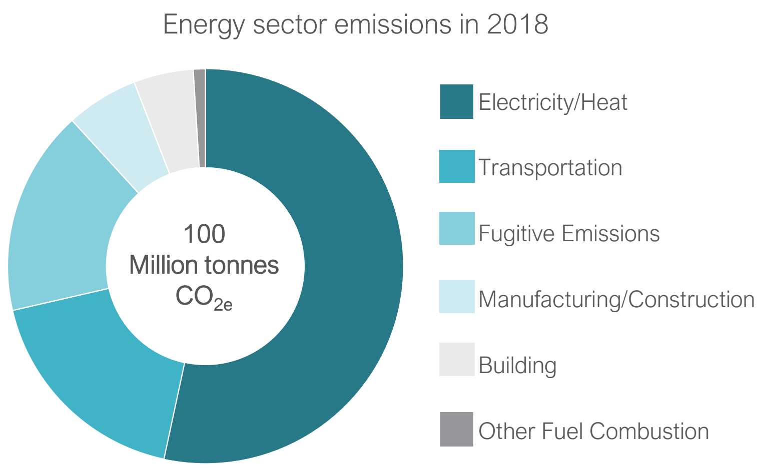


Figure 4: International assessment of energy sector emissions in Iraq, 2018 (Climate Watch 2022)



1.4.1 Electricity and heat

Iraq's net electricity generation grew on average by 8% from 2008 to 2018, reaching approximately 80 TWh. Over 97% of electricity is generated from oil and gas. The share of natural gas in power generation increased from 30% in 2016 to approximately 50% in 2018, primarily due to imports of Iranian gas rather than Iraq's own supplies. About 23% of Iraq's electricity is produced from natural gas produced in Iran and about 5% is imported from Iran (EIA 2021).

The country's electricity consumption is very seasonal and reaches its peak during the hot summer months. In general, power generation plants operate at low utilisation rates (with available production capacity much lower than installed capacity) due to poor transmission infrastructure, extremely high transmission losses (which average to 52% of the total electricity supply),[1] and damaged or inefficient power plants. This results in frequent power shortages, especially in the summer.

Population groups with higher incomes often use local neighbourhood generators to avoid blackout issues, adding to the consumption of liquid fossil fuels and associated emissions (IEA 2019).

1.4.2 Oil and gas industry

The oil and gas sector is the key pillar of Iraq's economy—it is by far the largest industrial sector and contributes to over 90% of total government revenues. Crude oil production has grown dramatically over recent years, from 3 million barrels per day in 2013 to over 4.7 million barrels per day in 2019 (EIA 2021).

GHG emissions from the oil and gas sector can be split into two main categories: (1) emissions from energy combustion for productive purposes; and (2) emissions due to resource waste through flaring, venting, and fugitive emissions of methane. While the first category might be significant due to the petroleum sector's high production volumes and its strategic importance to the country, they are not easily reduced (certain energy efficiency measures can be taken, but reduction in energy consumption will be minimal). The second category of emissions, including flaring of associated gas, venting, and unintentional (fugitive) methane emissions through leaks, are important to mitigate. They represent a resource waste that could be used

[1] These are the result of damaged infrastructure, poor system design and high rates of electricity theft.

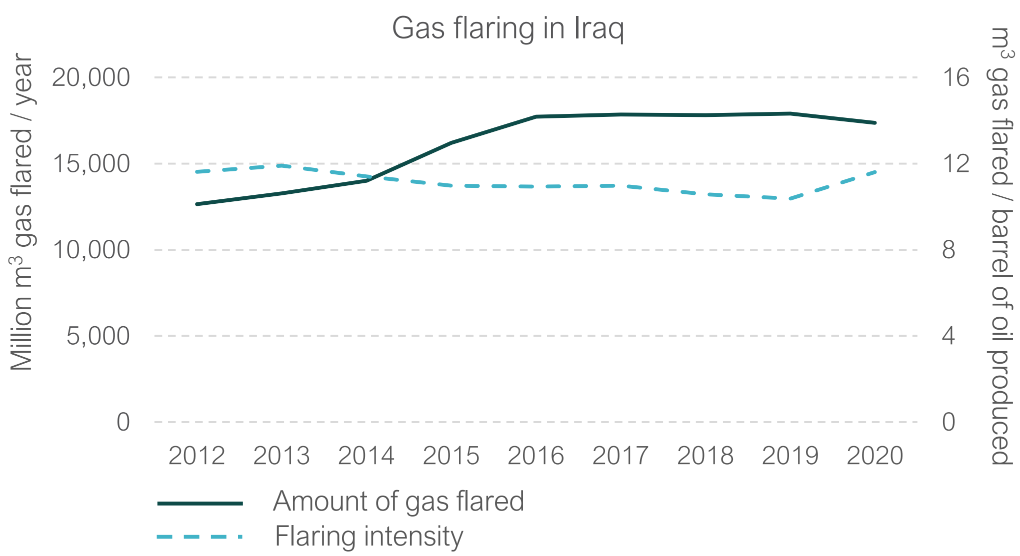
elsewhere in the economy for productive purposes—for example, power generation or transport. Hence the focus of this section will be on this emission category.

Associated gas flaring

One of the most significant sources of emissions, which can not only be avoided but also lead to emission reduction in other sectors (namely power generation), is associated petroleum gas (APG) flaring. Around 14 to 15 billion m^3 (bcm) of APG are flared annually in Iraq[2]. This amounts to an energy loss that could alternatively provide over 80 TWh of electricity, equivalent of the total current electricity production in Iraq (EIA 2021). The gas is flared primarily due to insufficient pipeline capacity and processing infrastructure.

The figure below presents international satellite-based flare estimates based on the data collected by a Visible Infrared Imaging Radiometer Suite (VIIRS)[3] and analysed by the US National Oceanic and Atmospheric Administration (NOAA).[4] This data is an important source for understanding the scope and location of flaring in a particular country. However, it is important to state that this source of information has its limitations and an assigned degree of uncertainty (estimated to be at ±9.5%).

Figure 5: Volumes and intensity of associated gas flaring in Iraq (The World Bank 2021)



As observed on the chart, flare intensity (amount of gas flared per unit of oil produced) has been slightly decreasing in Iraq from 2013 to 2019 due to an increasing number of gas utilisation projects. Iraq is pursuing several projects and negotiating agreements with various technology providers for natural gas capture and processing in power generation (Iraq Oil Report 2020). In particular, the Basrah Gas Company has made recent progress and is now capturing and processing around 10 bcm of gas per year (IEA 2019). Yet more efforts are needed to eliminate routine flaring—Iraq pushed back its target to eliminate natural gas flaring to 2025 (MEES 2020).

Venting and fugitive emissions through leaks

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[2] Based on the ministry's data.
[3] VIIRS, a scanning radiometer that is used to measure cloud and aerosol properties, ocean colour, sea and land surface temperature, ice motion and temperature, fires, and Earth's albedo. Climatologists use VIIRS data to improve our understanding of global climate change.
[4] For detailed description of the analytical approach, refer to Elvidge *et al.* (2016).

Venting and fugitive emissions are different from combustion emissions as the main GHG emitted into the atmosphere through direct releases of gas (without combustion) is methane. Methane is a powerful greenhouse gas that stays in the atmosphere for only 12 years. During this time, it contributes substantially more to climate warming than CO_2: the global warming potential of methane is over 25 times greater than CO_2 over a 100-year timeframe, and 86 times greater over a 20-year timeframe. As a result, methane emissions have contributed over one-quarter of global warming experienced today. Methane is emitted throughout the oil and gas supply chain, from unintentional leaks to planned and intended processes. The sector provides the greatest potential for emissions reduction—according to the International Energy Agency, over 70% of emissions can be abated with technology that exists today, and up to 40% at no net cost (i.e., the economic gains from deploying these technologies outweigh the costs) (IEA, 2021).

Unfortunately, no reliable national estimates of direct methane emissions exist in Iraq today. However, many international studies have explored the issue, some of which are presented in the following charts. The consensus is that methane emissions from Iraq's oil and gas sector are substantial, but improved estimates of the magnitude, location, and specific sources are necessary to begin mitigating these emissions.

Figure 6: Direct methane emissions in Iraq, 2020 (IEA Methane Tracker, 2021)

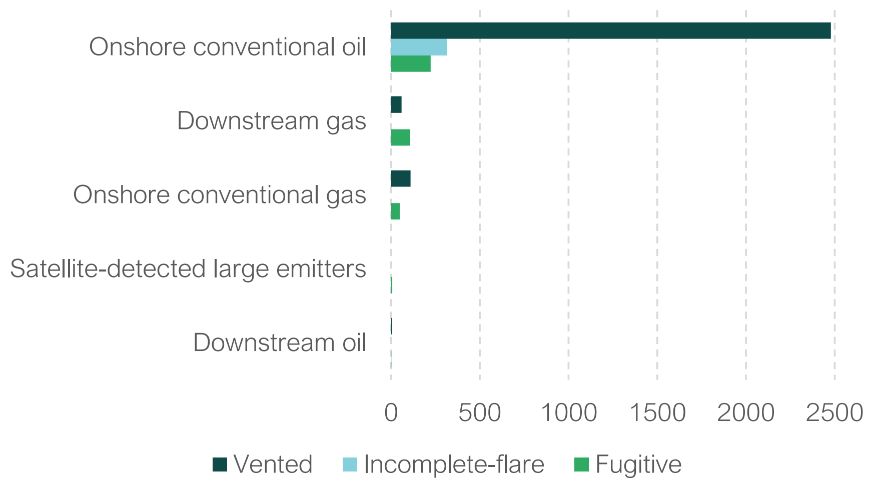
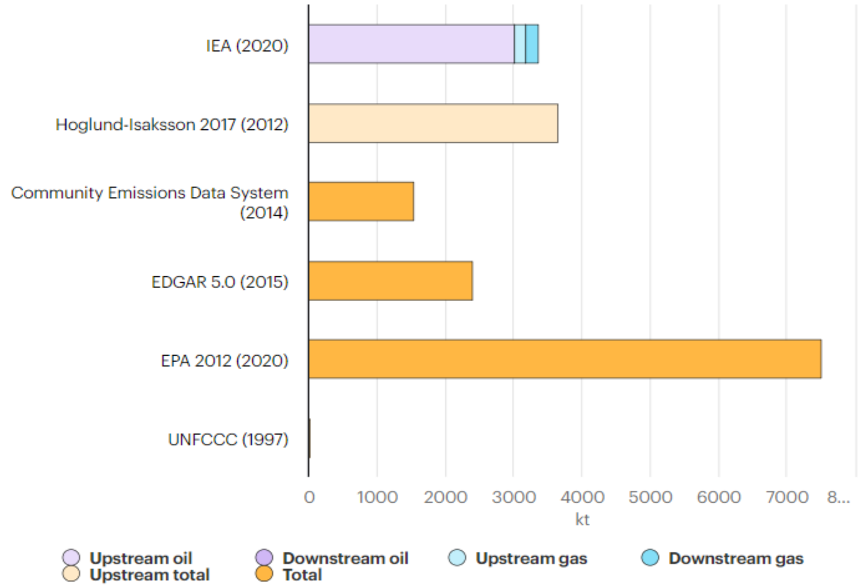


Figure 7: Comparison of international estimates of direct methane emissions in Iraq (IEA, 2021)



1.5 Vulnerability to climate change

Iraq is already experiencing significant adverse impacts of climate change in the form of rising temperatures and declining precipitation, leading to decreased water and food availability, desertification, and associated impacts on population health. Major industries will also be affected, including the oil and gas and agricultural sectors, which require significant water resources for their operations. The majority of water consumption—around 80%—is for agricultural purposes. Hydropower generation is also threatened; according to some scenarios, plant capacity could be reduced from 1,846 MW to 400 MW (NC 1, 2016) Drought and low rainfall have decreased river flow, drying out wells, springs, irrigation channels, and waterways, and making them more susceptible to pollution from industrial wastewater or agricultural irrigation, which carries contaminated organic materials or solid waste. Leakage of crude oil and petroleum into the environment is further polluting water resources, agricultural land, and soil, whilst harming local wildlife and damaging water purification stations by clogging filters and creating mechanical issues.

The country's vulnerability is further affected by conflicts happening within Iraq's territory in decades, which have damaged water systems, irrigation facilities, and disrupted value chains.

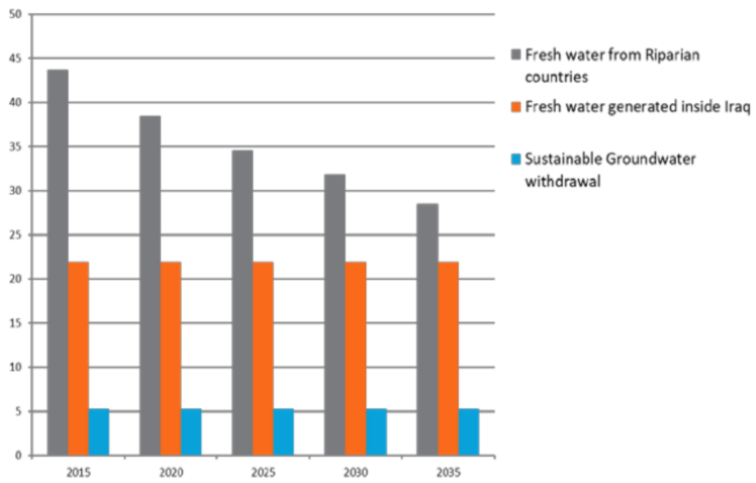
1.5.1 Water Resources

Water resources are especially vulnerable to climate change. Up to 98% of Iraq's water comes from the Tigris–Euphrates River Basin. By 2025, both rivers are expected to decline by a dangerous 50% and 25%, respectively, in addition to the decades of decline already observed. The Euphrates had a recorded volume of 30.6 bcm in the middle of last century; currently, its volume is estimated at 18 bcm.

According to The National Environmental Strategy and Action Plan for Iraq (2013 – 2017), salinity rates in rivers increased by 50% between 2002 and 2006 due to high temperatures, drought, low rainfall less than 50% of normal, and high evaporation rates, especially in the summer. To sustain water resources and compensate for natural or climate-induced water scarcity, methods of irrigations and cultivation can be developed to achieve the highest efficiency with the lowest rate of loss. It is, therefore, important to increase multi-use water allotments and focus on harvesting untraditional water, such as gray water, rainwater, industrial wastewater, wastewater, and treated water.

With a growing population and economy, production of both the oil and gas and agricultural sectors are expected to increase significantly in subsequent years, further intensifying the pressures on Iraq's water resources. Iraq's INDC indicated a 16% shortage of renewable water resource availability compared to actual needs in the early 2000s. This percentage is projected to reach 37% during the period 2020–2030, and 51% between 2040–2050. This will have ensuing impacts on agricultural production, environmental systems, and biodiversity. Though climate change is projected to continue affecting the region for decades to come, possible measures can be employed to help adapt to its impact on water supply.

Figure 8: Expected water supply sources and quantities in Iraq until 2035 (MWR, 2014)



1.5.2 Agriculture

The agricultural sector is one of the key consumers of water resources in Iraq (over 80%) and its development will strongly depend on the security of water resource in the future (NC 1, 2016). Agriculture in Iraq is mostly practiced on small farming units in a low-input, low-output system. Crop yields are low compared to other neighbouring countries as farmers aim to minimise costs around land preparation, planting, weeding, and harvesting. Most farming is for crop production (over 75%), while the rest produce livestock or a mix of crops and livestock. Grains, primarily wheat and barley, are Iraq's main crops in the north and central rain-fed areas. In central and southern Iraq, where agriculture depends mainly on irrigation from the Tigris and Euphrates rivers, mixed farming systems are predominant (FAO Investment Centre 2012). The amount of water used for irrigation is increasing due to the open and old irrigation canals, outdated irrigation techniques, and less efficient agricultural practices. This leads to rising groundwater levels, waterlogging, soil salinisation, and pollution of water supplies.

1.6 Existing national policies and development priorities in Iraq

In 2003, the Ministry of Environment (MoE) was established in Iraq to implement state policy that protects and improves the quality of the environment. As part of the Ministry of Health and Environment, the MoE also represents Iraq in international environmental agreements. In 2009, Iraq became a member of the United Nations Framework Convention to Combat Desertification (UNCCD) and ratified the UNFCCC and Kyoto Protocol. In the same year, the MoE worked with the UN Development Programme (UNDP), Global

Environment Facility (GEF), and UN Environment Programme (UNEP) to prepare and submit its Initial National Communication (NC 1) to the UNFCCC. Iraq signed the Paris Agreement in December 2016 but has yet to ratify the agreement.

This section explores the regulatory instruments to combat climate change in Iraq, and their specific objectives in terms of mitigation and adaptation.

1.6.1 National Development Plan 2018–2022

Iraq's National Development Plan (NDP) 2018–2022 considers various dimensions of development from economic, political, social, ecological, and cultural perspectives (Ministry of Planning, 2018). This plan establishes short-term actions to address the developmental challenges within the country, arising due to current policies, conflicts, and social issues resulting from large-scale population growth in recent years—increasing from just over 7 million people in 1960, to 40 million today.

The NDP is divided into four pillars, one being private sector development as a vital anchor for progress and the reduction of multidimensional poverty in Iraq's provinces. Another of which is sectoral and spatial development, in which plans for the economic and productive sectors of the country are established: agriculture, energy, manufacturing industries, and transport. The status and challenges of each sector are outlined in relation to a series of objectives, means of achievement, and techniques to face those challenges in the short-term.

The NDP also contains a chapter on environmental sustainability, which acknowledges the following:

- Iraq is exposed to many environmental phenomena, especially due to climate change;
- Decreasing water resources and precipitation, and increasing temperatures, humidity, evaporation, and sandstorms are currently the main climate impacts in the country;
- Loss of rainfall is predominantly due to evaporation from rising temperatures (75%), as well as surface water runoff (20%) and groundwater infiltration (5%);
- Iraq suffers from an environmental deficit, whereby the biological capacity of the land is lower than the international average whilst the ecological footprint continuously increases.

The priority of Iraq's NDP is to boost economic sectoral growth. Therefore, not all sectors address issues surrounding environmental protection and the fight against climate change. However, some sections more specifically mention an emission reduction objective, particularly the energy sector (electricity and oil and gas). The plan identifies renewable and clean energy sources, particularly solar energy, as key to limiting resource depletion and reducing demand on oil and gas sources. It also emphasises the increasing scarcity of freshwater resources due to climate change in both Iraq and neighbouring countries, as well as the financial crisis that made challenging environmental issues extremely challenging.

The key aspects of the sectors of interest within the NDP, in terms of both mitigation and adaptation goals, are summarised below.

1.6.1.1 Mitigation

Table 1: Current situation and related objectives of mitigation sectors of interest, NDP 2018–2022

Sector	Current situation	Objectives

Oil and gas	Available storage capacity will not be sufficient in the future due to the increase in targeted export capacities. Decline in locally refined oil. Six refineries taken out of service due to military operations, reducing total design capacity by 51%. Flaring of large quantities of gas due to failure to implement required processing and gathering infrastructure, which limited the separation of gas to high value components. Obsolescence of crude oil pipeline network with no connection between the north and the south.	Increase the production capacity of crude oil to 6.5 million bpd.[5] Increase the export capacity of crude oil to 5.25 million bpd. Raise the natural gas production to 3500 MMscf/d.[6] Enhance confirmed gas reserves. Achieve self-sufficiency and derivatives export by increasing refining capacity to 900,000 bpd.[7] Enhance storage capacity of petroleum products to secure storage of 2267 m3. Protect the environment from contamination, address problems resulting from existing oil and gas facilities, and reduce CO2 emissions.
Electricity	High production deficit after many plants were out of service. High load growth and increased electricity demand. Reduction in existing plants efficiency due to poor provision of adequate fuel. Decreased water levels and their negative impact on the operation of steam plants. Weak community culture about consumption rationalisation, and absence of belief that the citizen is responsible for covering the costs of provided services as national obligations. Obsolescence of the electricity system equipment over time, and the urgent need for maintenance and rehabilitation to keep them in operation. Inability of transmission and distribution grids to accommodate added energy.	Increase the total electricity production capacity to 20,869 MW. Improve electricity system efficiency. Improve quality of consumer services. Rationalise electricity consumption in different uses and reduce it by 7% annually. Improve the environmental impact of electricity activity by reducing CO_2 emissions.
Manufacturing and (non-oil) extractive industries	Difficulties in competing with imported products due to high production costs. Limited private sector capabilities with little opportunities to expand and develop. Weak infrastructure service provision to this sector (electricity, fuel, raw materials, etc.).	Support strategic industries, especially in the liberated areas that have minerals and natural gas as key component for these industries. Establish interrelations between manufacturing and other sectors and

[5] Al Faw and Al Nasiriya reservoir were completed to achieve this objective.
[6] Several projects for investing gas from oil fields were established to prevent gas burning.
[7] The north refineries (such as Beji refinery) were rehabilitated and brought back to service.

	Need for sectoral interrelation to complete the economic cycle, using agricultural resources and livestock in industry operations and vice versa; including, for example, mechanical industries, food, textile, leather, petrochemicals, fertilisers, and others.	involve the private sector to benefit from its potential Advance geological surveys to develop an integrated map of Iraq's mineral resources to render them into investment opportunities.

In relation to the objectives listed in Table 1, some of the proposed measures to address environmental challenges are to (Ministry of Planning, 2018):

- Establish new environment-friendly refineries based on international standards (EURO-5);
- Take measures to transition Iraq to the dry canal (railroad);
- Rehabilitate closed landfills;
- Ensure treatment of by-products and waste;
- Establish and equip laboratories to conduct environmental tests in all power stations;
- Introduce the combined cycle system which helps reduce emissions of power projects;
- Install fogging systems;
- Implement projects for green belts in the electricity sector;
- Increase the number of factories which utilise clean production mechanisms;
- Reduce sulphur content in diesel fuel (gasoil);
- Ensure gas waste disposal from industrial activities/services meets environmental requirements;
- Reduce carbon dioxide emissions;
- Utilise associated gas;
- Reduce the production of unleaded gasoline;
- Upgrade fuel and liquid gas stations.

1.6.1.2 Adaptation

Table 2: Current situation and related objectives of adaptation sectors of interest, NDP 2018–2022

Sector	Current situation	Objectives
Agriculture and water resources	There is a clear decline in incoming water resources, whether from transboundary sources such as the Tigris and Euphrates rivers with about 75% of the natural water resources for the Tigris and Euphrates derived from beyond Iraq's borders, or from rivers inside Iraq declining due to drought conditions. Many vital facilities were destroyed or damaged, such as the Ramadi and Fallujah Barrages, Warwar and Taqsim regulatory dams, and other important secondary facilities.	Achieve sustainable food security. Secure the annual demand for sustainable water uses in various fields (agricultural, industrial, municipal) and achieve water balance with the possibility to reduce annual demand by 500 million m^3. Provide sustainable water resources.

The agricultural sector faces a number of challenges, plagued by successive years of drought, fluctuation in rainfall, environmental changes, and various risks, in addition to the loss of key cycles in agricultural marketing. This has led to reductions in agricultural production and a lack of agricultural insurance companies and associations specialised in mechanisation, marketing, and transport.

Iraq's water resources are also suffering due to various environmental problems, which further represent the environmental obstacles hindering integrated water resources management. In brief, Iraq faces two main challenges in securing its water needs: water flow decline, and climate and geological changes.

Table 3: Adaptation related goals, NDP 2018–2022

Sector	Goals	Means of achievement
Agriculture	Increase GDP contribution of the agricultural sector (for non-oil activities) from 4.5% in 2015 to 5.2% in 2022 and achieve a sector growth rate of 8.4% in the target year.	1. Increase agricultural land and promote production and productivity by focusing on: • Expanding cultivation of on-farm crops, used directly in human food, and industrial crops, used as raw materials in many industries. • Manufacturing machinery and agricultural equipment to meet the growing domestic demand associated with the expansion of agricultural production (*regarding table page 133) • Establishing a factory for agricultural supplies (such as plastic covers to cover plantings, and supplies of modern irrigation such as sprinkling and drip irrigation); • Integrating reclamation of agricultural land. 2. Combat desertification; 3. Advance developmental and research programmes and agricultural extension; 4. Support domestic and foreign private sector investment; 5. Develop agricultural sector infrastructure; 6. Use modern technologies in irrigation and agriculture methods; 7. Control and monitor border outlets to prevent entry of agricultural products if locally produced alternative is available.
Water resources	Secure the annual demand for sustainable water uses in various fields (agricultural, industrial, municipal) and achieve water balance with the possibility to reduce annual demand by 500 million m^3.	1. Competent management of water resources; 2. Improve on-farm irrigation efficiency through integrated water resource management; 3. Reduce waste and losses in water use; 4. Increase water reservoir volume.
	Provide sustainable water resources	1. Reach an agreement with upstream and riparian states to ensure fair distribution and sustainable water rights; 2. Recover and develop marshes; 3. Invest in renewable groundwater; 4. Rehabilitate and reconstruct water resource infrastructure damaged by military operations (Haditha Dam, Adhaim Dam, Fallujah Barrage,

		Unified Canal Regulator, Ramadi Barrage, and Warrar Regulator).
	Minimise water loss by at least 10% of the baseline year	1. Provide modern standards for all participants to control waste and reduce the losses of pure water and ensure the optimal use of water through special awareness programmes. 2. Expand the production and distribution of raw water to all districts of Baghdad and provincial centres to replace the clean water in watering gardens. 3. Enforce provisions, laws, and legislation on those who violate public networks. 4. Use modern technologies (photovoltaic cells, etc.) in water structures and others to reduce losses of pure water.

