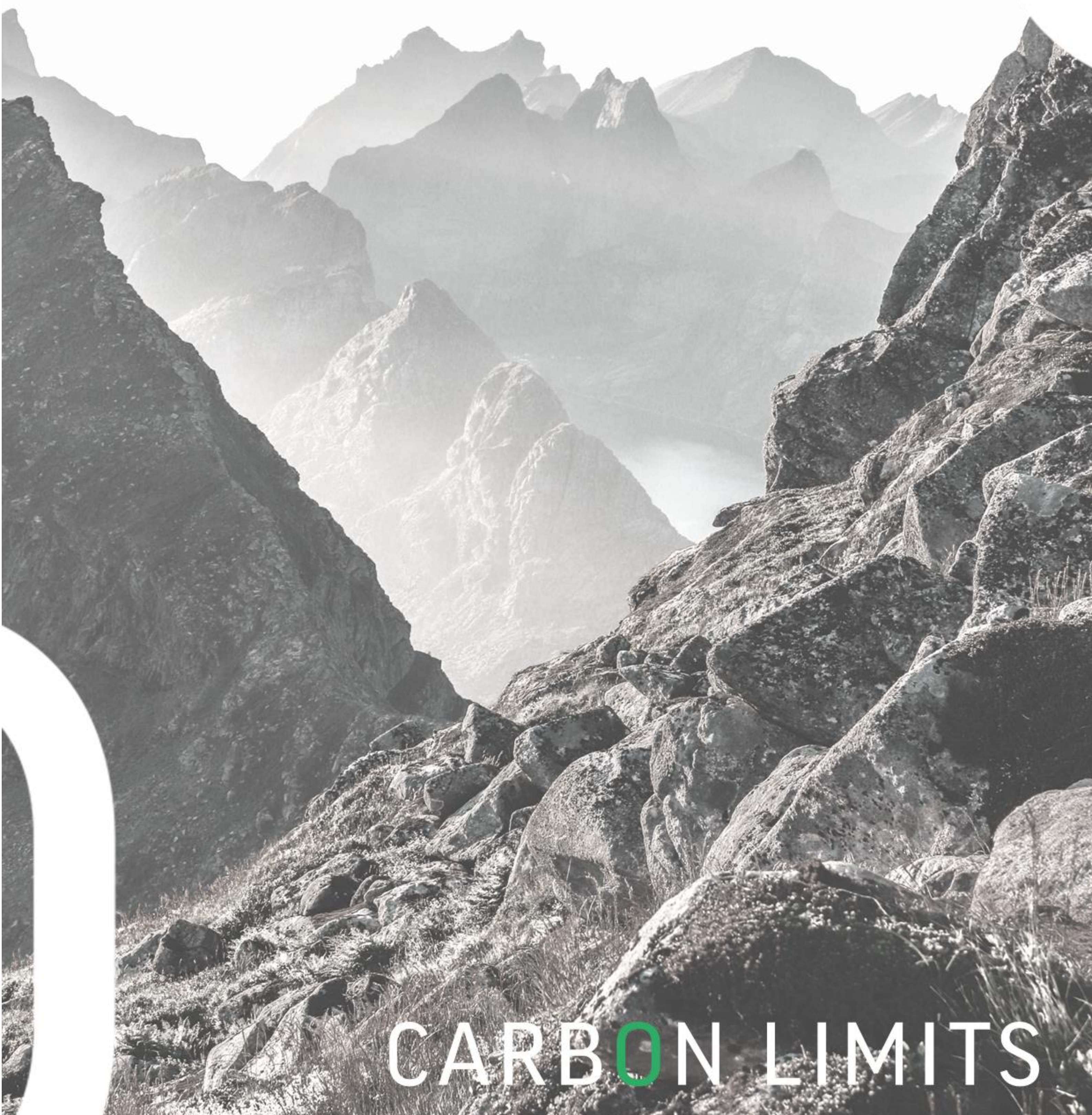
Iraq – Technology Action Plan for Mitigation and Adaptation

Technology Needs Assessment



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Iraq – Technology Action Plan

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Carbon Limits works with public authorities, private companies, finance institutions and non-governmental organizations 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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The consultant consortium, formed by Carbon Limits, OneWorld, and the University of Newcastle, contributed with their valuable experience and international lessons learned in the discussions and analysis presented in this report.