1.6.2 The National Environmental Strategy and Action Plan for Iraq 2013–2017

To consider the several challenges associated with preserving and improving Iraq's environment and harmonizing it with national, regional, and international requirements, the Ministry of Environment prepared the National Environmental Strategy and Action Plan (NESAP) for the 2013–2017 period (Ministry of Environment 2013). The strategy has not since been updated but serves to the purpose of this project as it contextualises the specific challenges around various environmental issues and establishes concrete actions to combat them.

According to this strategy, the MoE *"seeks to adopt sustainable development concepts; follow the approach of integrated environmental management; and combat poverty, poor environmental awareness, low income, and environmental deterioration*" (Ministry of Environment 2013). It intends to integrate clean energy, Environmentally Friendly Technologies (EFTs), natural resources management, reuse and recycling actions, and environmental awareness into the following components: 1) air quality; 2) water quality; 3) land degradation and desertification; 4) marine and coastal environments; 5) sustainable use of biodiversity; 6) environmental awareness and public participation; 7) oil pollution; 8) radioactive contamination; and 9) hazardous chemicals. These components can be separated into the two mains categories of this report, adaptation and mitigation.

Among other reasons, this planning instrument was developed to establish short- and long-term strategic solutions to combat climate change and its impacts at the local and regional level, build the necessary capacities, and strengthen the supervisory and inspection role of the MoE (Ministry of Environment 2013).

A principal element of this strategy is its identification of the main reasons for environmental deterioration—including population increase, urbanisation, desertification and land degradation, lack of environmental monitoring systems, wars, and the political situation. These it highlights as relevant aspects affecting the scarcity and pollution of freshwater and marine water resources, air pollution, and biodiversity, all of which creates high societal and environmental costs in the form of damage to health and quality of life, estimated at 3.7% of GDP in 2013 (56% of total losses), and to natural resources, 2.9% of GDP (44% of total losses) (Ministry of Environment 2013).

Based on the information cited in the NESAP, the total cost of environmental degradation amounted to 4.9–8.0% of GDP in 2008 (an average of 6.4% or 5.5 billion USD per year), the primary reasons being:

- Diseases resulting from drinking water of poor quality;
- Increased respiratory diseases due to polluted air;
- Neglected and pressured agricultural lands, leading to crop losses;
- Unsustainable management and non-recycling of waste;
- Insufficiently protected coastal resources;
- Inefficient production and use of energy, and non-use of renewable energies.

The components of interest, in term of mitigation and adaptation are presented below.

1.6.2.1 Mitigation

As air quality and oil pollution are challenges for the energy and industry sectors, the NESAP focuses significantly on clean energy. It outlines how clean energy can reduce polluting emissions in fixed and mobile sources, achieved by "*designing proper mechanisms to dispose of leaded gasoline and reduce sulphur in diesel oil to protect public health and environment*" (Ministry of Environment 2013).

Industrial and service facilities are described as using "*obsolete and Non-Environmentally Friendly Technologies (NEFTs)*" that have a high impact on resource consumption. According to this strategy, this requires a) encouraging EFT use and adopting cleaner production techniques to reduce emissions from fossil fuels, b) providing proper economic incentives to industrial activities that use EFTs, and c) building the technical capacities of these activities.

In terms of energy production, the NESAP emphasises that the country was experiencing an increase in emissions from power stations due to the excessive production and consumption of conventional non-renewable energy sources. Thus, the use of renewable energy such as solar, wind, hydroelectric, and biomass is a particularly relevant strategy for Iraq to significantly reduce emissions in the coming years.

Some of the programs and projects considered in this planning instrument are presented in Table 4 (Ministry of Environment 2013). The strategy breaks down every component by program and project and can be consulted extensively within the various individual sections of the document. However, for the purposes of this report, only climate change, energy, and industry related programs and projects are displayed.

Table 4: Future Projects related to energy and industry sectors considered in the strategy

Components	Programs	Projects
Component I: Air pollution from natural sources	1.2 Assessment of the impacts of and adaptation to climate change	1 Overall assessment of climate change for priority sectors
		2 Development of a national strategy to adapt to climate change
		3 Implementation of adaptation activities in the most fragile sectors, regions, and ecosystems in partnership with civil society
		4 Establishment of the national center for climate change.
Component II: Air pollution from	1.4 Control, enforcement, and	1 The private sector partnerships in controlling the emissions

fixed (point) industrial sources	compliance to reduce air pollution	
	1.5 Rehabilitation of facilities not meeting environmental requirements	1 Rehabilitation of Ministry of Industry and Minerals companies 2 Rehabilitation of oil sector companies 3 Establishment of new refineries according to international specifications 4 Rehabilitation of power plants
	1.6 Promotion the use of renewable energies	1 Preparation of wind and solar energy Atlas for Iraq 2 Using solar and wind energy to generate electricity and link to the national network 3 Using solar and wind energy to generate electricity in public buildings and facilities 4 Development of local technological industries of solar and wind energy technology
	1.7 Improvement of energy efficiency	1 National Project for energy efficiency in different sectors 2 Modernizing the technology used in electric power production 3 Cleaner fuel and its necessary specifications and legislations
	1.9 Development of craft industries in Iraq	1 Promoting the use of clean energies in craft industries
Component VI: Clean energy	1.14 Use of clean fuel	1 Using CNG (compressed natural gas), LNG (liquefied natural gas), LPG (liquefied petroleum gas) for means of transport 2 Establishing stations to fill cars with CNG
	1.15 Use of renewable energy	1 Using solar energy to support the electricity system 2 Promoting the use of solar energy in public buildings and facilities 3 Using wind energy for electric power generation in agricultural and desert areas
	1.16 Energy production from waste	1 Using biogas for domestic use 2 Electric power production from waste for residential use

Source: Ministry of Environment. The National Environmental Strategy and Action Plan for Iraq 2013-2017 (NESAP).

The programs and projects considered in the NESAP are general lines of action that do not specify the type of technology, project size, sector, location, or period of implementation. However, it may refer to plans by the Ministry of Environment to increase renewable energy, the use of less carbon-intensive fuels, and energy efficiency in industry, reflecting the broader governmental interest in taking action to reduce emissions.

1.6.2.2 Adaptation

Iraq is facing two main challenges in securing needed water: 1) decreased water supply from the Tigris and Euphrates rivers that feed in from neighbouring countries where numerous projects have been established upstream; and 2) climate change impacts on water resources. Water scarcity is further impacted by pollution, which results from the lack of integrated waste treatment plants (IWTPs) and wastewater treatment plants (WWTPs), which affects the quality of water discharged into rivers without proper treatment. In addition to pollution resulting from hospitals that produce and discharge untreated water directly into rivers, there is poor control over similar activities, poor enforcement of applicable laws to alleviate the negative impact of discharged untreated water, and inadequate implementation of closed cycle and water reuse policies.

These challenges have resulted in much focus on water management and resource-use in Iraq, with the need to construct sewage treatment stations for water recycling and to facilitate river recharge, facilitating water reuse and allowing natural surface water supply to be reinforced to reduce overall water scarcity. Water scarcity is also being addressed through water consumption management with modern irrigation methods that prevent misuse of allocated water shares, which is achieved through the activation of water-related legislations that give the Directors of Water departments within the governorates the authority to hold those who violate water allowances accountable. Further efforts to combat water scarcity include education and awareness raising through published media as well as educational workshops and seminars organised for water users at the local level on a recurring basis. Measures to effectively monitor and evaluate sustainable use of groundwater resources have been developed so that strategic groundwater reservoirs are not negatively impacted. These efforts have been prioritised within the Strategy of Water and Land Uses in Iraq (2015-20135) which was developed by the Ministry of Water Resources, that integrates national strategies and plans, such as the NDC, to ensure that the outputs of the strategy are aligned with Ministry and National priorities.Programs and projects in this planning instrument related to water resources are shown in Table 4.

Table 5: Projects related to water resources sector considered in the strategy

Components	Programs	Projects
Protect and improve water quality – Component: Regional dimension of water resource scarcity in Iraq	2.1 Cooperation with neighbouring countries to ensure water quality and quantity	2.1.1 Establishing a national database to monitor water quantity and quality in shared rivers 2.1.2 Drafting quality agreement with riparian countries
	2.3 Study on the impacts of climate change on water demands	2.3.1 Studying the effects of drought and higher temperature on water quotas
	2.4 Water quality improvement	2.4.1 Developing a program for monitoring and control of different water resources and sources of pollution 2.4.2 Rehabilitation of WWTPs 2.4.3 Rehabilitating rivers banks

		2.4.4 Remote sensing project (investment) to monitor the water quality of the Euphrates, Habbaniyah Lake and discharges flown into them (Anbar Environment Directorate) 2.4.5 Operational project to implement quality systems in Baghdad Directorate 2.4.6 Development of environmental monitoring and early warning systems 2.4.7 Improvement of quality of water resources in northern governorates through developing monitoring and install remote sensing systems
	2.5 R&D and capacity building	2.5.1 Using mathematical models for SMWR 2.5.2 Establishing a water resources information bank 2.5.3 Development of national environmental database and atlases
	2.6 Demand management planning	2.6.1 Mapping future water needs of different sectors 2.6.2 Water use rationalisation in different sectors
	2.7 Reduction of the marshlands’ water scarcity and deterioration	2.7.1 National plan to handle cases of the marshlands’ water scarcity 2.7.2 Using remote sensing techniques and GIS for the marshlands M&E 2.7.3 Construction of dams and regulation of the Marshlands water channels with monitoring and control system for water quality
	2.8 Restoration of the marshlands and mobilisation of international and regional support	2.8.1 National plan for rehabilitation and development of the marshlands’ villages (economic development – supply villages with electricity) 2.8.2 Taking advantage of recycling water and materials in the marshland communities 2.8.3 Including the marshlands in the international and regional agreements
	2.9 Sewage and agricultural wastewater treatment	2.9.1 WWTPs rehabilitation and using modern technologies (impermeable membrane technology) 2.9.2 Re-using sludge from WWTPs for agricultural purposes 2.9.3 Establishing a program to monitor and locate sewage disposal in rivers (to be included within the sewage systems development plan)

		2.9.4 Rehabilitating sewage networks 2.9.5 Issuance of instructions on the use of treated wastewater for the purposes of irrigation
	2.10 Industrial wastewater treatment	2.10.1 Rehabilitation of IWTPs within Ministry of Industry and Minerals companies 2.10.2 Rehabilitation of IWTPs within Ministry of Oil companies 2.10.3 Rehabilitation of IWTPs 2.10.4 Establishment of new IWTPs in large refineries 2.10.5 Establishment of WWTPs for the residential areas affiliated with the oil sector 2.10.6 Rehabilitation of IWTPs within Ministry of Electricity companies 2.10.7 Using magnetic systems and techniques for industrial wastewater treatment for preserving the environment 2.10.8 Encouragement of programs of cleaner production and recycling in plants and facilities to stop discharging wastes
	2.11 Monitor water quality in the downstream estuary	2.11.1 Monitoring and control of water quality in the downstream estuary

1.6.3 Intended Nationally Determined Contribution (INDC) to the New Climate Change Agreement 2015

Despite the difficult challenges, the Government of Iraq has laid out an economy-wide plan to reduce GHG emissions by around 14% from the business as usual (BAU) scenario over the period 2020 to 2035. Iraq's INDC envisages a national reduction of emissions by 1% below BAU by 2035, increasing by 13% with support from the international community. Emissions reductions from 2020 to 2035 consider two scenarios:

1) Reduction of total emissions by 1% through implementing 15 projects, which fall within the national reduction capabilities if security and peace are guaranteed;
2) Reduction of total emissions by 13% through implementing 27 projects, conditional on security and funding from the UNFCCC and international partnerships.

Accordingly, Iraq intends to offer 14% of total business in clean and renewable energy and carbon management for investment between 2020 and 2035.

The INDC initiates different measures in terms of mitigation and adaptation.

1.6.3.1 Mitigation

Based on its commitments and if security conditions are favourable, Iraq seeks to introduce 'clean and low-carbon technologies' to different sectors including electricity, industry, transport, waste management, housing, and oil and gas, through the utilisation of most of the associated petroleum gas (APG) (currently burnt), being able to reduce dependency on heavy fuel in power generation, transport, and industry sectors.

Table 6: Projects considered in the INDC in energy and industry sectors (Ministry of Environment 2015)

Projects for the scenario of 1% reduction	Projects for the scenario of 13% reduction
Energy	
1. Shift to combined cycle power plants; 2. Improve the performance of electricity system to maintain sustainability and stability with high reliability; 3. Utilise maximum levels of associated petroleum gas (APG), currently burnt to reduce dependency on heavy fuel in power generation and in other sectors, such as transport and industry.	1. Increase investment in combined cycle power plants; 2. Initiate energy conservation and efficiency programs; 3. Use clean, new and renewable energies; 4. Reduce the technical loss in power transmission and distribution; 5. Develop hydroelectric plants in the Kurdistan Region, which will increase the hydroelectric power contribution to total generation of 3.3% by 2035, supposing that the Mosul Dam will have been rehabilitated 6. Improve the quality of oil products to match the international standards through the construction of advanced refineries and rehabilitation and development of existing ones; 7. Use LPG as vehicle fuel to reduce dependency on gasoline; 8. Utilise the APG in the national oil fields.
Industry	
1. Heat recycling to produce electricity and use it for production purposes; 2. Develop manufacturing processes that reduce emissions, including in existing and planned industries such as the fertiliser industry; and 3. Replace some mechanical incineration systems in private brick factories with more efficient and environment-friendly systems.	1. Implement a strategic CCS project; 2. Develop manufacturing processes that reduce emissions in all existing and planned industries, such as the fertiliser industry; 3. Replace mechanical incineration systems in private brick factories with more efficient and environment-friendly systems; 4. Establish private and public industrial enterprises within the industrial zones envisaged by the Ministry of Industry and Minerals to encourage the manufacturing/ assembling of products including solar cells and other solar energy equipment such as heaters, lights, fridges, cars, pumps, stoves, etc.

It is worth mentioning that specific financial and regulatory related technology barriers that could be an obstacle for development and transfer of environmentally sound technologies were identified. However, Iraq's INDC initiated a first step for action and a plan to aid the removal of potential barriers to create an enabling environment for the technology options prioritised by Iraq[8].

The INDC is in line with the national plans expressed in the NDP and NESAP, which includes interventions aimed at environmental protection, including mitigation. The measures for the first scenario are aimed at improving the efficiency of energy production and the stability of the electricity system in addition to increasing the use of less carbon-intensive fuels, called "clean fuels" in the NESAP. For the industrial sector, energy efficiency is also considered, although the measures do not specify the industries in which they will be implemented. The measures in the second scenario are focused on improving the quality of oil products, as well as on renewables and a reinforced promotion of clean fuels in sectors such as transport and oil and gas. For industry, a CCS project is included in addition to the use of solar cells, heaters, lighting, and other solar-based equipment for industries, though the targeted industries are not specified.

Iraq faces great challenges to implement these measures, one being the energy losses in transmission and distribution lines that make the national electricity system one of the most inefficient and that urgently demand the diversification of energy and improved system stability. Without reducing losses, other measures such as increasing the installed capacity of renewables will not be feasible.

1.6.3.2 Adaptation

Regarding the agriculture sector, projects for the second conditional 1% scenario include the development of a system to protect, maintain, and increase natural forests. While the projects for the first conditional 13% scenario include land management, improved rice farming technologies and natural fertiliser management to reduce CH_4 emissions, increased use of nitrogen fertilisers to reduce N_2O emissions, and improved crop quality.

In terms of water resources, it is worth mentioning that the World Bank estimates from 2011 show a 16% shortage of renewable water resources compared to actual needs over 2000–2009. This percentage is expected to reach 37% during the period 2020–2030 and 51% over 2040–2050. This has adversely affected agricultural production, natural systems, and biodiversity.

For this sector, the INDC includes the following measures:

1. Rehabilite the Mosul Dam to ensure its stability
2. Introduce automated irrigation modalities (sprinkler and drip) across the country
3. Expand the Tharthar regulating duct and the duct at the forefront of the Samara Barrage
4. Increase the number of water treatment plants by 2035
5. Improve and expand the water system, steadily reduce losses, and expand the use of meters
6. Increase the number of wastewater treatment plants by 2035
7. Improve the existing water quality monitoring program at the Ministry of Water Resources
8. Rehabilitate major irrigation projects in Iraq and gradually link them to main drainage outfall areas or to evaporation basins to avoid returning them to rivers and freshwater streams
9. In case a continuous water flow of no less than 50 m^3/s from the Tigris along the Shatt al-Arab cannot be guaranteed, build a barrage on Shatt al-Arab at the entrance to the Al-Faw Port to prevent the expansion of the salty cape into the city of Basrah
10. Conduct more studies about the feasibility of continuing groundwater extraction and about the aquifers to help replenish groundwater supplies and improve conditions for sustainable extraction
11. Construct dams in the Kurdistan Region to harvest rainwater

[8] GCF 2019. Readiness proposal with the Climate Technology Centre and Network (CTCN) through UNIDO for Republic of Iraq.

12. Reuse wastewater

1.6.4 Nationally Determined Contribution of Iraq 2021

The first NDC document reflects Iraq's main policy in dealing with climate change on the national and international level. The NDC is one of the communication documents agreed under the terms of Paris Agreement and the UNFCCC. It tackles both mitigation and adaptation goals throughout various economy sectors. The points related to the four sectors of analysis in this report are summarised below.

1.6.4.1 Mitigation

Table 7: Summary of mitigations key points from Iraq's first NDC (2021)

Energy	
Context	• Energy sector contributes 75% of the national GHG emissions in Iraq
Objectives	• Dissemination of EFTs with focus on energy efficiency • Raise knowledge and provide capacity building • Reduce GHG emissions
Measures	• Energy efficiency in power generation: use of combined cycle • Fuel switching: gas, LPG, and dry gas fuel in electric power production stations • Energy efficiency in building: improve energy efficiency • Energy efficiency in building: LED lighting • Energy efficiency in building: increase transmission efficiency • Renewable energy: use of hydro power • Renewable energy: use of concentrating solar energy • Renewable energy: use of wind energy • Renewable energy: solar street lighting
Industry	
Context	• Financial value of methane emissions is estimated at over 600 million USD • Contribution equal to 2.4% of the national GDP
Objectives	• Reduce associated gas flaring and utilise it • Reduce emissions • Introduce low carbon technologies • Transfer of environmentally friendly industrial technologies
Measures	• Emissions monitoring • Periodic detections programs (LDAR) • Gas recovery and recycling • Carbon Capture and Storage (CCS) • Recycling plastic and tires

1.6.4.2 Adaptation

Table 8: Summary of Adaptation Key points from Iraq's first NDC (2021)

Water Resources	
Context	• Decrease in annual rainfall • Shortage and great scarcity in renewable water sources
Objectives	• Preserve groundwater • Develop awareness around rational water use • Strengthen regional cooperation • Increase resilience of water resources
Measures	• Reduce water losses • Use modern techniques in monitoring and controlling ground water • Desalination of sea water and river water • Dam construction • Establish underground reservoirs • Use efficient irrigation technology • Rehabilitate the main irrigation projects • Develop policies and legislation framework • Sewage and wastewater treatment from the different sectors • Rehabilitate the sewage sector
Agriculture	
Context	• Agricultural sector is one of the main contributors to GHG emissions
Objectives	• Reduce GHG emissions • Combat soil erosion • Increase awareness of climate-smart agriculture • Improve land management practices • Adopt smart agriculture • Increase resilience of the agriculture sector
Measures	• Reduce water consumption associated with agriculture • Rehabilitate degraded lands • Use efficient irrigation systems and fertilising techniques • Use appropriate feeds for cattle and sheep • Use greenhouses and plastic farms

1.6.5 Investment Map of Iraq 2019

Lead by the National Investment Commission, the Investment Map of Iraq was published in 2019 to identify and address investment opportunities in Iraq. According to the report, "*the map provides a detailed overview about the country, and an outline about each governorate including certain information on each sector*" (National Investment Commission 2019). Moreover, the document provides a list of investment opportunities classified by the available investment opportunities in each economic sector and governorate. This map includes several investment opportunities presented by different ministries.

The investment opportunities mapping is given by province and sector, with a description of the local circumstances. Regarding the sectors of interest for this assessment, a brief summary of the goals are provided below:

1.6.5.1 Mitigation

Electricity

Goal 1: Increase the production capacity in the electrical system to reach 20,869 MW.
Goal 2: Increase the per capita electricity supply to reach 4,041 kWh.
Goal 3: Improve the efficiency of the electrical system
Goal 4: Improve the quality of services provided to consumers according to categories (household, government, industrial, agricultural, commercial).
Goal 5: Rationalise the consumption of electricity for different uses and reduce it by 7% annually.
Goal 6: Improve the environmental impact of electricity activity by reducing CO_2 emissions.
Goal 7: Enhance the role of the private sector in managing production and distribution sectors.
Goal 8: Promote governance of the electricity sector and its institutions.

It is worth mentioning that construction of 'solar stations' is regarded as additional capacity of 355 MW.

Oil & Gas

Goal 1: Increase the production capacity of crude oil to reach 6.5 million bpd.
Goal 2: Increase the export capacity of crude oil to 5.25 million bpd.
Goal 3: Raise the capacity of the crude oil in export warehouses.
Goal 4: Raise natural gas production to reach 3500 mf^3 per day.
Goal 5: Strengthen proven gas reserves.
Goal 6: Achieve self-sufficiency and export of petroleum products by increasing the refining capacity to 900 thousand bpd.
Goal 7: Strengthen the reservoir energy of petroleum products to secure storage of 2267 m^3.
Goal 8: Protect the environment from pollution and address the environmental problems caused by the oil and gas activity of existing facilities and reduce CO2 emissions.

The plan is to increase oil production and exports in the following years by expanding refineries.

Manufacturing and Extraction Industries (excluding oil)

Goal 1: Increase the contribution of non-oil manufacturing and extractive industries to GDP by 40% from the base year.
Goal 2: Find other sources of funding for public sector projects and limit the financing of the investment budget for strategic projects only.
Goal 3: Activate the strategies related to this sector and modernise them according to the industrial strategic developments and implementation mechanisms in Iraq up to 2030.
Goal 4: Support important strategic industries, especially in liberated areas, which contain minerals and natural gas—major incentives for this support.
Goal 5: Achieve a sectoral interlinkage between the manufacturing sector and other sectors, involving the available potential of the private sector.
Goal 6: Revitalise geological surveys to develop an integrated map of the country's mineral resources to turn them into investment opportunities.

Specific goals to reduce GHG emissions were not identified.

Adding to this, considered measures to address this sector are:

- Production and maintenance of electrical and solar heaters;
- Creation of power stations with solar cell energy;
- Production and maintenance of water purification and sterilisation plants and solar water sterilisation systems;
- Production, design, assembly, and connection of solar energy systems to supply electricity for lab devices and internal lighting;
- Irrigation systems using solar energy;
- Production, design, and implementation of solar energy systems to heat waters for all industrial service sites.

Most of these measures are oriented to the electric and electronic industry. For other industries, no specific mitigation measures were found.

1.6.5.2 Adaptation

Agriculture and Water Resources

Goal 1: Increase the contribution of the agricultural sector to the GDP (non-oil activities) from 4.5% in 2015 to 5.2% in 2022. Achieving growth in the agricultural sector in the target year of 8.4%.
Goal 2: Achieve sustainable food security.
Goal 3: Secure the annual water demand for sustainable uses in the fields of agriculture, industrial and municipal, and achieve water balance with the possibility of reducing annual demand to 500 million m^3.
Goal 4: Work towards sustainable water resources.

The Investment Plan provides a list of proposed land for agricultural investment in different provinces (214 opportunities in Iraqi provinces for 2019).

Water and Sanitation

Goal 1: Ensure supply of potable water according to international standards and that per capita access to clean water matches population growth, at least 250 liters per day per person in Baghdad and provincial centers and 200 liters per day in the districts and villages.
Goal 2: Improve the quality of potable water.
Goal 3: Reduce losses by at least 10% from the base year.

1.6.6 Iraq: Reconstruction and Investment (2018–2030)

The document is structured around five key stages for a country following a series of conflicts: 1) Governance; 2) Reconciliation and Peacebuilding; 3) Social and Human Development; 4) Infrastructure; and 5) Economic Development. For each pillar, the framework suggests concrete reform priorities sequenced over the short-, medium- and long-term (World Bank, 2018).

The document provides a proposed framework to reconstruct the country by identifying Iraq's main structural challenges and the conflicts' impacts on liberated areas and formulating a reconstruction and development plan with local investment opportunities as well as national programs and reform priorities. Likewise, it presents the envisioned institutional arrangements, covering timing and geographic scope of the framework, implementation arrangements, accountability mechanisms, and strategic communication. To close, it addresses the envisioned financing strategy (World Bank, 2018).

According to this document, key challenges within the environment and natural resources sector include*: "(i) Conflict pollution, related to widespread contamination of land by military wastes, land mines, and hazardous chemicals; (ii) Oil pollution due to obsolete infrastructure occasioned by neglect due to multiple conflicts, a weak regulatory system, and weak capacity within the industry regarding hazardous chemical management; (iii) Management of natural resource scarcity including illegal and/or uncontrolled use of natural resources and poor farming practices resulting in widespread ecosystem degradation; and (iv) Climate change and desertification which exacerbates the ecological impacts of an already harsh climate characterised by low rainfall and high summer temperatures, with differentiated impacts on men and women, internally displaced persons, and vulnerable populations"*.

The document includes a sectoral needs assessment that identifies gaps and key criteria for each sector. Among the considered criteria are the reduction of environmental risks to people's health and safety and livelihood restoration, with a gender perspective. In terms of finances, it also provides a macroeconomic impact assessment for each sector where the impact of damage and loss is estimated. According to the results, oil and gas sector was the most affected, accounting for 25,674 billion IQD of losses and 4,969 billion IQD of damage, followed by housing, finance and markets, and power sectors, where losses and damage accounts for 8,095 and 8,173 billion IQD, respectively.

Below are key summaries related to adaptation and mitigation, from the reconstruction plan.

1.6.6.1 Mitigation

Based on the recovery and reconstruction strategy, the following priorities for the energy sector are summarised.

Short-term priorities (up to Year 1):

- Rehabilitate electricity infrastructure to increase supply availability and quality after clearance of explosive hazards.
- Add new on-grid and off-grid generation capacity, also through renewable energy sources.

Medium-term priorities (up to Year 3):

- Reinforce the electricity network by expanding and upgrading the generation, transmission, and distribution infrastructure, and by increasing power system efficiency.
- Improve supply reliability, reduce losses, and mobilise policy incentives and standards for increasing investments in renewable energy

Long-term priorities (up to Year 5 and beyond):

- Operationalise the new electricity law and undertake sector reforms.
- Develop a strategy for international power exchange to promote regional power grid integration.

According to this document, there are seven solar photovoltaic (PV) stations at planning stage in Iraq to be built over 15 years, demonstrating that enhanced renewable capacity is a priority for the country, considering a current capacity of 410 MW.

Finally, the document provides a master list of projects considered for the reconstruction process.

Table 9: Projects considered in energy and industry sectors for reconstruction of Iraq (World Bank, 2018)

Sector	Subsector	Projects
Power sector	Power stations	Biji Station Biji 2nd Gas Station North Station Hartha Commercial Station Salah Al-Deen Steam Station
	Solar stations	Solar PV: Al–hay Solar PV: Diyala University Solar PV: Abu Gharib Solar PV: Haditha Solar PV: Heet Solar PV: Al-Fallujah Solar PV: Jissan
Oil	Refineries	11 projects New Refinery in Al Faw: 300 thousand bpd New Refinery in Anbar (Haditha refinery): 36 thousand bpd New Refinary in Thi Qar: 100 thousand bpd Rehabilitation of Al Dora refinery Rehabilitation of Al Basra Refinery
	Tank Farms	Bin Omar reservoir for crude oil Al-Mosul reservoir for Oil Products Toba reservoir for Oil Products Al Aziziya reservoir for Oil Products Al Samara reservoir for Oil Products
	Sea water supply	Combined Sea water supply project in Basra
Industry	Cement factories	Rehabilitation of a cement factory in Al-Fallujah Rehabilitation of a cement factory in Anbar Rehabilitation of a cement factory in Mosul
	Chemical and engineering plants	Rehabilitation and development of engineering plants Caustic Soda project Sodium carbonate project Sodium sulphate project Acid and alkaline factories
	Petrochemical plants	Petrochemical Plant in Al Faw Polypropylene production plant Petrochemical Plant in Basra
	Glass factories	Rehabilitation and development of Glass factory in Al-Ramadi Float Glass factories in Karbala and Muthana provinces (2 projects)

	Fertiliser factories	Rehabilitation of existing fertiliser plant in Baiji Reconstruction and development of fertilizer plant in Abu Al Khaseeb New production lines for fertilizer plant in Khor Al Zubair Rehabilitation and development of phosphate plant in Qaim
	Food processing	Fruit juice factory in Halabja city Tomato paste factory in Duhok Grape juice factory in Duhok Vegetable oil factory in Erbil Vegetable oil factory in Sulaymaniyah Vegetable oil factory in Duhok
	Dairy products	Dairy products & ice cream factory in Erbil Dairy products & ice cream factory in Sulaymaniyah Dairy products & ice cream factory in Duhok
	Automotive	Bus and mini bus assembly in Erbil city Farm tractor and agriculture machines assembling in Sulaimaniyah city
	Pharmaceuticals	Pharmaceutical production (different capacity for variable drug) in Sulaimaniyah city

1.6.6.2 Adaptation

Water resources

Today, Iraq faces numerous technical challenges regarding water management due to an increase in climatic variability as well as water scarcity, partly resulting from reduced water flows from neighbouring countries. This situation is exacerbated by recent events, which include the destruction of barrages and dams, deferred maintenance in the areas now liberated from ISIS, and the earthquake of November 12, 2017, which raised concerns about the safety and management of the Darbandikhan and Dokan dams.

The water resources sector has several developmental challenges: (i) a complex legal and institutional framework with overlapping responsibilities; (ii) groundwater governance is perceived as individual property and used without considering sustainability, leading to its overexploitation; (iii) pressure on access to irrigation water services and drainage; and (iv) salinity. Past trends suggest that, even though absolute agricultural water withdrawals are high and increasing, the share of agricultural water withdrawals in total water withdrawals is declining. The water in the Tigris and Euphrates is also becoming increasingly saline; along with waterlogging, salinity is affecting agricultural production.

Agriculture

About 30 percent of Iraqis live in rural areas, providing abundant labor for the agricultural sector. Almost a third of the country's total area is arable land, half of which is used for rain fed agriculture. The sector is one of the largest non-oil sectors of Iraq's economy (with 5% of total GDP) and the largest source of employment (approximately 30%), including for the poor segments of the population and for women. The agriculture sector has been a leader in terms of the private sector, as Iraqi farms are mostly privately owned.

According to this document, cereal production—wheat, barely, rice, and corn—is the most important activity, in terms of both meeting local consumption needs and the size of cultivated land. Vegetable crops such as tomatoes, potatoes, and dates come second in their contribution to the GDP of Iraq. The key challenges of the agricultural sector include:

- Decades of conflict, isolation, and destruction. Not only do such conflicts damage production and production capacity but they also increase perceived risks to investment in the sector;
- Limited rural financing for private sector development;
- Weak research and extension capacity and weak links to centres of excellence for food and agriculture;
- Poor agricultural technology due partly to Iraq's prolonged isolation from the developed world; and
- Climate change related reduction in water inflows and increased salinity.

For the agricultural sector to recover and serve as a decent income source of farmers in rural areas, the following measures need to be taken in different time frames:

Table 10: Identified priorities in the "Iraq: Reconstruction and Development" report (World Bank 2018)

Term	Priorities for agriculture	Priorities for water resources
Short term (up to 1 year):	"Primacy of transfer": Specifically ensure that communities and households have access to the right inputs at the most appropriate time. Clearing appropriate infrastructure: Focus clearance of mines, unexploded ordnance (UXO) and booby traps on irrigation channels (and other conflict related assets). Re-establish commercial value chains, markets, and basic agricultural technologies. Improve access to finance for farmers and for small and medium farm enterprises.	Rehabilitate the partially damaged water and sanitation facilities after clearance of explosive hazards. Provide key equipment for water and sewerage operation and maintenance. Prepare detailed assessment for complicated damages to facilities, including preparation of designs.
Medium to long term (up to and beyond 5 years):	Pull financing mechanisms to draw private sector engagement Re-establish investment in public goods such as research extension. Develop a coordinated approach to rural investment which integrates energy, communications, and road infrastructure	Complete rehabilitation works for damaged and destroyed facilities. Establish safe operating procedures for dams and water structures for saving the lives and livelihoods of vulnerable communities.
Long-term priorities (up to Year 5 and beyond):	NA	Prepare a governorate master plan for water and sewerage for the coming 15-20 years. Promote private sector participation in the water and sanitation sector.

1.6.7 Ministry of Electricity and Renewable Energy Plan

Published by the Ministry of Electricity of Iraq, the Renewable Energy Plan contains a strategy for investment in PV solar energy from 2017 to 2020. The plans for this period are summarised below (Ministry of Electricity 2018):

- Capacity of 475 MW in 2020;
- Capacity of 2,695 MW between 2017-2020, from PV solar energy;
- 13 specific solar PV projects identified as potential, reaching 695 MW;
- Rehabilitation and reconstruction of power plants in the liberated areas.

The Generation Plan began in 2015 to encourage investment from independent power producers (IPPs) 9GW of power, including:

- Converting Simple Cycle plants to Combined Cycle (5GW);
- Encouraging generation from renewable energy (solar);
- Sustaining current plant production through initiatives (such as the Power Up Plan Program by General Electric (GE) and initiatives by other multinationals, e.g., Siemens);
- Rehabilitating and reconstructing power plants in the liberated areas

The Transmission Plan includes:

- Strengthening the transmission network throughout Iraq from the south to mid-Euphrates and central regions of Iraq (JBIC, JICA, Siemens, GE, ABB).
- Rehabilitating substations and transmission networks in the liberated areas in the north and west of Iraq to be reconnected with the rest of Iraq.

The plan includes a Renewable Energy Program to reach 2,695 MW of PV solar energy between 2017 and 2020, distributed in 11 provinces of the country. The program does not specify the solar technology to be used in the identified potential projects. Likewise, no actions related to other renewable energies are identified, concluding that solar energy is the most relevant for the country in the short term.

It is worth mentioning that according to the Regional Center for Renewable Energy and Energy Efficiency (RCREEE n.d.), the Iraqi government plans to expand the generation from natural gas and renewable energy facilities. In terms of renewables, Iraq is planning an increase of 2.24 GW by 2025.

1.6.8 Strategy for the Reduction of Poverty 2018–2022

The Poverty Reduction Strategy is aligned with the government's aspiration to achieve the Sustainable Development Goals through the Iraq Vision 2030 and the National Development Plan (NDP) for 2018-2022. The main target of this strategy is "*to reduce poverty by at least 25 percent by 2022*" (Ministry of Planning & High Committee for Poverty Reduction Strategy 2018). The strategy is divided in six pillars:

(1) Sustainable income for the poor from work
(2) Improved health status of the poor
(3) Improved education for the poor
(4) Suitable housing and environment responsive to challenges
(5) Effective social protection
(6) Emergency response activities

The strategy is developed across four chapters which present a diagnosis of the current situation, considering the major challenges facing the country such as stability and national security, governance, fair distribution and diversification of income, and the impacts of economic reforms on the poorest sector. In this regard, it is important to highlight that the fall in oil prices demonstrated the country's high dependence on oil, a challenge that must be faced to ensure adequate financial resources in the midst of a growing budget deficit. Likewise, some new challenges have arisen, one being the occupation of ISIS in territories of three governorates causing the widespread displacement of 3.3 million people. In addition, the cost of war and terrorism has forced the government to rethink their priorities, directing the budget towards reconstruction and social spending.

Undoubtedly, the main indicator of the situation in the country is increasing poverty. According to the second chapter of the strategy, *"the poverty rate was expected to decline from 19 percent in 2012 to 15 percent in 2014, but instead the rate increased to about 23 percent"*, limiting Iraq's potential for progress.

The third chapter subsequently lays out a program to advance poverty reduction, pointing out that one of the biggest concerns in terms of housing and the environment is the problem of slums, the provision of affordable housing for the poor, and the need to facilitate access and use of solar energy as a means of combating poverty in the neighbourhoods. The chapter ends with a focus on institutional mechanisms for the implementation of this strategy, with some recommendations to improve the current structure.

For the purposes of this assessment, it is important to note that this strategy highlighted a need to facilitate the use of solar energy in poorer and marginalised communities; off-grid solar PV technologies may therefore be relevant in this context.

1.6.9 Other documents

There are other reports that might be relevant for the purposes of this TNA, due to the kind of analysis and proposed near-future pathways for Iraq, the key messages of which are mentioned below.

The document "Iraq's Energy sector: A Roadmap to a Brighter Future" (IEA 2019) set a goal to double domestic generation, imports, and neighbourhood generation by 2030, for a total supply of over 250 TWh. It considers that one priority in the near and medium term is the investment in large-scale water treatment projects to supply water for reinjection in the oilfields in the South region.

The document also highlights the need to expedite the development of projects that can deliver water to the southern fields for oil recovery, notably the Common Seawater Supply Project, while *"encouraging companies to: enhance efforts on produced water reuse and recycling; push for full implementation of gas flaring reduction projects over the next years; clarify ownership of produced gas and responsibilities for its productive use; develop mechanisms to monetise ethane; and expedite full restoration of the Baiji refinery"* (IEA 2019)—increasing Iraq's operational refining capacity by 30% and reducing the 2–2.5 billion USD bill for annual oil product imports.

Likewise, the document established a goal to increase the share of solar PV in the power mix and reiterated the goal to increase the renewable share of the electricity supply up to 30% by 2030. Accordingly, the most severe and immediate shortfalls in supply can be mitigated by: *"the rapid initiation of network maintenance, targeting a small number of high-impact upgrades; the rapid deployment of new mobile power units; the upgrading of some existing power plants; and the enforcement of tariff regulations for all neighbourhood generators"* (IEA 2019). It pointed out the need to cut network losses and capture more gas to use in efficient power plants.

The document "The future we want – Iraq vision for Sustainable Development 2030" (Ministry of Planning 2019b) establishes that, following war and conflict, its priority is to create a diversified economy that does not depend on oil, in which growth is led by the private sector. The principles of fairness, sustainability, and governance are highlighted as guiding the development of Iraq in the coming years. The document is *"a roadmap and a strategic action plan"* for ministries, local authorities, and *"empowered Iraqis in a safe country, a unified society with diversified economy, sustainable environment, justice, and good governance*".

To reach the above, the vision is divided into five pillars: 1) man building; 2) good governance; 3) diversified economy; 4) safe society, and 5) sustainable environment. Within the third pillar, the goal to "Increase the oil sector efficiency" was established with the following targets:

- Develop the existing oil fields and invest in promising ones
- Develop the infrastructure supporting oil production
- Develop the export ports and transfer lines, increase their capacities, and develop oil tankers
- Increase investment in associated and non-associated gas and improve the structure of production, processing, transfer, and distribution
- Preserve the environment in oil-production areas and use environment-friendly technologies

Furthermore, the goals of the fifth pillar of the plan are:

- Reduce environment pollution and greenhouse emissions
- Efficient use of water resources
- Environmental conservation
- Develop the consumption and production patterns towards environmental sustainability
- Protect biodiversity and revive the Mesopotamian marshes

It is worth mentioning that no specific technologies in the industry and energy sectors are mentioned in this pillar. However, the guiding principles and goals per the pillars of this strategy serve as a driver for low-carbon economic and social development until 2030, supporting the policies, actions, and efforts aimed at reducing climate impacts.

Finally, Iraq's "Integrated National Energy Strategy (INES) 2012–2030" notes that renewable capacity is expected to exceed 2 GW by 2030, approximately 4% of system installed capacity (Booz & Company, 2012). The renewable capacity could increase to 8% of system installed capacity if Kurdistan Regional Government (KRG) renewable penetration is considered. To improve the power generation mix, the INES lists the retirement of less efficient generators and the development of solar and wind power capacity for grid connection as relevant power sector strategies. It also mentions a goal to reduce gas flaring, though no specific targets are established in this regard.

2 Institutional arrangements for the TNA and stakeholder engagement

2.1 Institutional arrangements and implementing partners

Out of the different sectors outlined in Iraq's NDC, four sectors were prioritised for an in-depth look at the most suitable available technologies. The consulting consortium leading the TNA process is formed by different members covering the experience needed in the sectors listed above:

- Carbon Limits is a consultancy team with extensive knowledge in climate change mitigation policy and strategy in more than 30 countries;
- Iraqi Green Climate Organisation is a local non-profit organisation engaged in climate change and sustainable development in Iraq;
- Newcastle University has an ecology research group led by Professor Mark Whittingham currently involved in research in Iraq with the Ministry of Health and Environment;

- One World is a consultancy team with a focus on resilience and socio-economic development, climate change policy, green growth, the water sector, energy, and food security.

As the TNA is a participatory process unique to the Iraqi context, the consultancy team established a National TNA Committee for Iraq. The National Center for Climate Change within the Ministry of Environment is the coordinating entity for this committee, due to its role in drafting national climate change documents such as the NDC. Here, its role is to lead the national team through the overall process.

The committee members are a group of multi-disciplinary backgrounds linking the different ministries and governmental entities. Their diverse background is aligned with the four understudied sectors. The members' input is a decisive factor to nationalise TNA process and make it more suitable to the local context. Figure 9 presents the organisation of Iraq's TNA committee and its members' different affiliations.

Figure 9: National TNA committee organisation and members affiliations

2.2 Stakeholder engagement

The TNA process must be locally driven to ensure that the prioritised technologies will be accepted and diffused in the country. Stakeholder engagements provides the legitimacy for the decisions throughout the process. Both private and public sectors were involved at various stages of the project to provide a wide national representation and deliver a feasible and well oriented action plan.

The methodology to map stakeholders relevant to the project followed the below steps:

- Identification: desk study and consultations to identify all relevant organisations, institutions, individuals, etc.
- Analysis: information collected about the responsibilities, mandates, and interests of the wider list of stakeholders through a consultation workshop (January 14th, 2021) and questionnaires shared with the selected stakeholder group.
- Mapping: drawing relationships between the different stakeholder groups in order to identify the key stakeholders.

- Planning of stakeholder engagement: selecting the most relevant stakeholders for engagement at specific project phases and methods for stakeholder engagement.

Identification of stakeholders began with a desk study and mapping of broad categories of stakeholders relevant for climate mitigation and adaptation in Iraq, who have strong relevance and can positively impact the deployment of climate technologies. According to the studied sectors, the following groups have been identified: ministries and officials, industry associations and businesses, private sector, electricity utilities, finance sector, local communities, NGOs, academia, media, and international organisations.

The team has also identified the possible engagement areas with the stakeholders in Iraq—i.e., how can stakeholders make the TNA process more robust, effective, and adapted to local conditions. Five roles were identified:

1. Providing data and technical assistance (on emissions, technologies, barriers, costs, etc.)
2. Providing financing for project implementation
3. Political decision-making
4. Social and institutional support, including dissemination of results
5. Project beneficiary

A workshop took place in Baghdad in January 2021 with a key group of relevant local members to discuss the stakeholders that should be engaged in the TNA process. The implementing team and ten other institutions completed a template (Table 11) for stakeholder identification.

The workshop discussion and template outcomes resulted in evident roles for the four ministries of each corresponding sector. In addition, the Ministries of Planning and Finance are also seen as important decision-makers, as decisions about project implementation and budget allocations are dependent on them. The Baghdad municipality was brought forward as another important stakeholder, highlighting the potential for project implementation in the capital. Some public and private sector companies have also been mentioned as potential project beneficiaries.

Having identified the main stakeholders, the team adopted an engagement approach considering the three steps of the TNA process. For each step, a set of relevant questions was identified, and according to these questions, stakeholders were selected for each step from the previously identified long list.

Table 11: Stakeholder Identification Template

Nº	Stakeholder	Category	Interests	Role	Relevance
	Name of identified stakeholder	- Private sector - Public sector (state, regional, municipal) - Civil society - Media - Academia	Strategic development of the sector, knowledge sharing, strategic development, synergy with other projects, financial gain, etc.	- Political decision-maker - Data or information provider (academia, industry) - Project beneficiary - Social and institutional support (NGOs, local authority)	Importance to technology transfer process
	Institution and, if possible, name and contact information	*Select one of the categories above. Add your own category if needed*	*Select one or several of the potential interests of the stakeholders in the TNA process*	*Select one or several of the categories above. Add your own category if needed.*	*How important is this stakeholder for the TNA process? Rank from 1 to 5, from 1 least important to 5 most important*

Different approaches were considered to collect stakeholders' feedback, information, and decisions, based on the different projects' stages and status, presented in the table below.

Table 12: Stakeholder's engagements approach

Technique	Possible application in the Iraq TNA process	Key groups of applicable stakeholders
Questionnaires and Surveys	Step 1: Identification and prioritisation of technologies • To detail and confirm stakeholder information • Organise content of stakeholder requirements • Preview and select potential technologies	• Relevant sectoral Ministries • Ministry of Planning • Ministry of Science and Technology • Ministry of Higher Education and scientific research • Industry associations • Private sector technology providers • Large state companies
Interviews	Step 2: Barrier analysis and enabling framework • Obtain information on a specific sub-sector and tech barriers • Allow for the introduction of relevant new information or concerns	• Industry associations • State companies • Private sector • Implementing agencies (e.g. Ministry of Health and Environment) and other decision-makers
Workshops and Focus Groups	During all 3 steps • Define priorities of requirements on sub-sectors and technologies • Discover and resolves potential conflicts between stakeholders • Identify requirements to establish solution scope within TAPs	• Key sector Ministries • Relevant technology providers or importers • Other Ministries involved in decision-making (e.g. Ministry of Planning and Ministry of Finance) • Vulnerable groups (e.g. farmers, minorities, etc)
Public Forums	Mostly at the beginning and end of the TNA process • Communicate the TNA process to a larger audience	• All possible stakeholders
Brainstorming	During all 3 steps • Resolve requirements or conflicts • Outline various options and solutions Can be part of the workshop or focus group	• Same as of Workshops and Focus Groups

2.3 Gender aspects in the TNA

The United Nations (UN) 2030 Sustainable Development Plan and its 17 goals were approved by all member states, including Iraq, who was one of first countries to ratify the charter. These goals have been in effect since January 2016. A stand-alone goal on women was included in the new development agenda—the fifth goal concerning "achieving gender equality and enhancing the status of women". It was emphasised that the role of women is not limited to the fifth goal only, but extends to include various policies across all sectors, and that achieving sustainable development goals will not be complete without the participation of women. Sectors such as security, environment, and services affect all members of society, especially women.

2.3.1 Gender status in Iraq

Gender equality is preserved in the Iraqi constitution. Article 20 states that Iraqis are equal before the law without discrimination based on gender, race, nationality, origin, colour, religion, sect, belief, or economic status. Article 20 adds that both women and men citizens have the right to participate in public affairs, to enjoy political rights, including the right to vote, and to be elected.

Still, this does not reflect the real status. According to Iraq's first national voluntary review on the SDGs (Ministry of Planning 2019a), regarding women's issues, there are still serious obstacles to opportunities for women's participation and empowerment, especially in the field of work and administrative advancement in public and private institutions. The ratio of girls to boys in education levels is still far from equal. Environmental deterioration and climate change affect women significantly in areas where they are most dependent on natural resources for their livelihoods and reduced capacity to respond to natural hazards, such as droughts, landslides, and floods, because women possess less land and fewer agricultural resources. Women are also worse affected by a lack of adequate sanitation as they are often in charge of providing water for their family, and the increase in the number of hours devoted to fetching water affects their education and employment opportunities.

Within this context, Iraq has pushed toward gender equality via several means, including:

- Establishing a department to empower Iraqi women in the General Secretariat of the Council of Ministers by Resolution No. 333 of 2016;
- Forming the Special Investigation Court to investigate human rights violations, including violations against women;
- Establishing a gender division in all Iraqi ministries;
- Establishing a women's care and protection department in the Ministry of Labour and Social Affairs;
- Enacting Legislation of the Anti-Human Trafficking Law that includes 8 articles that prevent the exploitation of children and women;
- Approving the quota for women in the parliamentary elections law at a rate of 25%, as well as the governorate councils;
- Ratifying the Convention on the Elimination of All Forms of Discrimination against Women;
- Emphasising on the application of the Personal Status Law, which prohibits marriage outside the courts and marriage under the legal age.

In the field of labour-related legislation, the government issued the new Labour Law No. 37 of 2015 which reflects the state's commitment to gender equality, addressing discrimination against women in the labour market and ensuring equal payments that are in line with international labour standards. In the field of support and empowerment, the country has adopted a set of programs within the framework of the social protection program, the psychological support program, the income-generating loan program, a vocational training program, and the 1325 implementation program.

2.3.2 Gender consideration in the TNA process

Hence, gender aspects have been considered throughout the TNA process—in the selection of the TNA teams, the national consultants' team, and the technical working groups, with 45% women, where the views and inputs of both men and woman were assessed equally. The national gender consultant along with the TNA committee team considered gender during the technology selection process, whether it will enhance the lifestyle of both genders, provide equal work opportunities, and access to resources, and reduce the burden on woman, especially rural woman.

3 Prioritisation process

Along with mitigation and adaptation, technologies serve as a leverage for the national development priorities in Iraq. The technology, selected for diffusion and implementation within the country, has to align with the national context and present an added value from economic, social, and environmental points of view. A prioritization process arises thus arises from the need for decision makers to identify the optimal technology that will have the maximum positive impact possible in their respective country.

Prioritization considers various aspects of each technology, whether quantitative, qualitative, monetized, or non-monetized. A Multi-Criteria Assessment (MCA) tool helps decision makers group these characteristics in a seven-step process. All relevant stakeholders must provide their input to reflect on the need for and importance of technologies within the country context. Technology prioritization is the first step of the TNA and a cornerstone for further development of the TAP.

In Iraq, the consulting team laid down the base for prioritization and prepared a review of national documents and strategies. A workshop was then held in December 2021 with the national TNA committee and other stakeholders in the presence of the Minister of Environment, to have the maximum national engagement possible. Ministry representatives from the four tackled sectors were also present.

The following section explains the steps of the MCA and the distribution of tasks in each step between the consultants and the national stakeholders. The same process is followed for both the adaptation and mitigation prioritization processes.

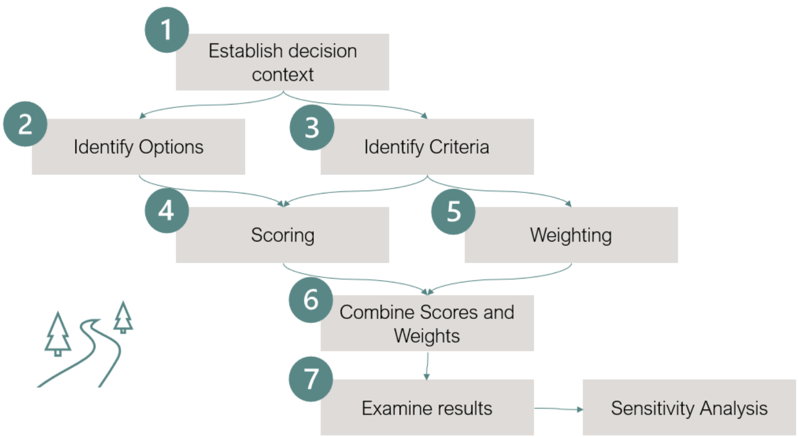


Figure 10: Multi-Criteria Analysis (MCA) steps

3.1 Step 1: Decision context

The decision context establishes the economic, social, and technological environment that surrounds each decision. It also considers the climate change and sustainable development circumstances in the country. The outcome of this step is a set of clear national objectives that guide the prioritisation process.

For Iraq, the consultant prepared an extensive literature review of national documents and retrieved a set of goals defined by official entities. For instance, based on its NDC, Iraq is seeking to reduce its national GHG emissions by 1 to 15% by 2030, depending on international support. These goals were adapted during the workshop based on participants' feedback.

3.2 Step 2: Identifying options

Options are identified from the technology pool, from which the prioritised technologies are selected. As part of this step, a long list of appropriate technology is prepared for each sector. The various technologies have been identified by the consultants from national documents and aligned with Iraq's vision for mitigation and adaptation. The lists were presented to the participants and stakeholders during the workshop for amendment, before each technology was evaluated.

3.3 Step 3: Identifying criteria

To differentiate between each technology's impact in the country, a list of evaluating criteria is prepared, covering economic, social, and environmental aspects. The criteria's main aspects are to be easy, measurable, and driven by the country objectives determined in step one.

The final aim of the TNA is to stimulate technology diffusion and financing in the country. The consulting team used the Green Climate Fund's evaluation criteria as a starting point. The goal is to familiarise national participants with the donor's prerequisites and to evaluate the financing possibilities of the proposed options. These criteria are then adapted to Iraq's objectives and the TNA process. The criteria are divided into sub-criteria to facilitate an evaluation.

Table 13: MCA List of Criteria

Criteria
Country Ownership
Paradigm Shift Potential
Impact Potential
Sustainable Development Potential
Needs of Recipient
Efficiency and Effectiveness

3.3.1 Country Ownership

This criterion refers to the extent to which the national agenda drives technology needs in the country. Country ownership considers the degree to which this relates to pertinent official national and sectoral policies.

3.3.2 Paradigm Shift Potential

This criterion refers to the extent to which there is a clear vision for how the chosen technology will catalyse impact beyond a one-off investment by promoting long term change or transformation. Such transformation could be achieved through upscaling and replicating the technology and long-term sustainability of results.

3.3.3 Impact Potential

Separate indicators may be applied for assessing the impact potential of each of adaptation and mitigation technology. Mitigation impact is measured in terms of lifetime emission reductions (in tons of carbon dioxide equivalent). Adaptation impact can be measured in terms of expected changes to loss of life and livelihoods, value of physical assets, and/or environmental or social losses due to the impact of climate related extreme events or disasters, within the geographical area of intervention.

3.3.4 Sustainable Development Potential

This criterion is measured in terms of the specific co-benefits realised through technology adoption in the country. The technology must demonstrate the potential to achieve at least two of the four coverage areas: i) economic co-benefits (job creation, poverty alleviation, financial inclusion (especially of women), and income enhancement); ii) social co-benefits (e.g., improvements in health and safety, access to education, access to energy, social inclusion, and improved sanitation facilities); iii) environmental co-benefits (e.g., improved air and water quality, conservation, and biodiversity) and; iv) gender empowerment co-benefits (i.e., how the intervention will reduce gender inequalities).

3.3.5 Needs of recipient

The technology should reflect the country's financial, economic, social, and institutional needs and the assessment able to address any barriers to accessing domestic and international sources of climate finance.

3.3.6 Efficiency and effectiveness

Separate indicators may be applied to address this criteria: i) mitigation efficiency and effectiveness, measured in terms of cost per tonne of carbon dioxide equivalent; ii) mitigation efficiency and effectiveness, measured as a ratio of co-financing mobilised relative to the funding body contribution to the total project; iii) mitigation indicator, measured by the internal rate of return (economic or financial) estimated depending on the needs of the project, and; iv) mitigation and adaptation indicator, measured in terms of the application of best practices and how the technology builds on best practices in the sector.

3.4 Step 4: Scoring

Scoring is the evaluation of a technology's performance based on each of the selected criteria. A normalised score from 1 to 5 is given for each technology, based on a relative assessment of all options. This step was undertaken entirely by the national representatives during the workshop. Participants were grouped in a team of six to complete the evaluation using an Excel tool provided by the consultants.

3.5 Step 5: Weighting

Weighting represents the importance of each criterion to the country. A sum of 100 is distributed over the criteria, following the guidelines of the decision context and goals defined in step 1.

The consultant set preliminary weights for the criteria, which were further discussed during the workshop with the participants to reach the final decision.

Table 14: Weight assigned for each criterion.

Criteria	Weight
Country Ownership	10%
Paradigm Shift Potential	30%
Impact Potential	30%
Sustainable Development Potential	5%
Needs of Recipient	10%
Efficiency and Effectiveness	15%

3.6 Step 6: Combining weight and score

After setting a score for each technology, the score is multiplied by the criterion's weight. The resulting weighted score represents the technology's performance and importance for the country. The technologies with the highest score are the ones that provide a high performance and align with the country's objectives.

As in the scoring step, the participants completed this step using the Excel tool provided by the consultant.

3.7 Step 7: Results and Sensitivity Analysis

The final step consists of selecting the technologies to prioritise based on the highest weighted score. The selected technology must be consistent with the objectives of step 1. A sensitivity analysis can be done to leverage certain choices over others, in instances where both technologies present close scores, yet the lower scoring technology has more acceptance from stakeholders.

3.8 From technology groups to technologies

In every sector, a significant number of climate mitigation and adaptation technologies are applied worldwide that could potentially be considered as suitable solutions for Iraq. Therefore, to optimise the alignment with the Iraq Vision, a two-step prioritisation process was conducted through the MCA.

3.8.1 Technology group prioritisation

First, the areas of interest across each sector in Iraq were retrieved from the different national plans and reflected in technology groups. This enabled the consultants and stakeholders to concentrate on areas of interest in the country and review the various available technologies.

A two-day workshop took place from the 22nd to 23rd December 2021. Representatives from the different ministries (Environment, Electricity, Oil, Construction Housing and Municipality, Industry and Minerals, Science and Scientific Research, Water Resources, Agriculture, and Transportation) participated in the workshop as the first step of prioritisation. On the first day, the consultants explained the goals of TNA process and its expected outcomes. The MCA tool was then introduced to the participants along with its importance in the TNA framework. During the second day, the participants complemented the process with their understanding of the national context and were then divided into four groups to score a set of eight technology groups from the four studied sectors: agriculture, water, energy, and industry.

After the workshop, the consultant collected the MCA scores of each group to combine them and share the outcome. The scores presented different averages per group, due to the varying points of view (conservative or optimistic). Therefore, Z-scoring was used—a statistical method often used in academia for comparing evaluation results (Chumney 2016). This methodology helps minimise the dominance of one group input over the others. Z-scoring specifies the exact location of an X value within a distribution by describing its distance from the mean in units of standard deviation. In other words, the Z-score shows the priority of each technology group option among all collected scores. The tables below present the Z-scoring per technology group after the December workshop.

Table 15: Z-scoring of the different technology groups, following the stakeholders' assessment.

No	Project	Z-score
1	**Project Name: Renewable Energy (Energy)**	**2.05**
2	**Project Name: Wastewater treatment (Water)**	**1.17**
3	**Project Name: Energy efficiency in power generation (Energy)**	**0.60**
4	**Project Name: Improved storage facilities (Agriculture)**	**0.26**
5	**Project Name: Effective flood management (Water)**	**0.15**
6	Project Name: Sustainable groundwater development (Water)	-0.03
7	**Project Name: Flared gas utilisation (Industry)**	**-0.04**
8	**Project Name: Heat recycling and co-generation (Industry)**	**-0.07**
9	Project Name: Efficient water use (Water)	-0.12
10	**Project Name: Conservation agriculture practices (Agriculture)**	**-0.21**
11	Project Name: Energy efficiency in buildings (Energy)	-0.30
12	Project Name: Reduction of methane leaks (Industry)	-0.39
13	Project Name: Ecological pest management (Agriculture)	-0.46
14	Project Name: CCS (Industry)	-0.54
15	Project Name: Fuel switching (Energy)	-1.87

Based on the outcome presented in Table 15, the two technology groups with the highest z-scores were prioritised. These results are presented in Table 16. The prioritised technology groups then moved to the next step, where specific technologies within these groups are explored in Iraq's specific context.

Table 16: Technology group prioritisation results

Number Priority	Mitigation		Adaptation	
	Energy	Industry	Agriculture	Water
1	Renewable Energy	Flared Gas utilisation	Improved Storage Facility	Wastewater Treatment

2	Energy Efficiency in Power Generation	Heat Recycling and Cogeneration	Conservation Agriculture practices	Effective Flood Management

3.8.2 Technology prioritisation

With a clear idea of the technology needs per sector, the consultants developed a long list of technologies for each of the prioritised technology groups. The list was based on an extensive literature review of all technologies mentioned in the national documents and other technologies available worldwide that might have significant potential for Iraq.

The consultants used their expertise to filter the list according to Iraq's context, narrowing it down to five to seven technologies per sector (Figure 9). A fact sheet was prepared for each shortlisted technology to present an overview of its characteristics. The factsheet provided guidance for evaluating the technology through the MCA framework. Both the consultants and stakeholders completed the evaluation exercise to prioritise further the technologies for each sector, as shown in Figure 10. This process was validated by all parties in a meeting held on 19th April 2022 between the consultants and all relevant stakeholders.

Figure 9: From technology-group to shortlisted technologies methodology.

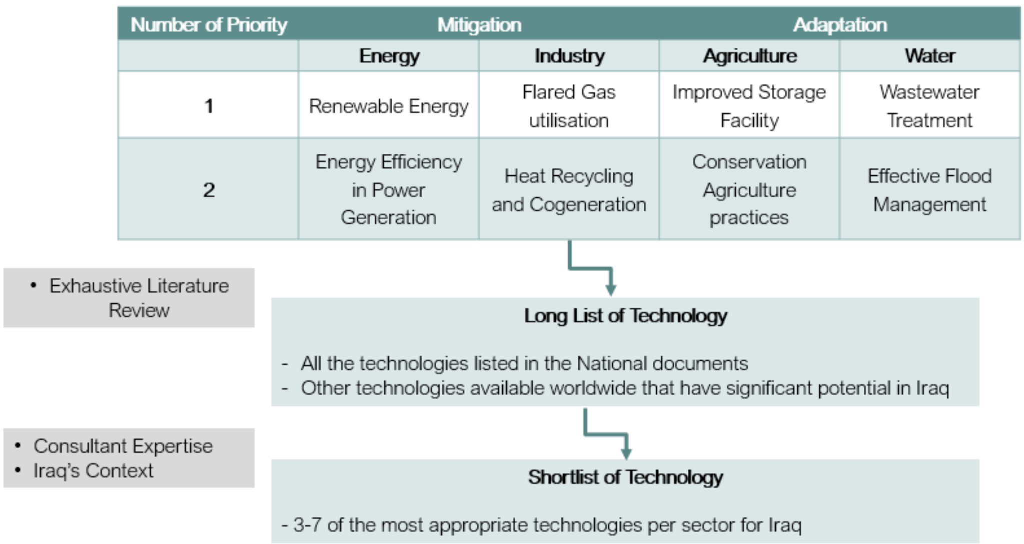
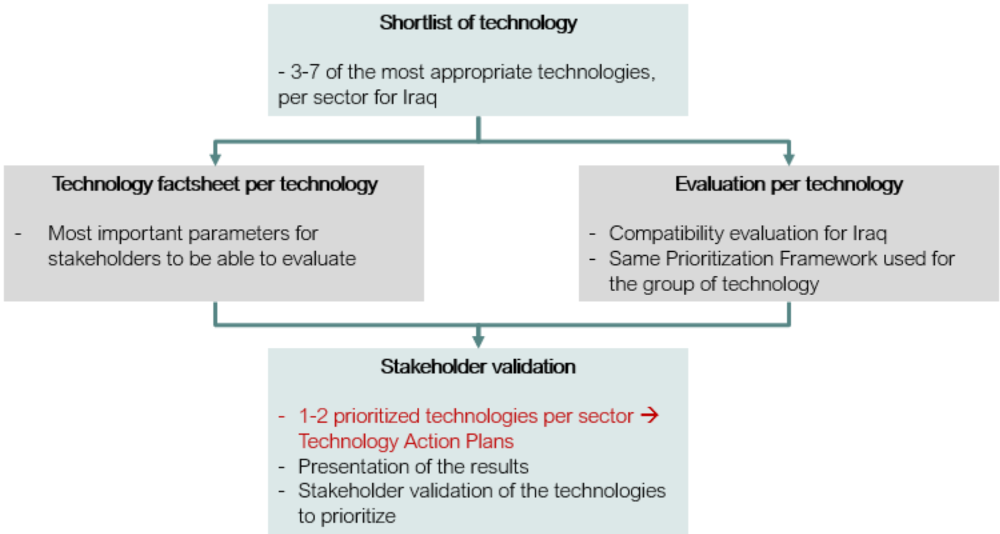


Figure 10: Prioritisation among the shortlisted technologies.



During this meeting, the distribution of mitigation technologies in each sector was also reconsidered, to optimise the benefit for Iraq. The Ministry of Industry representative highlighted the importance of non-oil industries and the need for new technology to boost these industries. On the other hand, as the oil and gas sector remains the backbone of Iraq's economy, there was an agreement to prioritise an additional technology in this sector to push the country forward. With several plans already underway in the energy sector, there was an agreement to select one technology for the energy sector and two for the oil and gas sector.

Table 17: Technology distribution per sector

Sector	Sub-sector	Number of Technologies	Category
Energy		1	Mitigation
Industry	Non-oil Industry	1	Mitigation
	Oil and Gas Sector	2	Mitigation
Water		2	Adaptation
Agriculture		2	Adaptation

The following sections will present the complete analysis for each sector and the findings at the end of the prioritisation process.

4 Energy Sector

In the context of this report the energy sector refers to power generation and energy in building and does not include the oil and gas activities. This section goes through the results for the energy sector prioritisation, starting from national context to the selection of the prioritised technology.

4.1 List of Technologies

A list of technologies related to measures, programs, or projects identified in various planning instruments relevant for Iraq's energy sector, is shown below.

Relevant planning instruments	Measures / technologies
NDC – Energy	Projects for the 2nd conditional scenario (1%): 1. Shift to combined cycle power plants 2. Improve the performance of the electricity system to maintain sustainability and stability with high reliability Projects for the 1st conditional scenario (13%): 1. Increase investment in combined cycle power plants 2. Initiate energy conservation and efficiency programs 3. Use clean, new, and renewable energies 4. Reduce the technical loss in power transmission and distribution 5. Develop hydroelectric plants in Kurdistan Region, increasing the hydroelectric power contribution to 3.3% of total generation by 2035, supposing that the Mosul Dam will have been rehabilitated
National Development Plan 2018-2022	Use good quality fuel (gas) instead of various types of liquid fuel in gas plants to reduce CO_2 emissions by 19,433,000 t/y Convert simple-cycle gas plants to combined-cycle plants to reduce CO_2 emissions by 8,150,000 t/y Open investment opportunities in renewable energy, especially solar, to provide 4.2% of total energy generated in the electricity system
The National Environmental Strategy and Action Plan for Iraq (2013 – 2017)	Use clean fuels for transport: CNG, LNG, LPG Promote the use of solar energy in public buildings and facilities, and to support the electricity system Wind energy for electric power generation in agricultural and desert areas Biogas for domestic use Electric power production from waste for residential use
MOE Plan and Renewable energy Plan	Convert simple-cycle plants to combined-cycle (5GW) Encourage generation from renewable energy (13 PV solar potential projects are identified) Rehabilitate and reconstruct power plants in the liberated areas
Strategy for the reduction of poverty, 2018 - 2022	Use solar energy
Investment Map of Iraq, 2019	Solar stations with an additional capacity of 355 MW
Iraq's Energy sector. A Roadmap to a Brighter Future, 2019	Develop a renewable energy industry, starting with a first round of solar PV and wind projects to build confidence, and then build on proven successes

	Push for full implementation of gas flaring reduction projects over the next two years
Iraq, Reconstruction and Development Framework (2018)	Increase on-grid and off-grid generation capacity, also through renewable energy sources
INES plan	Solar and wind power capacity for connection with the grid

The consultant has passed over the national plans and documents to collect the focus areas in the energy sector and the technologies Iraq is looking to introduce to its power sector. The consultant has grouped Iraq interest in Technology groups that tackles different part of the energy sector, to be prioritised.

4.2 Existing technologies in the sector

According to *PV Tech*, "*French energy major Total has signed an agreement with Iraq's Ministry of Oil to develop a host of energy projects in the country, including 1GW of solar PV*" (Stoker 2021). The agreement between the company Total and the Iraqi government was signed in October 2020. Taking into account Iraq's ambition to have an installed solar generation capacity of 10GW by 2030, (Stoker 2021), the country is currently planning to tender for around 700MW of solar capacity (Al-Maleki 2020).

Based on information published by the Iraq Energy Institute (Al-Maleki 2020), there are currently 6 solar projects for 755 MWp under development to be ready by the end of 2021, located in Muthana, Babil, Wassit, Karbala and Diwania.

As mentioned by Al-Maleki in 2020, the Ministry of Electricity also announced their long-term target of a 40% renewable electricity mix by adopting wind, waste-to-energy, and geothermal technologies.

According to the report from Middle East Africa at Frost & Sullivan, the use of rooftop photovoltaics (PV) in Iraq by home and shop owners has increased significantly, especially in the northern area of Iraq, to smoothen power outages (REVE 2018).

Based on "Iraq's Energy Sector: A Roadmap to a Brighter Future" by the International Energy Agency (IEA 2019), *"there are a number of pathways available for the future of electricity supply in Iraq but the most affordable, reliable and sustainable path requires cutting network losses by half at least, strengthening regional interconnections, putting captured gas to use in efficient power plants, and increasing the share of renewables in the mix"*. The report shows available options in the long term to improve the situation in the power sector. The considered options to face the challenge of electricity supply are shown in Figure 11.

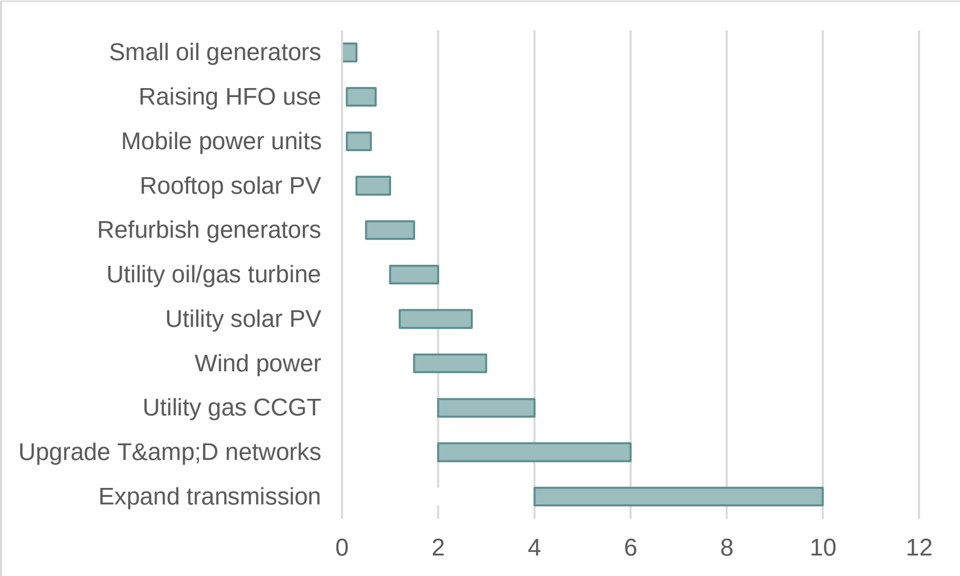


Figure 11: Technology options to improve electricity supply by development time in Iraq (years)

Source: IEA, 2019

4.3 Prioritisation process

4.3.1 Technology group prioritisation

Four main technology groups were included in further analysis for the energy sector, grouped in Table 18. Energy efficiency in building is the first technology group, encompassing all measures to reduce energy consumption at the end-user level. Residential complexes in Iraq consume more than 47% of the national energy consumption, with an additional 23% for governmental and commercial buildings and facilities (Sultan 2019). Electricity consumption is primarily divided between air conditioning, lighting, and water heating.

Iraq is a major oil producer. Its energy use, mainly for transportation and power generation, thus relies on heavy fuel and diesel oil, making these sectors the most significant GHG emitters. A focus within the national plans is to switch to a lower emitting, better quality fuel like natural gas and biogas as a solution to reduce emissions.

A majority of power plants in Iraq are based on an open cycle gas turbine (OCGT), reducing the efficiency of the power generation to less than 40% (Soares 1998). According to the representative from the Ministry of Electricity, there are around 70 power plants running on OCGTs, with a capacity of 3,000 MW.[9] Upgrading these power plants to a combined-cycle gas turbine can increase the efficiency to more than 60%. In combination with other energy efficiency measures, such as the use of more efficient turbines and optimised operating parameters, this can improve the power generation efficiency in Iraq and reduce resulting emissions. These elements are reflected in the energy efficiency in power generation technology group.

Due to its location, Iraq has important potential for renewable energy which can be used to diversify its energy portfolio and break its dependency on fossil fuel in the power sector. The high solar radiation in the

[9] Statement by the Ministry of Electricity representative during a meeting on 19^{th} April 2022.

country makes solar an attractive option, though other types of renewable energy are also considered under this technology group.

As described in section 3.8, communication between the consultant and the stakeholders helped to verify the technology alignment with sector objectives, following which the stakeholders prioritised the technology groups using the MCA framework during the December workshop. The evaluation framework takes into consideration the needs for each technology group and its impact on various economic, social, and environmental aspects in Iraq.

Table 18: Energy sector technology group prioritisation

Long list of technology groups	Z- Score
Energy efficiency in building	-0.30
Fuel switching	-1.87
Renewable energy	2.05
Energy efficiency in power generation	0.60

→

Prioritised technology group
Renewable energy
Energy efficiency in power generation

The scores show a clear dominance for renewable energy prioritisation, followed by energy efficiency in power generation. Both groups were then moved to the next step to select a specific technology within these groups.

4.3.2 Prioritisation of technologies within selected technology groups

For each prioritised technology group, the consultant prepared a list of technology following the methodology described in section 3.8.2. For the energy sector, a list of fourteen technologies were gathered from both national documents and worldwide research, presented in Table 19.

Table 19: Technologies longlist for the Energy sector

No.	Technology group	Technology	Initial screening
1	Renewable energy	Large-scale solar PV	Major development already planned in Iraq
2	Renewable energy	Rooftop solar PV (off-/on-grid)	Shortlisted
3	Renewable energy	Solar water heaters	Shortlisted
4	Renewable energy	Onshore wind	Based on Iraq Wind Atlas, wind resources are "relatively" limited compared to other available resources in the country[10]
5	Renewable energy	Concentrated solar power	The technology is still expensive and not widely deployed at the international level

[10] Assuming a wind speed greater than 6.5 m/s at 80 m above the ground, overlapped with an installation density of 8 MW/ km^2, and according to public atlas data from the Global Wind Atlas (2021).

6	Renewable energy	Large-scale hydropower	Iraq does not control its water resources, and water is becoming scarcer due to climate change
7	Renewable energy	Incineration of landfill waste	Excluded because reorganisation of the waste sector is essential for the development of these technologies, which might be an essential barrier to their deployment
8	Renewable energy	Capture of landfill gas	
9	Renewable energy	Biogas from organic waste	
10	Energy efficiency in power generation	Combined-cycle gas turbine	Shortlisted
11	Energy efficiency in power generation	Use of efficient turbine	Limited impact / potential
12	Energy efficiency in power generation	New (or rehabilitation of) power lines	Technologies already exist in Iraq, and the security situation and political context are essential barriers to development
13	Energy efficiency in power generation	Efficient transformers	Limited impact / potential

All the presented technologies would provide an added value to the country and might be considered at a later stage. In the context of the TNA project, though, the aim was to focus on technologies with the maximum value for the current situation. This does not mean that the remaining technologies are unsuitable or cannot be applied to Iraq. According to this perspective, the technologies were filtered into a shortlist of three technologies:

1. Off-/on-grid rooftop solar PV
2. Solar water heaters
3. Combined-cycle gas turbines

4.4 Selected technology

For the three shortlisted technologies, the consultant assembled a technology factsheet (see Annex). This information was shared with the stakeholders to evaluate the technologies in the MCA framework. The results were discussed during a meeting on the 17th February 2022 between all relevant stakeholders. The results were then communicated with the relevant ministries for final decisions.

Rooftop solar PV led the score at 13.9, with 2 points difference from combined-cycle gas turbines and solar water heaters, as presented in Table 20. This result was approved by the Ministry of Electricity, which expressed a need for this technology in Iraq.

Table 20: Final Score for Energy Technologies.

Technology	Score
Off-/on-grid rooftop solar PV	13.9
Combined-cycle gas turbines	12.3
Solar water heaters	12.0

4.4.1 Technology 1 – On/Off-grid PV solar system

Iraq faces instability in the electricity grid and a gap between generation and demand for electrical power. Rooftop (intrinsically small-scale) solar PV has the potential to increase generation capacity while bypassing central governmental decisions.

The technology is composed of a residential system that can be installed on-grid or off-grid, decreasing the dependency of users on the unreliable national grid. Solar panels are used to convert solar energy into electrical energy then, for the off-grid system, batteries are added to store the surplus energy for use during the night-time or on cloudy days. In these forms rooftop systems can be deployed in both urban and rural areas. The International Renewable Energy Agency (IRENA) estimates that 90% of Iraq's area has a potential for 1600 to 1800 kWh/kWp per year, making the technology more profitable for households. Additional information about the technology is presented in Annex. This choice of technology is aligned with the national plan, as Iraq aims to install 10 GW of solar generation capacity by 2030.

Based on the stakeholder evaluation, rooftop solar PV has a higher paradigm shift potential in the country, with the possibility for replication and scale-up in different regions. A more in-depth study will take place in the Technology Action Plan to map the barriers hindering the deployment of this technology and the steps to enable its integration into the Iraqi market.

5 Industry Sector

5.1 List of Technologies

A list of technologies related to measures, programs or projects identified in various planning instruments relevant for Iraq's industrial sector, shown below.

Relevant planning instruments	Measures / technologies
NDC	Projects for the 2nd conditional scenario (1%): 1. Heat recycling to produce electricity and use it for production purposes 2. Develop manufacturing processes that reduce emissions, including in existing and planned industries such as the fertiliser industry 3. Replace some mechanical incineration systems in private brick factories with more efficient and environment-friendly systems Projects for the 1st conditional scenario (13%): 1. Develop manufacturing processes that reduce emissions in all existing and planned industries, such as the fertiliser industry 2. Replace mechanical incineration systems in private brick factories with more efficient and environment-friendly systems 3. Establish private and public industrial enterprises within the industrial zones envisaged by the Ministry of Industry and Minerals to encourage the manufacturing and assembling of products including solar cells and other solar energy equipment such as heaters, lights, fridges, cars, pumps, stoves, etc.
The National Environmental Strategy	Develop local technological industries for solar and wind energy

and Action Plan for Iraq (2013 – 2017)	Promote the use of clean energies in craft industries
Investment Map of Iraq, 2019	Produce and maintain electrical and solar heaters Produce and maintain water purification and sterilisation plants of various capacities, including solar water sterilisation systems Produce, design, assemble and connect the solar energy system to supply electricity for lab devices and internal lightning, and all industrial services sites

5.2 Existing Technology

The industrial sector has been proven to be one of the main indicators for the economic growth of a country. Iraq is an extremely oil-dependent country that lacks development across other sectors, leading the national budget to become highly dependent on the money generated from oil (KAPITA & GIZ 2020).

Data from 2018 indicates that the leading industrial establishment in Iraq, in terms of number of facilities, is the food and beverage industry (31.9%) followed by the metal processing industry excluding machinery (23.5%) and furniture manufacture (20.7%). The greatest revenue volumes for large enterprises was are generated by the manufacturers of refined petroleum and coke products with a total of 3,740,948,584 million IQD (KAPITA & GIZ 2020). The focus of the analysis under this project was, however, on the industrial processes that are energy-intensive and are therefore responsible for the large share of emissions of the sector – for instance, cement and brick production.

5.3 Prioritization Process

5.3.1 Technology group prioritization

For the industry sector, one technology group that tackles heat recycling and co-generation, was prioritised. Several kinds of technologies are available to reuse this wasted resource, including those that recover heat for steam or electricity generation, as well as for on-site space climatization. Heat recycling can minimise fuel combustion thus limiting carbon emitted to the atmosphere. The switch to a lower emitting fuel is also considered as part of this technology group.

The group was prioritized during the December 2021 workshop and evaluated by representatives of the different industries using the MCA framework. Heat recycling and co-generation had the highest score for the industry sector and were therefore prioritised for the next step. The results were approved by stakeholders in the workshop. Heat recycling has major potential for non-oil and gas industries and can promote new industries to diversify the economy.

5.3.2 Prioritization of technology within selected technology groups

As the next step, the consultants generated a long list of technologies for the heat recycling technologies group. This research was based on the national plans and the technologies available worldwide. The below table presents the shortlisted one.

Number	Technology-group	Technology	Initial Screening

1	Heat recycling and co-generation	Use of natural gas in brick and plaster production plants	Shortlisted
2	Heat recycling and co-generation	Heat recycling in cement power plants	Shortlisted

The industrial sector is important and must benefit from new technologies to be able to flourish in the country and to increase its share of GDP. That is why these two technologies were shortlisted based on their impact to the important cement and brick production in the country. This does not exclude the remaining technologies from playing a future role in Iraq, only that the two shortlisted technologies exhibited a higher potential to create added value for the country.

5.4 Selected technology

To finalise a decision from the two shortlisted options, the consultants gathered primary inputs in a fact sheet (see annex) and shared it with the stakeholders. The factsheets served as a basis to assess the impact of each technology in Iraq. The stakeholders then scored both technologies according to the MCA.

Table 21: Final score for industry technologies

Technology	Score
Use of natural gas in brick and plaster productions plants	13.6
Heat recycling in cement power plants	17.5

With the highest score, heat recycling in cement power plants was thus prioritised for the industrial sector, in alignment with the view of the Ministry of Industry as confirmed in an April 2022 meeting. The technology selected to pass forward to the next step in the industry sector is:

1. Heat recycling in cement power plants

5.5 Selected Technology

5.5.1 Industrial Sector Technology – Heat recycling in cement power plants

Studies estimated that about 20 to 50% of industrial energy consumption is discharged as heat (Interreg 2017). Cement production processes are particularly energy intensive, requiring a lot of burned fuel to provide the energy needed, thus leading to high GHG emissions. The high temperatures involved in this process generate huge waste if not recovered. Cement production is widespread in Iraq and operated by both the public and private sectors.

Heat recycling can be classified into three basic temperature categories: low, medium, and high. At medium and high temperatures, heat recycling technologies are effective and commercially well-deployed, making them suitable for the cement sector. They have an economic benefit in addition to emissions mitigation with a negative abatement cost of -24 to -13 USD per tonne of CO_2 (IEA 2020). If successful, the technology can be transmitted to other industries, following the same principals adapted to the flow and temperature of wasted heat. Heat recovery was also mentioned in several Iraqi national documents. Due to these reasons, heat recycling ranked highest and was prioritised for an in-depth study in the subsequent TAP.

6 Oil and Gas Sector

The industry sector is divided into two mains branches, oil and gas related industries and non-oil industries. This section passes through the results for the industry sector prioritisation, starting from national context to the selection of the prioritised technology.

6.1 List of Technologies

A list of technologies related to measures, programs or projects identified in various planning instruments relevant for Iraq's industrial sector, shown below.

Relevant planning instruments	Measures / technologies
NDC	Projects for the 2nd conditional scenario (1%): Use maximum amounts of APG, burnt to reduce heavy fuel dependency in power generation and other sectors such as transport and industry Projects for the 1st conditional scenario (13%): 1. Improve the quality of oil products to match international standards through the construction of advanced refineries and the rehabilitation and development of existing ones 2. Use LPG as vehicle fuel to reduce dependency on gasoline 3. Use APG in the national oil fields 4. Implement a strategic CCS project
The National Environmental Strategy and Action Plan for Iraq (2013 – 2017)	Rehabilitate oil sector companies Establish new refineries according to international specifications Use cleaner fuel and adhere to necessary specifications and legislations
Iraq's Integrated National Energy Strategy: Summary And Key Recommendations, 2012-2030	Reduce gas flaring
Iraq's Energy sector. A Roadmap to a Brighter Future, 2019.	Large-scale water treatment projects to supply water for reinjection in the oil fields Implement gas flaring reduction projects

6.2 Existing technologies

Iraq is already implementing projects in the oil and gas sector, related to flare gas utilization, often with large international partners. However, there is a lot of remaining potential for further emission reductions in the oil and gas sector. Two thirds of Iraq's natural gas come from the associated gas in super giant oil fields in the south of the country. Around 630 bcf of the associated gas was still flared in 2021, making Iraq the largest flaring country behind Russia (The World Bank, 2022).

Iraq plans to capture an additional 1.2 bcf per day of flared gas by the end of 2023, based on comments from the deputy oil minister in October 2020. As the country attempts to meet the rising demand for gas to produce electricity and lower carbon emissions (Szymczak 2021), it is relevant for the purposes of this assessment to consider technologies that reduce gas flaring in this industry.

6.3 Prioritisation process

6.3.1 Technology group prioritisation

The dominance of oil and gas in Iraq led to the prioritisation of three technology groups within the oil and gas sector. Iraq has major oil fields and has thus expressed a wish to switch to natural gas in different sectors to mitigate the high emissions from heavy fuel. Associated gas is often considered a by-product with low economic interest for utilisation. Flared gas utilisation was highlighted as one of the main technology groups with the highest score in the evaluation framework during the December workshop, as shown in Table 22. This technology group encompasses technologies that can utilise the gas instead of flaring it, such as for onsite power generation or CNG production.

The second group, reduction of methane leaks and vents, aims to reduce the direct gas losses to the atmosphere. Leaks happen along the entire value chain due to aging of infrastructure, irregular maintenance, wear and tear of the equipment components, etc. Vents, on the other hand, are engineered emission points that release gas in order to control pressure, etc. They are typically harder to eliminate and often require replacement or upgrade of equipment. Leaks can vary in size, from super-emitters with an emissions rate higher than 1000 kilograms per hour, which are detected and monitored at the facility level using satellites or drones, to small sources with emissions rates around a few kilograms per hour, detected and quantified at the component level with technology such as infra-red cameras or high flow-samplers. Reducing and recovering methane leaks and vents can provide fuel for onsite use or for other purposes if enough quantities are available.

Carbon capture and storage (CCS) is the third technology group linked to the oil and gas sector. This encompasses all CO_2 capturing technologies and the various available options for CO_2 storage. This solution is mainly linked to the oil and gas sector, as it requires large natural reservoir for storage, usually provided by available data for oil and gas reservoirs. Another use is CO_2 injection as an enhanced oil recovery (EOR) technique to increase productivity in the sector.

The three groups were presented during the December workshop and evaluated by representatives of the different industries using the MCA framework. Flared gas utilisation, and reduction of methane leaks and vents had the higher scores and were therefore prioritised for the next step. The results were approved by stakeholders in the workshop. CCS was not prioritised due to being in its development stage, whereas flared gas utilisation tools are already commercialised and applied worldwide for the oil and gas sector. The consultants in Iraq, based on their previous expertise on the decarbonisation of the oil and gas sector, encouraged the stakeholders to consider reduction of methane leaks and vents due to its potential in Iraq, especially given the current worldwide momentum.

Table 22: Industry sector technology-group prioritisation

Long List of Technology Group	Z- Score		Prioritised technology group

Flared gas utilisation	-0.04
Reduction of methane leaks and vents	-0.39
CCS	-0.54

Flared gas utilisation
Reduction of methane leaks and vents

6.3.2 Prioritisation of technologies within selected technology groups

As the next step, the consultants generated a long list of technologies for the prioritised technology groups. This research was based on the national plans and the technologies available worldwide.

Number	Technology-group	Technology	Initial Screening
1	Flared gas utilisation	Gas to pipeline	Already developed in Iraq. Oil companies gather their gas and transport it to a central gathering point
2	Flared gas utilisation	Gas to power – feed electricity to grid	Shortlisted
3	Flared gas utilisation	LNG production	Shortlisted
4	Flared gas utilisation	CNG production	Shortlisted
5	Flared gas utilisation	Hydrogen Production	Shortlisted
6	Flared gas utilisation	Gas to liquids (syngas)	Expensive technology
7	Flared gas utilisation	Gas to chemicals (ethanol/methanol)	Expensive Technology
8	Flared gas utilisation	Crypto mining	No commercialised technology
9	Reduction of methane leaks	Systematic advanced leak detection and repair (LDAR)	Shortlisted
10	Reduction of methane leaks	Vapour recovery units for oil storage tanks	Shortlisted
11	Reduction of methane leaks	Reciprocating compressors rod packing replacement	Limited potential in Iraq compared to other key methane sources
12	Reduction of methane leaks	Mobile compressor units	Expensive technology
13	Reduction of methane leaks	Improved flare efficiency	Focus on flared gas utilisation
14	Reduction of methane leaks	Replacement of old infrastructure	Expensive technology

The oil and gas sector in Iraq is one of the largest in the world and a combination of several technologies can be used to improve the activities within this industry. Therefore, six technologies were shortlisted for the next step:

1. Gas to power
2. LNG production
3. CNG production
4. Hydrogen production
5. Systematic advanced LDAR
6. Vapor recovery units for oil storage tanks
7.

This does not exclude the remaining technologies from playing a future role in Iraq, only that the eight shortlisted technologies exhibited a higher potential to create added value for the country.

6.4 Selected technology

To finalise a decision from the eight shortlisted options, the consultants gathered primary inputs in a fact sheet (see annex) and shared it with the stakeholders. The factsheets served as a basis to assess the impact of each technology in Iraq. The stakeholders then scored the eight technologies according to the MCA.

Table 23: Final score for industry technologies

Technology	Score
Gas to power	15.7
LNG production	13.7
CNG production	15.7
Hydrogen production	15.0
Systematic advanced LDAR	17.1
Vapor recovery units (VRU) for oil storage tanks	16.2

VRU and LDAR had the highest score according to the MCA evaluation. Following a discussion with the Ministry of Oil, gas to power prioritised over LDAR due to the need for on-site energy production and a switch to cleaner fuel. The two technologies validated by the stakeholders for the next step, were:

1. VRU for oil storage tanks
2. Use of dry gas for power generation

6.4.1 Oil and Gas sector Technology 1 – Vapor recovery units (VRU) for oil storage tanks

Oil storage tanks are found in all oil and gas facilities. The stored liquid emits gases that accumulate on top of the storage tanks. Though frequent, the rate of accumulation varies depending on the temperature, liquid composition, and other factors. The gas is vented to the atmosphere to avoid overpressure in the storage tanks. Formed mainly of methane, the vented gas is a wasted resource that has many applications both on-site and at the country level more widely. In Iraq, over 1.8 million m^3 of methane can be saved using vapor recovery units ('IEA Methane Tracker 2021' 2021). This can be an important climate mitigation measure in the short term and also supply additional gas/condensate to decrease Iraq's dependency on imported natural gas.

In addition to the high environmental impact potential, this technology is also economically attractive as it can provide savings for local operators in the country. The abatement cost of VRU is mostly negative, from -20 to 0 USD/t, meaning that the revenues generated by the VRUs from capture and sold gas/condensate cover fully the costs of the equipment and its maintenance, as well as generate additional revenue beyond that. The TAP will assess the barriers to this technology and the steps required for its development within the oil and gas sector in Iraq.

6.4.2 Oil and Gas sector Technology 2 – Use of associated gas for power generation

Flaring is the process of burning associated gas for safety reasons or in the absence of economically viable alternatives. The burning of gas emits CO_2 to the atmosphere, with some methane slip due to flare inefficiency. Centralised gas gathering can collect significant quantities of gas making it viable for electricity generation. This system can be used with anywhere from 10 million m^3 per year of associated gas or more. For smaller facilities, gas can be gathered in clusters and utilized centrally before being delivered for power generation. It can increase Iraq's generation capacity, reducing the demand gap, whilst helping to avoid millions of tonnes of CO_2 emissions.

Like VRU, gas to power often net-zero abatement cost, indicating the potential profit that the technology holds. The synergies between VRU and gas to power validate the prioritisation of both, as they are complementary technologies on the value chain of methane valorisation. The TAP will explore further the deployment of the two technologies in Iraq, as well as challenges and possible solutions.

7 Agriculture Sector

7.1 List of technologies

A list of technologies related to measures, programs, or projects identified in various planning instruments relevant for Iraq's agriculture sector are shown below.

Relevant planning instruments	Measures / technologies
Investment map of Iraq (2021)	Achieve food security • Improvements in drying technology • Improvements in freezing technology Postharvest/processing/distribution • Improvements to storage to prevent loss from pests (e.g. metal containers to store grain) • Crop diversification
Ministry of Agriculture and National Development Plan 2018-2022	Increase the contribution of agriculture to 5.2% of the GDP by 2022 • Postharvest processing and distribution • Improvements in drying technology • Improvements in freezing technology Raise irrigated area by 17% • Agricultural water management
Iraq vision for sustainable development 2030 (2019)	Recognises the relationship between water, food, energy, and environmental security • Mulching for water conservation

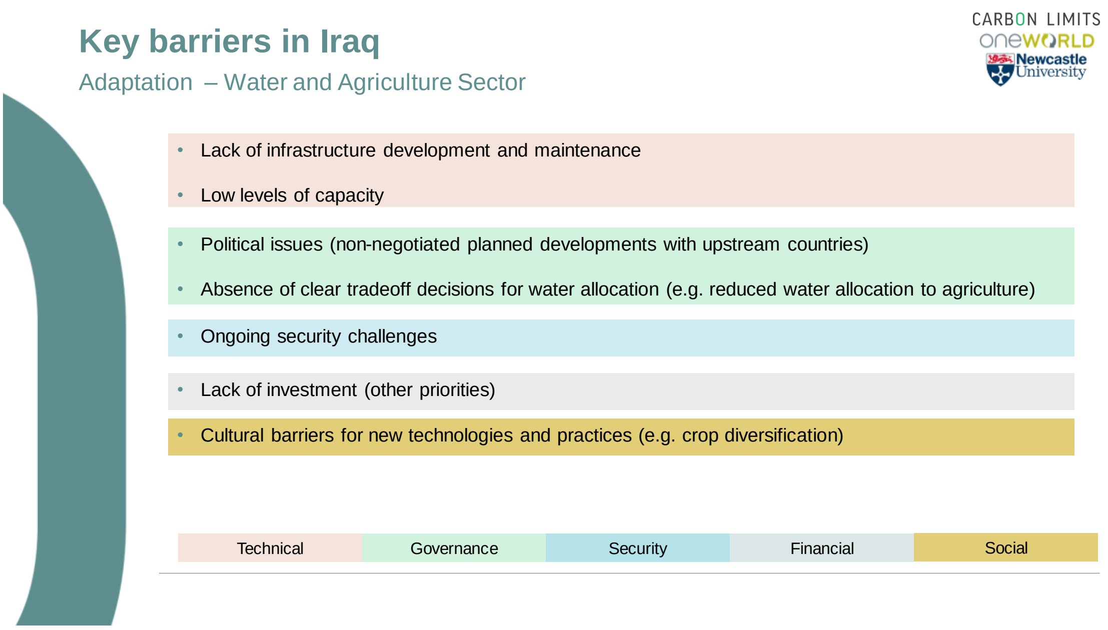
	• Reduced input costs, such as fertiliser • Agricultural water management • Conservation-friendly agriculture
INDCs (2018)	Increase agriculture density to 115% • Agricultural water management Reduce extent of land for rice production • Crop diversification • Land rotation

7.2 Existing technologies in the sector

7.2.1 Challenges to the sector

Iraq's agricultural sector faces a range of environmental challenges, driven primarily by climate change but also other drivers such as warfare (for example, the impacts of ISIS conflicts across different regions in Iraq, notably around Mosel). Climate change is manifested through drought, fluctuations in rainfall, increases in temperature (sometimes in excess of 50°C when work must be prohibited). Two additional challenges in the sector include a lack of both agricultural insurance companies and agricultural stakeholders (e.g., for adequate transport, marketing, and more). These factors all combine to reduce agricultural production (see also Figure 11).

Figure 11 Example of slide shown to stakeholders in workshops describing agricultural (and water) sector barriers in Iraq



7.2.1.1 Climate change

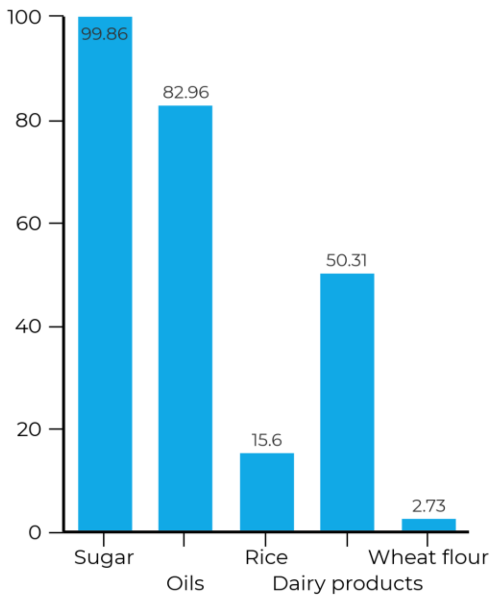
Climate change is manifested through, for example, drought, fluctuations in rainfall, increases in temperature (e.g., temperature in excess of 50°C when work is prohibited). These drivers combine to reduce agriculture production.

Droughts and floods have become a common feature and their co-existence poses a potent threat, which cannot be eradicated but must be managed. Transfer of the surplus monsoon water to areas of water deficit is a potential possibility. Droughts have two basic components: climatic (decrease in precipitation) and demand (use of water). In responding to droughts, Iraq needs to concentrate most of their efforts on reducing the demand for water, although there are limited options for controlling the climatic component. Thus, drought-planning strategies should have a clear objective and purpose; involve stakeholder participation; have a good inventory of resources; identify groups at risk; be able to integrate science and technology with policy; publicize the proposed plan and invite public responses; and have an appropriate education program.

7.2.1.2 Food security

To give an idea of what might be needed to achieve food security then looking at imports gives a good insight. The main food commodities imported in 2015 included wheat and flour (USD 128.1 million), chicken (USD 110.1 million), sugar (USD 306.5 million) and eggs (USD 53.4 million) (taken from National Strategy of Food Security in Iraq 2018) (see Figure 12).

Figure 12: Proportion of imports of key food stuffs into Iraq in 2015 (taken from National Strategy of Food Security in Iraq 2018)



7.2.1.3 Biodiversity loss

The Earth is either already in or near to entering the 6th species extinction phase. The biggest driver of biodiversity loss is habitat loss and the largest contribution for this comes from agriculture (IUCN 2022). The services that are provided by species in the natural environment include pollination, flood control and pest control.

7.3 Prioritisation process

7.3.1 Technology group prioritisation

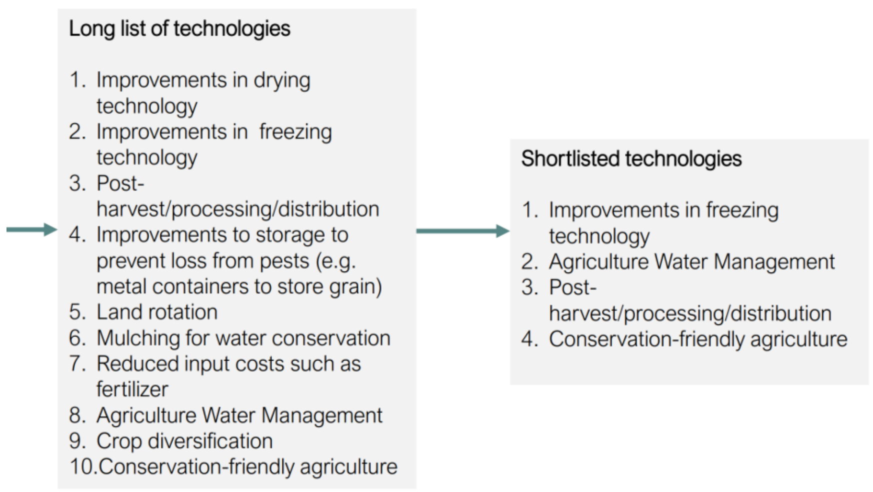
The range of technologies that were considered in the long list are shown in Figure 13. These were harvested from examples in legislation, strategies, and planning documents (see Table in the section above). These technologies were linked to three broad themes: climate change, food security and environment (biodiversity).

Management of water is a key part of **climate change** adaptation. In the longer list two technologies are listed: agricultural water management and mulching for water conservation. Agriculture water management incorporates the political decisions made about use of water in Iraq (and also issues upstream in particular) and the proportion of water allocated to farming versus domestic use. Mulching is a technique for more efficient water use in crop production.

Enhancing **food security** in Iraq requires more in-country food supply which can be linked to greater farm production and/or efficiency from 'farm to fork'. Drying and freezing technologies (infrastructure), storage and post-harvesting/processing/distribution are all linked to improving the supply chain from farm to fork. Part of these advancements involve new potential technology but mainly this would involve an increase in infrastructure enabling crops to be stored and distributed efficiently.

Biodiversity can be increased in farming via conservation-friendly agriculture. Such methods include reductions in fertilizer and pesticide use, promotion of natural crop pests (e.g., intercropping to promote pest enemies) and management to encourage pollinating insects. Crop and land rotation (i.e., not being too reliant on a single crop) also promote species diversity and abundance.

Figure 13 The long list of technologies gleaned from a search of relevant policy and related documents



7.3.2 Prioritisation of technologies within selected technology groups

An excel spreadsheet with 20 different sections was completed (i.e., information gathered and used to populate each section) for each of the following four areas shown in Figure 13 (right hand side short-list). These sections included information on climate change (e.g., greenhouse gas emissions linked to each technology), maturity of technology, applicability, replicability, limitations, status in Iraq, implementation assumptions and barriers, examples of technology providers, implementation timeline. They also included three sections on the benefits (or disbenefits) of the technology (social, economic and development). Finally, costs were considered including capital costs, operation and maintenance and abatement cost of greenhouse gas reduction. These sections were populated using information collected from relevant policy documents and other sources from a literature search using the words: "agriculture" AND "Iraq" in appropriate databases (notably Scopus and Google Scholar).

The information gathered above was then used to enter scores into an algorithm (see section xx earlier in report). An example of some of the scores used in the calculation are shown in Figure 14 below. The completed scores from the Algorithm are shown in Figure 15. **These scores were provided to the stakeholder group who were in agreement with the four short-listed technologies (see Figure 6.2) but slightly amended the priority list to: (1) Agricultural water management; (2) Conservation-friendly agriculture; (3) Post-harvest / treatment / distribution; (4) Improvements in freezing technology (where 1 was highest priority).**

The technologies were prioritized via: (i) an evaluation framework (using a range of factors linked to likely importance and impact); (ii) discussions amongst the author team of this report (to road-test decisions made): and finally (iii) a stakeholder workshop held in December 2021 in which key stakeholders were actively encouraged to review and revise the results.

Figure 14 An example of some of the scores used in the algorithm was shown in this Table: this list is not exhaustive but just to give an idea of some of the criteria used and the range of scores. There are four broad subsections shown as the criteria in the first column of the Table which were used to provide scores for each of the short-listed technologies (shown in the top line of the Table)

Criteria	Improvements in freezing technology	Agriculture Water Management	Post-harvest/ processing/ distribution	Conservation-friendly agriculture
Cost	3.5	2	3.5	1 (least expensive)
Applicability	4	4	4	4
Potential economic development	4	4	4	1 (least likely to benefit)
GHG reduction	4	3	4	1 (most reduction)

Figure 15 The final scores for each of the four short-listed categories

Technology	Score
Conservation-friendly agriculture	14.2
Agriculture Water Management	12.9
Improvements in freezing technology	9.5
Post-harvest/ processing/ distribution	9.3

7.4 Selected technology

The process described in section 6.3 to narrow down the technology selection to a shorter list (see Figure 6.2) was undertaken in collaboration with the stakeholder group, populated primarily by the Ministry of Agriculture staff and other relevant groups. Two meetings were held online in February and April 2022, each lasting between two and three hours. Documents outlining the work completed by the team were also shared via email with the stakeholder group to distribute to the relevant ministries, allowing them time to generate a carefully considered response (rather than an immediate one, as would be the case in an online meeting).

7.4.1 Technology 1 – Agriculture water management – drought-resistant crop varieties

Water management for agriculture is a key issue in Iraq given the rapidly changing climate leading to increasing temperatures and more erratic rainfall. Fifty-five per cent of irrigation water comes from groundwater sources in Iraq. Several key crops in Iraq require extensive irrigation (e.g., wheat, sugarcane, and rice). Whilst reducing the production area used to grown some of these crops (e.g., rice) is proposed, the production of other crops (which require substantial amounts of water such as wheat and sugarcane) are key to increase food security in Iraq which is a key target (see Section 6.1 & Figure 6.1).

Agriculture was recently characterised as being associated with small-farming units (FAO Investment Centre 2012) and so it is likely linked to livelihoods of many rural individuals and families. As such it is of particular importance to wider issues of gender and social justice.

Although there are varieties of key crops (e.g., drought-resistant varieties) which can reduce water demands. An example is drought-resistant wheat varieties: one variety has been shown to increase yield by 400% (e.g., see IAEA 2016); while options can also be provided via genetic modification or crop breeding.

7.4.2 Technology 2 – Conservation-friendly agriculture – drip feed irrigation

Conservation-friendly agriculture provides a range of benefits to the environment (e.g., lowers GHG, decreases intensification via less use of fertilizers and pesticides which promotes biodiversity) and so this technology is likely to provide a range of wider benefits to stakeholders in Iraq. However, such management also often leads to reductions in yield per unit area which will trade-off against different targets (e.g., see those set out in section 6.1).

Actions that can promote conservation-friendly agriculture include:

1. Adoption of appropriate technology widely in promoted pilot areas (north, middle and southern of Iraq) where dryland crops are prominent, through demonstrations, extension, research and training.
2. Develop a research program on conservation cropping, with collaborative, multi-site research in Iraq. Research themes should be linked to agronomy, rotations, residues, crop-livestock interaction, pest disease-weed dynamics and control, and soil fertility-structure-biology dynamics and management.
3. Develop and promote efficient and sustainable farmer-based seed production. Together with development of formal variety release systems to increase farmer access to and uptake of well-adapted crop varieties.
4. Evaluate adoption and impact of project technologies (e.g. early sowing) through socio-economic surveys and evaluation.
5. Provide capacity development and training of Iraqi scientists.

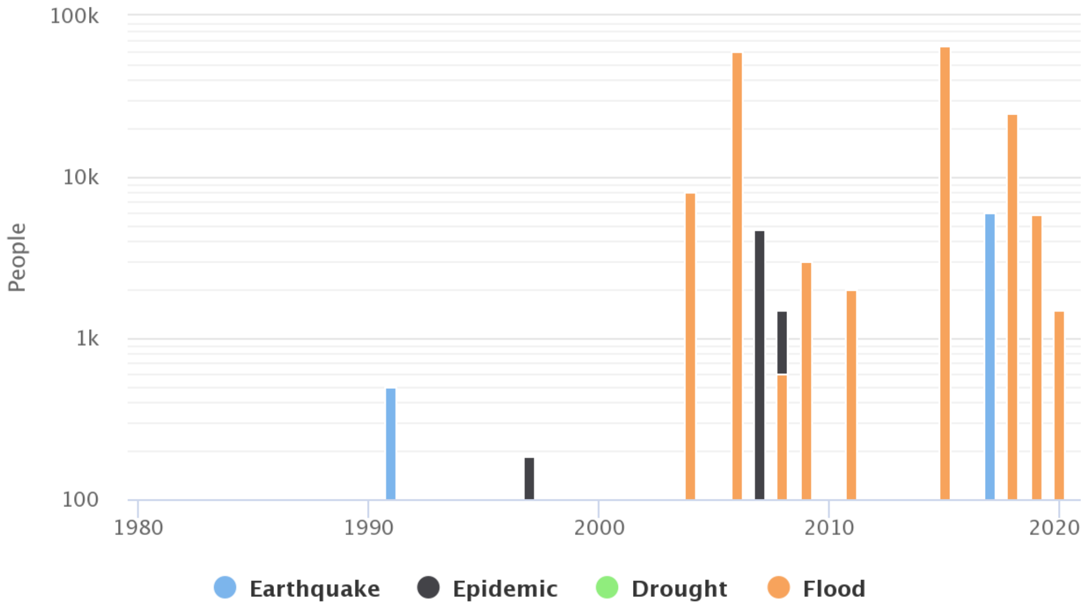
Drip irrigation systems are characterised by efficient water and nutrient delivery systems for growing crops. These systems deliver water and nutrients directly to the plant's root zone. This results in higher yields whilst saving water, fertilizer, and energy.

8 Water Resources Sector

Most of the Iraq's water supply derives from transboundary rivers such as the Tigris and the Euphrates. Water supply in the country has been significantly impacted by upstream infrastructure projects in neighbouring countries, and further exacerbated by the impact of climate change. A major identified concern in the water sector in Iraq is the severe variations in incoming water from Tigris and Euphrates Rivers, which leads to droughts and flooding, affecting many communities. In the summer of 2018 this was witnessed in Basra province where most of the small rivers and irrigation canals dried up. This has led to reduced country freshwater revenues, leading to the southern parts of the country unable to deliver safe water to their populations (UNICEF, 2019).

Apart from continuous droughts experienced throughout the country, Iraq has also been vulnerable to flooding with unexpected flooding in the northern region of the country has caused major economic and societal damage (IFRC, 2021). Iraq has high flood risk across the country affecting livelihoods and agriculture and damaging critical infrastructure. Flooding is mainly a result of the yearly fluctuation in the annual discharge in the Tigris and Euphrates Rivers. The Tigris River floods during the spring period between February and June, while the Euphrates floods from March through July. Water levels in the Tigris River can rise over 30 cm per hour, which causes flooding and the collapse of levees, mainly in the southern parts of Iraq. Floods have affected thousands of people in Iraq over the last two decades (Figure 16), with severe flood events becoming a frequent occurrence and rising in intensity. In recent years, floods have been occurring twice annually (FloodList, 2022) and the December 2021 floods affected more than 7,500 people in the Erbil and Kirkuk provinces (IFRC, 2021).

Figure 16. Number of people affected by key natural hazards in Iraq from 1980–2020 (World Bank Group, 2022)



The impacts of flooding are set to worsen under climate change, with rising temperatures and reduced overall precipitation but more intense rainfall events. Climate change is expected to drive increased river fluctuations, resulting in intensified flood occurrences and aggravating damage to infrastructure. Increased duration and severity of drought events is expected, leading to dry, eroded soils which water cannot infiltrate easily and thus increasing runoff and contributing to greater flood intensity. Worsening flood impacts will also drive an increase in secondary effects, such as increased water pollution and contamination which is likely to intensify epidemics, particularly cholera.

The water sector in Iraq is further faced with internal challenges. The water quality in the country has been inadequate as a result of inefficient water supply distribution networks and an unstable drainage system. Other internal challenges to the water sector in Iraq include high waste ration in irrigation water, low investments in water resource projects, and difficulties in controlling water reservoir and drainage through regulator dams. These supply failures are further compounded by a rapidly population growth.

With the water sector being directly related to other sectors, such as the agriculture sector, failures within the first sector will have unavoidable repercussions on the latter sector. The Iraqi Ministry of water recognizes this dependence and has implemented a strategic plan that displays the balance between the competing uses of water. (Hussein and Qahtan, 2021). The allocated water for agriculture has been agreed to be reduced by 30% in 2035 despite the increased irrigated areas as a result of taking measures such as planting new crop composition that consumes less water and raising the total irrigation efficiency using modern irrigation methods. Despite these measures water needs are still far from being met in Iraq, with the shortcoming being expected to increase as a result of the impact of climate change.

Water harvesting is likely to become increasingly important within Iraq to address water scarcity and improve overall water security. While interventions can be carried out to address some impacts of water availability from rivers and groundwater sources, the impacts of climate change have already severely shifted water resource availability to the point where alternative water sources must be explored, and water losses reduced or avoided. Improved water resource management and reduced pollution will greatly improve water security but water harvesting from alternative sources will be needed to supplement growing water demand. This will be most prominent in rural areas with little or no access to piped water infrastructure and in areas where groundwater resources are not readily available. Water storage will be a significant additional process, allowing water harvested to be stored for times of need such as droughts and heat waves. Furthermore, water losses experienced as a result of flood events must be reduced through, for example, improved flood

8.1 List of technologies

A long list of technologies was compiled by identifying the technologies listed in the National documents of Iraq, as well as other technologies available worldwide that have significant potential in Iraq.

Relevant planning instruments	Measures / technologies
Investment Map of Iraq, 2021	Water & Sanitation Goal 1: ensure the supply of potable water according to international standards and access to the share of per capita consumption of clean water to fit the population growth and at least 250 litres / day per person in Baghdad and provincial centres and 200 litres / day in the districts and villages. Goal 2: Improve the quality of potable water. Goal 3: Reduce the lost by at least 10% of the base year.
National Development Plan 2018-2023	Objective 4: Provide sustainable water resources 1.Reach an agreement with upstream and riparian states to ensure fair distribution and sustainable water rights; 2. Recover and develop marshes; 3. Invest renewable groundwater; 4. Rehabilitate and reconstruct water resources infrastructure damaged by the military operations (Haditha Dam, Adhaim Dam, Fallujah Barrage, Unified Canal Regulator, Ramadi Barrage, and Warrar Regulator).
National Development Plan 2018-2027	Objective 1: Provide drinking water according to international standards reach per capita consumption commensurate with population growth (at least 250 l/d in Baghdad and provincial centres and 200 l/d in qadhas and nahias 1. Adopt an integrated system for managing and organising production, maintenance, filtration, distribution and fee processes to ensure the best performance of systems and improve the efficiency of employees to keep up with modern water projects management and implementation. 2. Prepare plans and studies for pure water needed up to 2030 and qualify and develop current projects to increase and improve production and to increase the capacity of the liquidation projects conducting to population growth. 3. lay water networks to uninhabited areas, renew clean water networks and improve distribution.

National Development Plan 2018-2027	Objective 2: Improve the quality of potable water 1. Improve water quality through annual rehabilitation of the production facilities. 2. Ensure appropriate quantities of water purification materials (both quantity and quantity). 3. Improve and develop laboratories in projects and all production and distribution sites to increase the number and types of tests according to Iraqi and international specifications.
National Development Plan 2018-2027	Objective 3: Minimise water loss by at least 10% of the baseline year 1. Provide modern standards for all participants to control waste and reduce the losses of pure water and ensure the optimal use of water through special awareness programmes. 2. Expand the production and distribution of raw water to all districts of Baghdad and provincial centres to replace the clean water in watering gardens. 3. Enforce provisions, laws and legislation on those who violate public networks. 4. use modern technologies (photovoltaic cells and others) in water structures and others to reduce losses of pure water.
The Future we want, Iraq vision for Sustainable Development 2030 (2019)	Goal (5-2): Efficient use of water resources. Goal indicator: Water stress level = 70% Water agreements with the neighbouring countries = 3 agreements Improve the irrigation and drainage systems. Increase water reserves. Develop an integrated water management system. Enhance international cooperation on water
The Future we want, Iraq vision for Sustainable Development 2030 (2019)	Goal (5-4): Develop the consumption and production patterns to achieve environmental sustainability. Develop irrigation systems and effective water management. Adopt a risk management framework for the agricultural sector to be applied in case of an unstable market and production.
The National Environmental Strategy and Action Plan for Iraq (2013 – 2017)	Objective 2: Protect and improve water quality 2.1 Cooperation with neighbouring countries to ensure water quality and quantity 2.3 Study on the impacts of climate change on water demands 2.4 Water quality improvement 2.5 R&D and capacity building 2.6 Demand management planning

	2.7 Reduction of the Marshlands water scarcity and deterioration 2.8 Restoration of the Marshlands and mobilization of international and regional support 2.9 Sewage and agricultural wastewater treatment 2.10 Industrial wastewater treatment 2.11 Monitor water quality in the downstream estuary
Intended Nationally Determined Contributions (INDCs) to the New Climate Change Agreement 2019	1. Rehabilitating the Mosul Dam to ensure its stability 2. Introduce automated irrigation modalities (sprinkler and drip) all over the country. 3. Expand the Tharthar regulating duct and the duct at the forefront of the Samara Barrage 4. Increase the number of water treatment plants so that by 2035 5. Improve and expand the water system, steadily reduce losses, and expand the use of meters. 6. Increase the number of wastewater treatment plants by 2035 7. Improve the water quality monitoring program already implemented in the Ministry of Water Resources 8. Rehabilitate major irrigation projects in Iraq and gradually link them to main drainage outfall areas or to evaporation basins to avoid returning them to rivers and freshwater streams. 9. In case a continuous water flow of no less than 50 m3/s from the Tigris along the Shatt al-Arab cannot be guaranteed, build a barrage on Shatt al-Arab at the entrance to the Al-Faw Port to prevent the expansion of the salty cape into the city of Basrah. 10. Conduct more studies about the feasibility of continuing the extraction of groundwater and about the aquifers to help replenish groundwater supplies and improve conditions for sustainable extraction 11. Construct dams in the Kurdistan Region to harvest rainwater 12. Reuse wastewater
Iraq, Reconstruction and Development Framework (2018)	Short-term priorities (up to Year 1): Rehabilitate the partially damaged water and sanitation facilities after clearance of explosive hazards. Provide key equipment for water and sewerage operation and maintenance. Prepare detailed assessment for complicated damages to facilities, including preparation of designs. Medium-term priorities (up to Year 3): Complete rehabilitation works for damaged and destroyed facilities. Establish safe operating procedure for dams and water structures for saving lives and livelihoods of the vulnerable communities. Long-term priorities (up to Year 5 and beyond): Prepare a governorate master plan for water and sewerage for the coming 15-20 years.

	Promote private sector participation in the water and sanitation sector.

8.2 Existing technologies in the sector

During the NDP 2013-2017 much focus was placed on groundwater development. Some of the successful implementation of groundwater development projects includes three ground tanks being built in 2013 within Baghdad; the completion of the Eastern Tigris Water project in 2014; an additional two ground water tanks being built in 2015; and the completion of the Rusafa water project in 2016. Furthermore, between 2013 and 2016, a total of 227 wells water production plants being established and 409 solar-powered water production plants created in 2015. More recently, local projects have been implemented to preserve groundwater in Iraq. In Pirmam, Iraqi locals have been experimenting with alternative water methods to sustain trees by promoting artificial recharging projects (Dadson, 2022). Recent years have also seen the development of literature and studies related to the spatial distribution of precipitation, and the assessment of physiographical divisions in Iraq, to enable researchers to a deeper understanding of the groundwater aquifers in Iraq (Saleh et al., 2020).

Several projects were also implemented in, and around Baghdad to treat wastewater. These include two waste treatment plant plants with a capacity of 100 000 m3/day (implemented o 2013), implementing one pump station in 2013, improving and expanding sewage and rainwater networks in the old city of Baghdad and implementing the main line for the Quds street with one vertical pumping station. Three provincial sewerage projects have also been completed. Despite the activities to treat wastewater, the proportion of those with access to wastewater and rainwater systems remains low, and large amounts of wastewater is still thrown in rivers and streams. This leads to the persistence of poor water quality in Iraq.

Since the 1950s several flood management projects in Iraq have been successfully implemented. Most of these relate to the building of multipurpose dams to mitigate flood conditions such as the Mosul Dam, Dokan Dam, Debrendikhan Dam and Haditha Dam (Abdullah et al., 2020). There have also been numerous other large, often related to infrastructure, use of water technologies, such as developing depressions, as exhibited by the Wadi Tharthar flood control project (The World Bank, 2021)., as wells as the construction of levees and training works. In recent years there has also been an increased research output related flood mapping in Iraq using GIS-Mapping for river floods (Allafta & Opp, 2021), as well as flash floods (Al-Nassar & Kadhim, 2018). This research has provided valuable insights into understanding where floods are likely to occur, which can assist in allocating limited resources, effectively.

8.3 Prioritization process

8.3.1 Prioritization of technology groups

The prioritization process used the above summarized literature and policies as a departure point. First a set of technology groups were identified within the water sector as follows:

- Efficient water use
- Effective flood management
- Robust drainage systems,
- Restored landscapes
- Sustainable groundwater development
- Minimal industrial and municipal water waste
- long term planning

Second, these technology groups were presented and reviewed in a stakeholder workshop conducted in December 2021 through participatory application of a multi-criteria analysis framework. The results of the multi-criteria analysis can be found in Annex 1. Stakeholders prioritized wastewater treatment and effective flood management technology groups for the water sector. Notably, the prioritization analysis was conducted across all four project sectors, with these two groups ranking high in the stakeholders' order of priorities.

8.3.2 Prioritization of technologies within selected technology groups

The third step comprised a comprehensive literature review which examined all technologies listed in national documents, and other technologies available worldwide that would have significant potential in Iraq, also evaluated against current best practice. This review yielded a long list of technologies related to the two prioritized groups of technologies. The long list includes the following technologies:

1. Pond systems: anaerobic, conventional, high performance, ponds integrated with other advanced technologies.
2. Growth treatment technologies: rotating biological contractors, trickling filters
3. Suspended growth treatment technologies: nitrogen removal activated sludge processes through nitrification and denitrification.
4. Nutrient removal activated sludge processes: concentrated micro-organisms suspended above the water
5. Chemical disinfection technologies
6. Decentralized wastewater treatment systems
7. Pond enhanced treatment and operation
8. Packaged plants (combines different growth treatment technologies)
9. Surveillance technologies: drones, UAVs
10. Flood risk mapping
11. Probabilistic flood forecasting
12. Monitoring stations for unmonitored areas

As a fourth step, four technologies were shortlisted from the long list of technologies, based on the consultant's expertise, and its applicability to the Iraqi context. Each group included two technologies. For wastewater treatment this was pond systems and growth treatment technologies and sludge processes, as well as nutrient removal activated sludge processes. In the flood management group, flood risk mapping for effective flood management, and probabilistic flood forecasting for mapping uncertainty and providing longer term forecasting were prioritized, again through application of the multi criteria prioritization framework. The result of this can be found in the annex.

8.4 Technologies selected

A technology factsheet was designed for each of the four shortlisted technologies. These were then evaluated by the same prioritization framework used for the group of technologies. In the water sector, probabilistic flood forecasting, and flood mapping was evaluated to be the most compatible for Iraq.

These results were then presented to the stakeholders, which validated these two technologies. In the final stakeholder verification meeting Dr Ibrahim form the Ministry of Water resources explained that due to climate change, Iraq is becoming more vulnerable to flash floods, and requires technologies such as those listed to mitigate the effects of flooding. In Iraq, river and urban flood hazard has been classified as high hazard level (thinkhazard.org). Which suggest that damaging and life-threating floods are expected to occur at least once in the next ten years. Recent floods include December 2021 floods in the northern Kurdish Region, which caused a flash flood in Erbil and Kirkuk Governate, this has caused intense damage to houses, infrastructure and vehicles and caused several deaths. This flooding is also related to the loss of agricultural crops and soil erosion, negatively affecting the agriculture sector (Abdul-Jabbar and Khtan, 2021). Floods a further risk to Iraq, with the damage caused to upstream dams, which could leave to intensified flooding of downstream villages. By compounding flood risk mapping and probabilistic flood forecasting, the chosen technologies support the immediate needs of Iraq to mitigate future flood damages.

In April 2022, Iraqi stakeholders undertook a review and approval process, resulting in the validation of longer-term probabilistic flood forecasting, and flood risk mapping, as the two priority technologies for detailed assessment in this project. These technologies are briefly outlined below.

8.4.1 Probabilistic Flood Forecasting (Early Warning Systems)

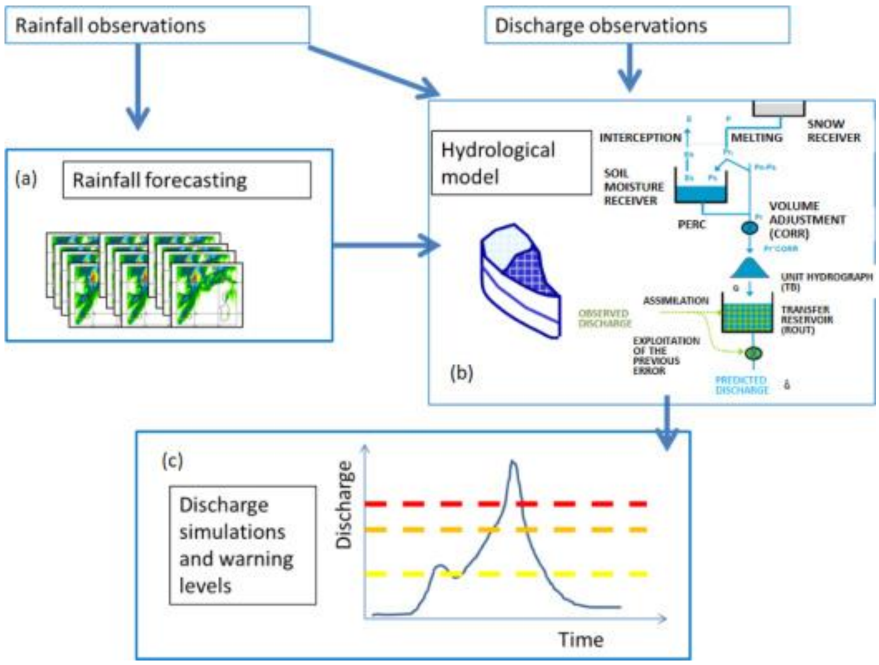
It is critical that Iraq establishes a robust network of Early Warning Systems (EWS) that can allow for timeous response to flood risks and flood onset to minimise the negative impacts on people and infrastructure. For EWS to be effective, they need high quality flood forecasting information which can be generated by probabilistic flood forecasting methods. The technology can represent and explicitly quantify flood forecasts, thus expressing the uncertainty associated with the predictions. This is done by generating multiple possible forecasts of water levels, or rainfall intensities, based on slightly different initial conditions, to reflect the uncertainty involved. Probabilistic forecasting provides information on the forecasting of floods, particularly on uncertainties. Unlike deterministic forecasts, probabilistic flood forecasts try to calculate and represent this uncertainty to enable longer forecasting and warning lead times.

Probabilistic flood forecasts provide a range of possible forecast outcomes that indicate the probability of a flood occurring (Dale *et al.*, 2014). While all forms of flood forecasting have inherent uncertainty, the forecasts developed through probabilistic methods are able to represent and quantify the level of uncertainty explicitly, informing on the general reliability of the forecast. There are numerous ways of developing a probabilistic forecast, but the standard methodology is to generate multiple possible forecasts for an ensemble prediction model using a variety of parameters that have slight variations in the initial conditions (Cloke and Pappenberger, 2009). These will include differences in water levels, rainfall intensities, wind speed, and other meteorological variables to reflect the uncertainty involved in the forecasting (Dale and Wicks, 2013). The ensemble of the forecasts is then run through forecasting systems that generate an overall probabilistic forecast through Bayesian[11] systems based upon a robust theoretical framework used for probabilistic forecast through deterministic hydrologic model of any complexity (Krzystofowicz, 1999). Ensemble flood forecasting has gained significant momentum over the past decade due to the growth of ensemble numerical weather and climate prediction, expansion in high performance computing, growing interest in shifting from deterministic to risk-based decision-making that accounts for forecast uncertainty (Wu et al., 2020).

11 Bayesian analysis is a method of statistical inference that allows one to combine prior information about a variable parameter with evidence from information contained in a sample to guide the statistical inference process.

Bayesian forecasting systems (BFS) consists of three parts: (i) an input uncertainty processor (IUP); (ii) a hydrologic uncertainty processor (HUP); and (iii) an integrator (INT) (Han and Coulibaly, 2019). As the name suggests, the IUP is designed to quantify input uncertainty from the basin average precipitation amount during the forecast period. The HUP aims to quantify hydrologic uncertainty, which is the aggregate of all other uncertainties, including measurement and estimation error of model inputs, model structural and parametric uncertainty, model initial condition uncertainty and so on. Finally, the INT combines them together for the final output. Application of a HUP postprocessor has been shown to improve performance for short-range forecasts.

Figure 17. Example structure of information flows in a probabilistic flood forecasting system



Probabilistic flood forecasting is a widely applicable technology, that can be used at multiple scales. Ideally use of these systems should prioritize flood-prone areas which can be based on historical data of the hotspots from a 40-year record of previous data. Probabilistic flood forecasting can be used over longer forecasting times and it allows action to be taken earlier and provides a detailed picture of the event as it develops which can be used to inform more effective flood incident management decision making.

Depending on the method of forecasting different inputs are required for probabilistic flood forecasting. Basic methods can include only determining a probability threshold based on judgment and local knowledge. This method can be expanded by including a probability threshold that is based on quantification of the costs and benefits of taking flood mitigation action. Both these methods require local knowledge, the recent flood history and historic forecast performance. A more rigorous way is by using Bayesian forecasting system which offer an ideal theoretic framework for uncertainty quantification, which can be developed by means of a deterministic hydrologic model. This model provides an advanced way of flood estimation and considers all sources of uncertainties related to the possibility of the flood, thereby providing a more accurate and reliable flood forecast. In the Bayesian forecasting system, the total uncertainty associated with the hydrologic forecast is broken down into two sources namely precipitation uncertainty and hydrologic uncertainty. Precipitation probability relates to the future average precipitation amount, whilst hydrologic uncertain is the aggregate of all other uncertainties such as imperfections of the hydrologic model, measurement error of physical variables, incorrect temporal, and spatial downscaling of the total precipitation. The integrations of precipitation uncertainty and hydrologic uncertainty produces the probabilistic forecast (Krzystofowicz, 1999).

For basic probabilistic flood forecasting it is first necessary to determine water-level threshold and the probability thresholds. Water level thresholds refers to a water level (or rainfall depth for surface water flood risk) that relates to a particular response, such as flooding of first property or the flooding of critical infrastructure. The water level thresholds can be set through standard methods, consistent with the Environment Agency operational work instruction: 'Threshold setting in flood incident management (Number 55_07)'. Probability thresholds is a percentage value that acts as the trigger for taking an action. These can be determined by using a tool that sets the threshold for a specific location and action over a specific time window prior to a potential flood peak. This can be done by dividing the estimated flood incident management action cost, by the monetized benefit of taking that action.

The Bayesian method requires the development of a hydrologic model, that have two processors attached to it. One processor communicates the precipitation uncertainty into the output uncertainty under the assumption of nonexistence of hydrologic uncertainty, whilst the other processor maps the hydrologic uncertainty into the output uncertainty based on the assumption that no precipitation uncertainty exists within the process. The integration of these two enable the generation of a probabilistic forecast (Krzystofowicz, 1999). Regardless of the method used to conduct probabilistic flood forecasting, it is very technical process that would require experienced hydrologists that are able to develop hydrologic models.

By combining the results of the basic methods and the Bayesian frameworks, decisionmakers are equipped with a thorough understanding of the likelihood of the flood risks, as well as the anticipated damage to infrastructure would be, and what the cost benefit ratio would be for mobilizing flood management resources. The results can be presented to stakeholders quantitively, reducing ambiguities and subjectivities in flood forecasting decision making. The results capture the uncertainty and incorporates risk-based decision making into flood management (Dale *et al.*, 2014). From the variety of results presented by probabilistic forecasting, decision makers can deliberate on their risk preferences, and from there make an objective decision to mobilize the necessary resources.

The results of the probabilistic flood forecasting can be used to structure closure of operation, to issue flood warning and to forecast surface water flood risks and contribute to making decisions earlier in the timeline of the event. Probabilistic flood management can also be done to determine the likely impact of a certain intervention, and in determining if resources should be mobilized for flood management. This can be done by examining the relationship between the forecast probability and the probability threshold. If the forecast probability is higher than the probability threshold, the decision- maker should consider taking a flood management action that is linked to the pre-set probability threshold at the time of the forecast, or decide to wait until the next forecast is received, if time allows (Dale *et al.*, 2014). Clearly communicating to stakeholders what the results of probabilistic flood forecasting implies would be crucial to ensure that the necessary actions are implemented.

The implementation time of the technology is short to medium term. The technology is low maintenance, requiring maintenance only every two years. It would require high quality data, to ensure higher probabilities, which in Iraq might be problematic. The forecasting is then done by expert hydrologist by using the available data and developing a deterministic model of their choice. The costs of probabilistic flood forecasting vary. Access to data, or accumulating data sets are though necessary, which can drastically increase the costs.

The benefits of probabilistic flood forecasting include strengthened EWS, human health and wellbeing; effective flood risk mitigation and management. In terms of economic development priorities, its implementation will contribute to reduced costs incurred from flood damage to infrastructure, and saving human lives, whilst mitigating flood effects to human settlements and agriculture land. Environmentally, probabilistic flood management will reduce the risk of flood damage, which could be detrimental to the environment. Investing into early warning systems can reduce damage and loss caused by natural disasters by 30%. Investments of around US$800 million into developing countries to develop early-warning systems can avoid losses of between US$3-16 billion per year (C40, 2021).

8.4.2 Flood Risk Mapping

Flood risk maps are a vital tool to provide various valuable information for reducing flood damage and spatial planning purposes. The process involves classification of regions into different zones according to their susceptibility to floods (Al-Abadi *et al.*, 2016) and flood risk maps provide information on the consequences of flooding and are an important tool for holistic flood risk management. Similar to probabilistic flood forecasting, flood risk mapping is widely applicable and usable at multiple scales, prioritizing flood-prone areas. As flood risk mapping does not cause a reduction in flood risk, it requires integration into other procedures.

Generally, flood risk mapping has four main functions:

1. Assisting in the early identification of populations and elements at risk.
2. Guiding spatial planning of development activities in flood-prone areas.
3. Serving as the information base for implementation of flood insurance schemes.
4. Helping to raise awareness among the people living in flood-prone areas.

The socio-economic benefits of flood mapping are similar to that of probabilistic flood forecasting, in that it reduces overall vulnerability of floods. Effective risk mapping can offset an mitigate significant losses and impacts of flood events. Thus, implementation and successful utilisation of flood risk mapping can contribute to improved safety and increased well-being, reducing the cost related to flood damages to infrastructure, human lives and settlements, and agriculture lands. This could be especially valuable to women and other marginalized groups that are most adversely affected by flooding.

Flood modelling does not require readily available statistics and data, which is a constraint in Iraq. Computer software like Geographic Information Systems (GIS) in combination with an Artificial Neural Network (ANN) and rainfall-runoff modelling can be used (Shareef and Abdulrazzag, 2021). GIS systems can provide visual representation of flood damage and a 'real-time' assessment on the possibility of flooding during heavy rainfall events. GIS, global positioning systems (GPS) and remote sensing (other geographical tools) can be used in combination when analysing and reviewing floods and their damage as it assesses the land damage, environmental damage and can provide warnings of flooding before the event occurs.

The cost of flood risk mapping depends on the availability of data, software and the rate of a GIS expert that has experience of flood modelling particularly in arid regions. Ideally, existing data sets from other sources can be used to reduce the need for primary data collection. A further way to ensure that the efficient use of resource is to focus on the high-density areas and areas that are at high risk of flooding. Future flooding in Iraq is very likely and having highly organized preparation and response to flooding will be the most effective way of reducing impacts. The time to map flood risks can vary anywhere between two weeks to two months, depending on the availability of data and complexity of the models. Mapping should be updated every five years at minimum, or when there has been a drastic informational advancement, or changes to the geology. It is advisable that the mapping is done by someone that is familiar with the context. Utilizing local knowledge through collaboration within country academic institutions can be highly beneficial, and also contribute to in-country capacity building.

Fundamental steps for developing a flood risk mapping system are to:

1. **Determine the study area:** Establishing what area to map. This can be determined by local knowledge and by examining high-risk areas based on previous flood occurrence.
2. **Select flood hazard or causative factors:** The selection of flood causative factors and variables varies depending on the geographic characteristics of the area (Tehrany *et al.*, 2013). Factors can include ground surface elevation, slope angle, curvature, topographic wetness index (TWI), stream power index (SPI), soil type, and distance to intermittent streams. The data on these characteristics must be gathered and collated.
3. **Standardize the data:** The standardization process makes the data dimensionless to facilitate the comparison of the different data points.
4. **Choose the method of assessing the flood hazard map and determine what modelling programmes would be use:** There are different ways of doing this, commonly different types of Multiple-Criteria Decision Analysis (MCDA) are used (see details below). Having determined the method to assess the flood hazards, a programme should be chosen to model the map, with the variables and their predetermined weights. The programme used can vary, depending on the expert's access to programmes and knowledge of the programmes.

Multiple-Criteria Decision Analysis (MCDA)

MCDA can be described as a collection of techniques for comparing, ranking, and selecting alternatives using quantifiable or nonquantifiable criteria. MCDA is useful in helping researchers and practitioners to solve problems, such as choice, sorting, ranking and description problems (Zavadskas *et al.*, 2014). There are various ways to implement MCDA such as through an Analytical Hierarchy Process (AHP) which is the most common in flood mapping.

The results of the flood risk mapping are obtained by determining variation exhibited in a sensitivity analysis of the results. A sensitivity analysis observes the changes in results using different sets of variable inputs and can guide hydrologist to select the flood causative factors that require more detail information for reliable demarcation of flood-prone areas. The variables with the higher variation indices are indicative of what factors are the most important causative factors. Using the data from the sensitivity analysis, a graphical presentation of results can be derived and mapped. These maps can be directly presented to stakeholders, which can provide a graphical display of what regions are most vulnerable. This can be done through static images, or a dynamic interface that stakeholders can navigate. Other methods of presenting the results can include flood footprint maps and inundation risk maps. These results can then be used by relevant stakeholders to assist in disaster management and flood planning.

Flood risk mapping has readily been implemented in certain areas of Iraq. Al-Abadi (2016) used GIS modelling and integrated a catastrophe model and analytical hierarchy process for mapping flood susceptibility in the north-eastern parts of Southern Iraq. This model found that 38% of the study area (812 km2) are highly susceptible to floods, and 21% of the study area is moderately susceptible to flooding. The flood-susceptible zones were found to be around intermittent streams and the lowlands of the southeast. Allafta and Opp (2021) developed a flood hazard model with GIS and MCDA and analytical hierarchy process to determine what areas of the Shatt Al-Arab basin (located in Iraq and Iran) is most vulnerable to flooding.

8.4.3 Meeting the GCF investment criteria

The two flood technologies are critical not only for more effective water resource management, and social, environmental, and economic safeguarding in the face of climate-related flood events, but also for other sectors, such as agriculture, as well as for the economy, and for social well-being.

Flood events and climate disrupted rainfall patterns have negative impacts for farmer livelihoods, through reduced crop yields, damaged crops, livestock and farming infrastructure, reduced soil nutrition, and reduced functionality of critical infrastructure such as roads that provide farmers with market access. Floods can also result in costs to the economy. Disrupted agriculture productivity has been demonstrated to reduce this sector's contribution to GDP in affected countries, while flood-damaged infrastructure, such as houses, buildings, energy and transport systems, is both costly to repair, while also disrupting income producing socio-economic activities. From a social well-being perspective, floods take lives, injure people and eradicate homes and livelihoods of the most vulnerable.

These technologies, although classified within the water sector, have the ability to cover a wide geographical area, with potential for positive impacts across substantial proportions of the country's population. They can also bringing co-benefits for all four categories of the sustainable development potential criterion, and demonstrating efficiency and effectiveness and meeting the needs of the recipient. These technologies provide the basis for a robust GCF proposal because they can address each of the GCF's investment criteria, while bringing benefits across the economy and society.

9 Conclusions

Iraq has set a variety of goals for mitigation and adaptation to ensure development and sustainability across several sectors of the country. This Technology Needs Assessment (TNA) aims to support the country in these endeavours, considering four primary sectors for adaptation and mitigation selected based on the essential priorities in the country. These are water resources and agriculture for adaptation, and energy and industry for mitigation. The objective is to accelerate the country's ongoing actions and prepare national projects for financing proposals.

The energy sector in Iraq is highly dependent on fossil fuels, with oil being the main fuel used in power generation. A critical gap remains between production capacity and consumption, exacerbated by extreme losses in transmission power lines, reaching only 52% of total electricity supply. The industrial sector is also key to Iraq's economy, contributing to more than 90% of the government revenues, yet is a major source of GHG emissions through both venting and flaring processes. Both sectors have been selected for mitigation due to their high potential to reduce national emissions.

The severe effects of climate change put pressure mainly on Iraq's water resources and agricultural productivity, forcing them to adapt to new conditions. Iraq is facing 50% less rainfall, 50% salinity increases, and reduced supply from upstream countries. These conditions have a direct effect on agriculture, which consumes 80% of the country's water resources using old irrigation techniques and less efficient practices.

The TNA began with this context, searching for solutions to address weakness and increase efficiency in the four sectors. A context-driven approach was employed throughout the prioritisation process. This was ensured by active stakeholder engagement through meetings and workshops, and a transparent evaluation framework to reflect each technology's impact in the country. The evaluation was not limited to the mitigation and adaptation potential, but it went further to assess the impact of technology adoption on the social and economic situation in Iraq.

The extensive prioritisation process lasted over a year and resulted in eight prioritised technologies, that will be explored further in later elements of the TNA, namely the Technology Action Plan (TAP):

Sector	Sub-sector	Technology	Category
Energy		Off-/on-grid solar PV	Mitigation

Industry	Non-oil industry	Heat recycling and co-generation	Mitigation
Industry	Oil and gas sector	VRU for oil storage tanks	Mitigation
Industry	Oil and gas sector	Use of dry gas for power generation	Mitigation
Water		Probabilistic water management	Adaptation
Water		Flood risk mapping	Adaptation
Agriculture		Agricultural water management	Adaptation
Agriculture		Conservation-friendly agriculture	Adaptation

This next phase includes developing a TAP for each of these technologies. The main components of this study are barrier analysis, provision of enabling frameworks, and a deployment plan for projects in Iraq. The overall objective is to lay the groundwork for infiltration of these technologies in the Iraqi market and for the financing of these impactful technologies in the country.

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Annexes

Annex 1. Technology Factsheets for selected technologies

Energy Sector:

Table 24: Energy Sector Factsheets

Sector	Energy		
Technology name	Off/On-grid Rooftop Solar PV	Solar Water Heater	Combined cycle gas turbine (CCGT)
	General		
GHG emissions (CO_2eq)	CO_2	CO_2	CO_2
Background	- PV system for residential used, able to provide independent source of power supply	- Solar heater collector that can be installed on the roof of residential house to provide hot water	- Power generation cycle where a steam turbine is couple to the exhausted of a gas turbine to recover heat from exhaust gas.
Technology characteristics	- 25 to 50 kWp considering an average household size of 144 m2 - Energy Produced for a house with a 144 m2 roof is 40,000 kWh per year	- 10 m2 of collectors produce 3,700 kWh per year - The collector Area needed 10 to 50 m2 for a four-bedroom house	- Large range of sizes (280 to 1300 MW)
Applicability	- 90% of the country area has a potential of 1600 to 1800 kWh/kWp/year - Household electrical consumption 16000 kWh per year	- 90% of the country area has a potential of 1600 to 1800 kWh/kWp/year - Water Heater accounts for 30% of the energy bill	- 38 Gas turbines power plants exist in Iraq (more than 8 GW) - 1.5 GW are planned to be generated from CCGT

Limitations (if applicable)	- Limited Rooftop area - Batteries lifetime (number of cycles)	- Roof - dwelling distance in buildings, which increase the amount of insulation needed - Limited Roof Area	- Fuel supply (Natural gaz) - Limited local expertise
Status of the technology in Iraq	Solar generation capacity of 10 GW by 2030 (Mainly PV)	Solar generation capacity of 10 GW by 2030 (Mainly PV)	5 GW conversion from simple cycle plant to combined cycle plant
Reduction in GHG emissions	- 32 ton of CO2 per system per year	3 ton of CO2 per system per year	6.7 Gt CO2 per year (Total capacity calculated)
Implementation Timeline	Short (Less than 2 years)	Short (Less than 2 years)	Medium (2 to 4 years)
Costs			
Capital Costs	- Levelized Cost of Electricity LCOE 125 to 160 USD per MWh - Off grid system cost 1,651 USD per kWp	- Average price for residential 1300 USD - Average price per liter 8 USD per liter	- LCOE 50 to 80 USD per MWh - Around 1,000 USD per kWe
Annual Operation & Maintenance	- 3% of initial cost	- 0.5 to 1% of the initial cost	- 4% of the initial cost

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https://www.energy.gov/energysaver/estimating-cost-and-energy-efficiency-solar-water-heater)

Industry Sector:

Table 25: Industry Sector Factsheets

Sector			Oil and gas					Industry
Technology group name	Flare gas utilisation	Flare gas utilisation	Flare gas utilisation	Flare gas utilisation	Reduction of methane leaks & vents	Reduction of methane leaks & vents	Use of Less emitting fuel	Heat recycling/regeneration
Technology name	Gas to power	LNG production	CNG production	Hydrogen production	Systematic advance leak	VRU for storage tanks	Burning Fuel in brick and plaster	Heat recycling in cement production plants

					detection & repair		production plants	
				General				
GHG emissions (CO_2eq)	Primarily CO_2, but also CH_4 through flare reduction	Primarily CO_2, but also CH_4 through flare reduction	Primarily CO_2, but also CH_4 through flare reduction	Primarily CO_2, but also CH_4 through flare reduction	CH_4	CH_4	CO_2	CO_2
Background	Centralised gas gathering & NGL removal - Use of dry gas for power generation - Feed electricity to grid	Centralised GPP with full fractionation - Use of dry gas for LNG production	Centralised gas gathering & NGL removal - Export dry gas using virtual pipelines (CNG)	Centralised GPP with full fractionation - Use of dry gas for hydrogen production	Majority of current practice leak repairs are based on safety aspects and conventional technologies. Use of advance leak detection technologies and systematic repairs are advised	Installing vapour capture units on oil and oil product storage tanks in order to capture evaporation losses. The vapour is rich - gas can be used on site and liquid components sold to market.	Switching from the use of heavy fuel oil to the use of Natural gas in brick and plaster production power plants.	Cement production is an energy-intensive process, with a high need for heat (thermal energy). Heat regeneration from waste energy can decrease the need to burn additional fuel. It can be based on simple heat exchanger or advanced heat pump system
Technology characteristics	Anywhere between 10 MMm^3/year to multi BCM/year	Anywhere between 10 MMm^3/year to multi BCM/year	Anywhere between 10 MMm^3/year to multi BCM/year	Anywhere between 10 MMm^3/year to multi BCM/year	Between 1000 to 10000 m^3 of CH_4 per MMm^3 of gas	Over 1.8 million m3 of CH4 can be saved in Iraq	Anywhere from small to large scale industries.	55 to 500 MWh/year in developing countries 20 to 50% of the industrial energy

					produced can be saved			consumption is discharged as heat
Applicability	Very relevant, covers the need for more electricity generation	Very relevant, could be exported and used as a new revenue source	Very relevant, CNG could be used as transport fuel and reduce emissions in transport	Very relevant, could be exported and used as a new revenue source	Applicable to all gas value chain - focus on upstream & mid-stream	Applicable as a lot of oil storage capacity (one of the largest oil producers)	Applicable in a wide range of industries, especially the energy intensive ones. Modifications are required to the power generation system to adapt for the use of natural gas	Applicable in all industries including cement industry
Limitations (if applicable)	Grid losses are high, so not all energy will reach final consumer	Require large scale	Preferably from smaller fields, transport infrastructure is needed for trucks	Not mature technology, new markets	No limitations	If storage tanks with floating roofs are dominating, this technology is unnecessary	Need for appropriate gas storage tanks	Technology efficiency for low-grade temperature (below 200º C) recovery
Status of the technology in Iraq	Have been assessed, not a preferred	Already some projects ongoing	NA	Not implemented	Assumed to be at the conventional	Not common	Mentioned in the INDC	Mentioned in the INDC

	implementation route now				level - None advanced			
Reduction in GHG emissions	Multi-million tCO_2 reductions (largely depends on size of flares reduced)	Multi-million tCO_2 reductions (largely depends on size of flares reduced)	Multi-million tCO_2 reductions (largely depends on size of flares reduced)	Multi-million tCO_2 reductions (largely depends on size of flares reduced)	Total for country: 200 $ktCH_4$ to 400 $ktCH_4$ - Multi million tCO_2eq	Total for the country: Over 1.8 million m3 of CH_4 can be saved in Iraq	8 kg of CO_2 reduced per each MWh produced (Diesel fuel compared to natural gas)	18 to 25 kg of CO_2 per each MWh recovered from waste heat (considering natural gas as a fuel for lower limit and Diesel for upper limit)
Implementation Timeline	Long	Long	Medium	Long	Short lead time of a few months	Medium	Short term	Short to Medium term
				Costs				
Capital Costs	0.8-1.6 USD/scfd	2-7.5 USD/scfd	1.2-2.8 USD/sfcd	8-18 USD/scfd	<150k USD per camera	200-500 kUSD (depending on the size of the storage tank farm)	Around 75,000 USD	thousands to million USD based on the application 5.4 to 10.79 USD/kWh
Annual Operation & Maintenance	1%	1%	1%	1%	A few thousands USD per facility in repair costs	5% of CAPEX	Low operating cost	1%
Abatement cost of GHG reduction	-20 to 0 USD/t	-25 to +25 USD/t	-30 to 0 USD/t	5-55 USD/t	-10 to +20 USD/t	-20 to 0 USD/t	-	-24 to -13 USD/t
Industry sector factsheets references								

IEA Methane Tracker 2021, https://www.iea.org/articles/methane-tracker-database
UNECE's Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector, https://unece.org/sustainable-energymethane-management/best-practice-guidance-effective-methane-management-oil-and
Oil and Gas Methane Partnership Technical Guidance Documents, https://www.ccacoalition.org/en/content/oil-and-gas-methane-partnership-technical-guidance-documents
US EPA's Natural Gas Star Program, https://www.epa.gov/natural-gas-star-program/recommended-technologies-reduce-methane-emissions
Carbon Limits project-related information (confidential)
Cost quotations from technology providers

Agriculture Sector:

Sector	Agriculture	Agriculture	Agriculture	Agriculture
Technology name	Improvements in freezing technology	Agriculture Water Management	Post-harvest/processing/distribution	Conservation-friendly agriculture
General				
GHG emissions (CO2eq)	CFC	Carbon dioxide, methane, and nitrous oxide	Carbon dioxide	Reductions in methane (e.g. less tillage)

Background	Enable freezing of produce (e.g. chicken) to increase quantity of produce and supply chains	Irrigation is a method of supplying water to plants at regular intervals for farming. It is used to help grow crops, maintain landscapes and cultivate disturbed soil in dry areas and during dry seasons.	Technology that maximises merchantability for the entire process of screening, pre-cooling, storage, packaging, transportation of harvested agricultural and livestock products.	Through a combination of reduced tillage, crop rotations, and stubble retention, conservation agriculture allows farmers to increase yields while reducing production costs and improving soil health. Also can make less use of artificial fertilisers and pesticides and be more reliant on natural pest control and fertilisers (manure).
Technology characteristics	Can be multiple scales	Can be multiple scales	Can be multiple scales	Can be multiple scales
Maturity	Mature	Mature	Mature	Medium
Applicability	Needed to preserve many different agricultural products - likely to be potentially widely applicable (e.g. Tomatoes important crop in Iraq)	Applicable in Iraq and identified as important issue	Potentially widely applicable (e.g. Dates)	Example of use of crops within rotations include: arable (e.g. wheat) and clover, broad beans, potatoes, sunflower, maize, tomatoes, cucumbers, Ochre.
Replicability	Yes	Yes	Yes	Yes

Limitations (if applicable)	Electricity grid system may limit geographical spread	Electricity grid system may limit geographical spread	Damage from conflicts to infrastructure	
Status of the technology in Iraq	Not known	About 16 percent of Iraq, or 7 million ha, is classified as arable land, of which about 5.9 million ha are under irrigated or rainfed cropping. Most of the country's irrigated agriculture is found in the central and southern governorates and is dependent on the Tigris and Euphrates rivers for most of its water source. About 64 percent of cultivated land was irrigated.	Not known	Some examples but appears to be limited in scale

Reduction in GHG emissions	Likley to increase (CFC production)	May increase GHG (e.g. compared to the rainfed system, the irrigated system in a study in the midwest of USA had 45% more GHG emissions and 7% more C sequestration	Transport will potentially increase GHG (e.g. petrol vehicles). Electric vehicle potential but needs infrastructure	Decrease in methane and other GHG throught less use of fertilisers/pesticides
Implementation timeline	Medium	Short/medium	Medium	Short/medium
Costs (relative assessment; 1 is the least expensive / 3.5 the most expensive)				
Capital Costs (relative assessment; 1 is the least expensive / 3.5 the most expensive)	3.5	2	3.5	1
Operation & Maintenance	3.5	2	3.5	1

Agriculture sector factsheets references
Al-Haboby, A. et al. (2016) The role of agriculture for economic development and gender in Iraq: a computable general equilibrium model The Journal of Developing Areas 50, 431-451.
Al- Nasser THE OPTIMAL CROP ROTATION OF Al-RASHEED DISTRICT FARMS USING LINEAR PROGRAMMING TECHNIQUE Iraqi Journal of Agricultural Sciences –2019:50(Special Issue):113- 127
https://www.fao.org/emergencies/resources/documents/resources-detail/en/c/1155163/
https://www.fao.org/family-farming/detail/en/c/1127732/

McGill, B.M. et al. (2018) The greenhouse gas cost of agricultural intensification with groundwater irrigation in a Midwest U.S. row cropping system. Global Change Biology, 24(12):5948-5960
Sprinkler - £900 per zone (zone differs between crops). Drip-feed - £282.50 per zone. [Costs taken from https://www.checkatrade.com/blog/cost-guides/irrigation-system-cost/].

Water Resources Sector:

Sector	Water			
Technology name	Wastewater treatment: Pond systems and growth treatment technologies	Wastewater treatment: Nutrient removal activated sludge processes	Flood Management: Flood Mapping	Flood Management: Low data probabilistic flood forecasting
General				
GHG emissions (CO2eq)	Carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O)	Carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O)	No direct emissions	No direct emissions

Background	Pond systems e.g. anaerobic ponds, conventional or high-performance pond systems and ponds integrated with other advanced technologies are used where the cumulative impact of several wastewater treatments is low. Pond effluent can be treated to meet irrigation standards or coupled with advanced treatment technologies to meet discharge standards	The activated sludge is a process with high concentration of microorganisms, essentially bacteria, protozoa, and fungi, which are present as loose clumped mass of fine particles that are kept in suspension by stirring, with the aim of removing organic matter from wastewater	Flood maps are a vital tool to provide various valuable information for reducing flood damage and spatial planning purposes. Flood risk maps provide information on the consequences of flooding and are an important tool for holistic flood risk management.	Probabilistic forecasting provides information in the forecasting of floods, particularly on uncertainties. Unlike deterministic forecasts, probabilistic flood forecasts try to calculate and represent this uncertainty to enable longer forecasting and warning lead times
Technology characteristics	Can be multiple scales	Can be multiple scales	Can be multiple scales	Can be multiple scales
Maturity	Medium	Medium	High	Early
Applicability	Potentially widely applicable (water pollution takes place at scale and the technology can be applied at scale to treat industrial and agriculture wastewater	Potentially widely applicable (water pollution takes place at scale and the technology can be applied to industrial and municipal wastewater systems (removes human waste for example)	Widely applicable and at multiple scales but should prioritise flood prone areas (based on historical data of hotspots from the last 40 years)	Widely applicable and at multiple scales but should prioritise flood prone areas (based on historical data of hotspots from the last 40 years)
Replicability	Yes	Yes	Yes	Yes

Limitations (if applicable)	Energy intensive	Not a very flexible system (. e.g., if sewage volumes increase there are adverse effects on the workings of the process; high operational costs	Flood risk mapping does not cause a reduction in flood risk in and of itself. It must be integrated into other procedures, such as emergency response planning and town planning, before the full benefits can be realised	
Status of the technology in Iraq	Apparently not widely used	Apparently not widely used	Some examples exist and these can be used to update tools/technologies, and as a precedent. There is little evidence of using flood risk mapping in town and rural planning, although flood risk mapping is sometimes used to inform EWS.	Evidence of this being used is not available
Reduction in GHG emissions	May increase GHG emissions (but this likely balanced by substantial socio-economic co-benefits, for example for human health)	May increase GHG emissions (but this likely balanced by substantial socio-economic co-benefits, for example for human health)	No reduction	No reduction
Implementation timeline	Short/medium	Short/medium	Short	Short/medium
		Costs		

Capital Costs	Dependent on scale of the system. Costs will come down with scaled or programmatic application	Dependent on scale of the system.	Costs vary according to scale, but utilisation of expertise, for example from academia can reduce cost; costs lie in conducting necessary topographical surveys and using LiDAR or remote sensing surveys as well as in GIS software licenses if these are not already avail be to the government department doing the flood mapping	Varies, scale should be limited to flood prone areas using historical data; costs primarily for human/modelling resources
Operation & Maintenance	Costly to install, opex costs exist but relatively low	High opex with concomitant human resource costs (hence jobs benefits)	Need to update every 5-10 years	Low maintenance, but needs to be done very 2 years

Water sector factsheet references
Abbas, Z.D., Al-Haidarey, M.J.S., Jassim, O. 2020. Flood water risks and the cost of reconstruction in a section of the euphrates river using GIS, KUFA-IRAQ. Water Quality of groundwater aquifers in Iraq
Alfonso, L., Mukolwe. M. M., Di Baldassarre, G. 2016. Probabilistic flood maps to support decision-making: mapping the value of information. Water Resources Research. https://doi.org/10.1002/2015WR017378
Aziz, A. M. & Aws, A. 2012. Waste water production treatment and use in Iraq. Republic of Iraq Ministry of water resources.
CTCN. Flood Hazard Mapping. Available Online: https://www.ctc-n.org/technologies/flood-hazard-mapping
Campos, J.L., Valenzuela-Heredia, D., Pedruso, A., Val del Rio, A. Belomonte, M. & Mosquera-Corral., A. 2016. Greenhouse gases emissions from wastewater treatment plants: minimisation treatment and prevention. Journal of Chemistry https://doi.org/10.1155/2016/3796352
Dames, J (2019). More Floods, More Effective Flood-Fighting technology. Domestic Preparedness. https://www.domesticpreparedness.com/preparedness/more-floods-more-effective-flood-fighting-technology/
Dakkak, A. 2021. Wastewater treatment and its benefits. EcoMENA. https://www.ecomena.org/wastewater-treatment/
Ganaraska Region Conservation Authority. 2015. Metadata Inventory of Existing Conservation Authority Flood mapping.

UNEP. 2015. Economic valuation of wastewater- The cost of no action. https://wedocs.unep.org/bitstream/handle/20.500.11822/7465/-Economic_Valuation_of_Wastewater_The_Cost_of_Action_and_the_Cost_of_No_Action-2015Wastewater_Evaluation_Report_Mail.pdf.pdf?sequence=3&isAllowed=y
Wendland, A. 2005. Operations costs of wastewater treatment plants. https://cgi.tu-harburg.de/~awwweb/wbt/emwater/documents/slides_c2.pdf

Annex 2 List of stakeholders

Table 26: List of Institutions involved in the TNA process.

Institutions
National Center for climate change
Ministry of Electricity
Ministry of Agriculture
Ministry of Water Resources
Ministry of Industry
Ministry of science and technology
Ministry of Higher Education and Scientific research
Ministry of construction, habitat, and municipalities
Ministry of oil
Ministry of Planning
Ministry of Transportation
Baghdad Municipality
Ministry of Health and Environment
Iraqi Green Climate Organisation
The Iraqi Federation of Industries

Table 27: December 2021 Workshop's list of Participant

No.	Full Name	Position / Affiliation
1	Jassem Abdul Aziz Hamadi	President of supervisory Commission (Minister)
2	Issa Fayad	Director of technical committe
3	Lamyaa Abbass	Director of administrative and financial committe
4	Mostafa Mostafa	Director of National Center for climate change
5	Hadi Mahdi	National Center for climate change
6	Halah Fouad	National Center for climate change
7	Sahar Jassem	National Center for climate change
8	Zaynab Joumaa	Director of industrial activity monitoring
9	Haydar Yaaour	Technical office
10	Satar Aatiyeh	National Center for climate change
11	Angham Kazem	Ministry of electricity
12	Soumaya Assaad	Ministry of oil
13	Douaa Fahmi	Ministry of construction, habitat and municipalities

No.	Full Name	Position / Affiliation
14	Omar Rachid	Ministry of Industry
15	Bassem Hachem	Ministry of science and technology
16	Ibrahim Khalil	Ministry of water ressources
17	Ghadir Hussein	Ministry of Agriculture
18	Zaman Jihad	Ministry of Transportation
19	Lara Karim	National Center for climate change
20	Nabil Mohamad	National Center for climate change
21	Haydar Ibrahim	National Center for climate change
22	Abdallah Abdel Razak	National Center for climate change
23	Mohamad Dawoud	National Center for climate change
24	Dergham Jaber	Center of Information technologies
25	Kousay Mostafa	Planning and follwoing committe

Table 28: April 2022 Workshop list of Participants

NO.	Name	Correspondent Ministry
1	Mrs. Angham Musa	Ministry of Electricity
2	Mrs. Maha Ibrahim	Ministry of Electricity
3	Dr. Hadi Hashem	Ministry of Agriculture
4	Dr. Ibrahim Abdel Razzaq	Ministry of Water Resources
5	Dr. Ghufran Diab Abdul Hussein	Ministry of Water Resources
6	Dr. Maysoon Iyad Hamid	Ministry of Water Resources
7	Mr. Omar Ghazi Rashid	Ministry of Industry
8	Mrs. Souad Abdul Mahdi	Baghdad Municipality
9	Dr. Aws Hilal Jassim	Ministry of Higher Education
10	Mrs. Maysoon Abdel Gawad	Ministry of Planning
11	Mrs. Zaman Hamid Jihad	Ministry of Transportation
12	Dr. Bassem Mohamed Hashem	Ministry of Science and Technology
13	Dr. Abdel Hamid Mohamed Jawad	Ministry of Higher Education
14	Mrs. Esraa Mohamed Kateh	Ministry of Oil
15	Dr. Mukhtar Khamis Habbeh	Iraqi Green Climate Organisation
16	Mrs. Afnan Fawzy Jawad	Ministry of Transportation
17	Mrs. Zainab Zamel Juma	Ministry of Environment / Technical Department

NO.	Name	Correspondent Ministry
18	Mrs. Sarah Durad Ahmed	Ministry of Environment / Technical Department
19	Mr. Mustafa Mahmoud Mustafa	Manager of National Climate Change Center
20	Mrs. Halah Fouad Saleh	National Climate Change Center/ Project manager
21	Mrs. Sahar Hussain Jassim	National Climate Change Center
22	Mr. Oday Hashem Kazem	National Climate Change Center
23	Mrs. Hana Jassim Mohammed	National Climate Change Center
24	Mr. Nabil Mohamed Zaki	National Climate Change Center

Annex 3 Sectoral Working Group

No.	Member	Institution
	Steering Committee	
1	Jasim Abdul Azeez Hammadi	Ministry of Health and Environment
2	Essa Al-Fayad	Technical Directorate
3	Adiba Naji Abdul-Hussein	Technical Directorate
4	Yousif Muayad Yousif	International Environmental Relations Department
5	Mustafa Mahmoud Mustafa	National Center for Climate Change
	Project Management Unit	
1	Halah Fouad Saleh	National Center for Climate Change
2	Sattar Abdul Redha Attia	National Center for Climate Change
3	Lara Hatem Karim	National Center for Climate Change
4	Talal Abdul-Karim Abdul-Rahman	Planning and Technical Follow-up Department
	Energy Sector	
1	Mustafa Mahmoud Mustafa	
2	Mustafa Alaa El Din Sihoud	Ministry of Electricity
3	Israa Muhammad Kata	Ministry of Oil
4	Doaa Mahmoud Fahmy	Ministry of Construction and Housing & Municipalities Public
5	Israa Ali Kazem	Monitoring and Evaluation of Industrial and Service Activities Department
6	Maha Ibrahim Dawood	Ministry of Electricity
7	Aws Hilal Jasim	Ministry of Higher Education and Scientific Research
	Industry Sector	
1	Zainab Zamil Jumaah	
2	Omar Ghazi Rashid	Ministry of Industry and Minerals

No.	Member	Institution
3	Basem Muhammad Hashem	Ministry of Science and Technology
4	Nour Saadi Mahdi	Environmental Impact Assessment and Land Use Department
5	Farah Chakib Rasheed	Information Technology Center
6	Samar Youssef Issa	National Center for Climate Change
7	Representative	The Iraqi Federation of Industries
Agriculture Sector		
1	Hala Fouad Sleh	National Center for Climate Change
2	Ghadeer Adnan Hussein	Ministry of Agriculture
3	Yasser Madhhar Mahdi	Water and Soil Monitoring Department
4	Shatha Mustafa Mohamed	National Center for Climate Change
5	Saif Mohamed Saleh	National Center for Climate Change
6	Doaa Mahmoud Hussein	National Center for Climate Change
7	Representative	Ministry of Planning
Water Resources Sector		
1	Frah Hatf Abdul Amir	Water and Soil Monitoring Department
2	Sura Hammoudi Ali	International Environmental Department
3	Enas Akram Redif	National Center for Climate Change
4	Abdul Hamid Muhammad Jawad Al-Obaidi	Ministry of Education and Scientific Research
5	Hdi Hashem Hussein	Ministry of Agriculture
6	Representative	Ministry of Water Resources

Annex 4 December 2021 workshop scoring results

Table 29: Stakeholders MCA evaluation Scores.

Technology Group	Group 1	Group 3
Renewable Energy (Energy)	15.8	14.15
Heat recycling and co-generation (Industry)	14.45	10.65
Reduction of methane leaks (Industry)	13.7	10.55
Sustainable groundwater development (Water)	13.05	10.25
Energy efficiency in buildings (Energy)	13	9.75
Efficient water use (Water)	12.9	9.45
Ecological pest management (Agriculture)	12.8	8.45
Conservation agriculture practices (Agriculture)	11.7	8.4
Average Score	13.42	10.20

Technology Group	Group 2	Group 4
Energy efficiency in power generation (Energy)	20	18.5
Wastewater treatment (Water)	19.2	17.35
Conservation agriculture practices (Agriculture)	15.75	16.55
Improved storage facilities (Agriculture)	15.65	16.55
CCS (Industry)	15.3	15.4
Flared gas utilisation (Industry)	15.15	14.85
Effective flood management (Water)	13.95	12.6
Fuel switching (Energy)	9.25	10.45
Average Score	15.53	15.28

Annex 5 MCA Evaluation Framework

Country Ownership	Alignment with National Vision	Alignment with other policy initiatives	Have stakeholders been consulted and engaged?	Would receive political buy-in	National control of up-stream resources
Score	Interpretation				
1	Detracts from National Vision	Detracts from other policies	Not at all	No political buy-in	No control
2	No alignment with National Vision	No alignment with other policies	Low levels of engagement/consultation	No impact	Partial control
3	Weak alignment with National Vision	Weak alignment with other policies	Moderate engagement/consultation	Political buy-in exists	Negotiated control
4	Moderate alignment with National Vision	Moderate alignment with other policies	High levels of engagement/consultation	Potential for strong political buy-in exists	Majority of control
5	Strong alignment with National Vision	Strong alignment with other policies	Excellent levels of engagement/consultation	Proven political buy-in exists	Full control
Weight of Indicator for Country Ownership					10%

Impact Potential	Extent of CO_2 reduction for project lifetime	Extent of expected change in loss and damage	Extent of expected change in loss of lives	Proportion of beneficiaries of the project
Score	Interpretation			
1	Very Low	Very Low	Very Low	Very Low
2	Low	Low	Low	Low
3	Medium	Medium	Medium	Medium
4	High	High	High	High
5	Vey High	Vey High	Vey High	Vey High
Weight of Indicator for Impact Potential				30%

Paradigm Shift	Is there any Innovation involved (either in delivery, technology or implementation)	Is there any replication and scale-up potential?	Is there potential for knowledge and learning?	Is there potential to bring about policy change?	Is there potential to bring about lasting behaviour change?
Score	Interpretation				
1	Very low	Very low	Very low	Very low	Very low
2	Low	Low	Low	Low	Low
3	Moderate	Moderate	Moderate	Moderate	Moderate
4	High	High	High	High	High
5	Very High	Very High	Very High	Very High	Very High
Weight of Indicator for Paradigm Shift					30%

Sustainable Development Potential	No. of Jobs created	Contribution towards poverty alleviation	Contribution towards financial inclusion	Contribution toward social inclusion	Longevity beyond funding cycle
Score	Interpretation				
1	Very Low	Very Low	Very Low	Very Low	Very Low
2	Low	Low	Low	Low	Low
3	Moderate	Moderate	Moderate	Moderate	Moderate
4	High	High	High	High	High
5	Very High	Very High	Very High	Very High	Very High
Weight of Indicator for Sustainable Development Potential					5%

Needs of Recipients	Vulnerability of the country (adaptation only- will the project decrease vulnerability?)	Vulnerable groups and gender aspects (adaptation only- will the project decrease the vulnerability of these groups?)	Economic and social development levels of the country and the affected population (will the project improve these aspects?)	Absence of alternative sources of financing (does the project require financing?)	Need for strengthening institutions and implementation capacity
Score	Interpretation per Indicator				
1	Could increase vulnerability	Could increase vulnerability	Could increase vulnerability	No, there are plenty of other sources	No need

2	Not at all	Not at all	Not at all	No, there are a few other sources	Low need
3	Slightly	Slightly	Slightly	Maybe, 50/50	Moderate need
4	Moderately	Moderately	Moderately	Yes, there is very few alternative sources	High need
5	Significantly	Significantly	Significantly	Yes, there are no other sources	Significant need
Weight of Indicator for Needs of Recipients					10%

Efficiency & Effectiveness	Cost per tonne of CO2 emissions avoided/ mitigated (Reverse ranking: 1 for high and 5 for low)	Extent of potential co-financing	Level of expected IRR for projects which generate revenue or ERR for adaptation projects
Score	Interpretation per Indicator		
1	Very high cost	Low/no potential co-funding	No/Low IRR/ERR
2	Moderate to high cost	Small contributions from 1-2 co-founders expected	Low IRR/ERR
3	Moderate cost	Medium levels of contributions expected from 3 or more co-funders	Small but definite IRR/ERR
4	Low cost	Moderate levels of co-funding with a ratio of 2:1 expected	Moderate IRR/ERR
5	Low to no cost	High potential with a ratio of 4:1 expected	Significant IRR/ERR
Weight of Indicator for Efficiency & Effectiveness			15%