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Abbreviations

AC	Alternative Current	INT	Integrator
ANN	Artificial Neural Network	IOC	International Oil Company
APG	Associated Petroleum Gas	IQD	Iraqi Dinar
bcf	billion cubic feet	IRENA	International Renewable Energy Agency
bcm	billon cubic meter	ISIL	Islamic State of Iraq and the Levant
BFS	Bayesian Forecasting System	ITF	Iraq Trust Fund (World Bank)
bpd	barrel per day	ITMO	Internally Transferred Mitigation Outcomes
BOT	Build Operate Transfer	IUP	Input Uncertainty Processor
BSMEFFGS	Black Sea and Middle East Flash Flood Guidance System	JOD	Jordanian Dinar
CCS	Carbon Capture and Storage	JREEEF	Jordan Renewable Energy and Energy Efficiency Fund
CDM	Clean Development Mechanism	kt	kilo tonnes
CPAI	Cement Producers Association in Iraq	kWe	kilowatt effective
DBB	Design Bid Build	kW(h)	kilowatt (hour)
DC	Direct Current	kWp	kilowatt peak
DRR	Disaster Risk Reduction	LDAR	Leak Detection and repair
ECMWF	European Centre for Medium-range weather forecast	MCA	Multi-Criteria Assessment
FAO	Food and Agriculture Organisation	MFD	Maximising Finance for Development
FRM	Flood Risk Management	MMscf	Million standard cubic feet
GCF	Green Climate Fund	MoA	Ministry of Agriculture
GDP	Gross Domestic Product	MoE	Ministry of Electricity
GEF	Global Environmental Facility	MoI	Ministry of Industry
GHG	Greenhouse Gases	MoHE	Ministry of Higher Education
GIS	Geographic Information System	MoF	Ministry of Finance
GM	Genetically Modified	MoO	Ministry of Oil
GloFAS	Global Flood Awareness System	Mt	Million tonnes
GW	Giga Watt	Mta	Million tonnes per annum
GWP	Global Warming Potential	MW	Megawatt
HAP	Hazardous Air pollutants	MW(h)	Megawatt (hour)
HUP	Hydrologic Uncertainty Processor	NAMA	Nationally Appropriate Mitigation Action
H_2S	Hydrogen Sulphide	NOAA	National Oceanic and Atmospheric Adminstration
IEA	International Energy Agency	NOC	National Oil Company
IEC	International Electro-technician Commission	NEEREA	National Energy Efficiency and Renewable Energy Action
NDC	Nationally Determined Contributions	TWh	Terra-Watts hour

NGOs	Non-governmental organisation	UN	United Nations
ODA	Official Development Assistance	UNDP	United Nations Development Programme
OPEC	Organisation of the Petroleum Exporting Countries	UNFCCC	United Nations framework Convention on Climate Change
PV	Photovoltaic	UNIDO	United Nations Industrial Development Organisation
REDD+	Reducing Emissions from Deforestation & Forest Degradation (United Nations)	USA	United States of America
scf	Standard Cubic Feet	USD	United Stated of America dollar
SSFS	Small Scale Farming System	VOC	Volatile Organic Components
TAP	Technology Action Plan	VRU	Vapour Recovery Unit
TNA	Technology Needs Assessment	WMO	World Meteorological Organisation
tpd	tonnes per day	WHR	Waste Heat Recovery
TSC	Term Service Contract		

1 Introduction

1.1 Background on the TNA project

The objective of the Technology Needs Assessment (TNA) is to scale-up climate technology transfer suitable to the local context. It involves a participatory process within a specific country to prioritise technologies that either reduce greenhouse gas (GHG) emissions, through mitigation, or confront the effects of climate change, through adaptation. The TNA aims to contribute to the country's ongoing climate action program and to develop an adequate project pipeline for financing proposals.

Iraq began developing its national readiness program in 2017 with the support of grant assistance from the Green Climate Fund (GCF). As part of this, appointed by the United Nations Industrial Development Organization (UNIDO), a consultancy consortium led by Carbon Limits began a comprehensive TNA process. Discussions with Iraqi stakeholders (ministries, agencies, organisations, and private companies) raised four key sectors to be prioritised for assessment: two mitigation sectors, energy and industry; and two adaptation sectors, water and agriculture.

Priority sectors were chosen based on Iraq's future ambitions and existing policy objectives. Energy and industry are two sectors where Iraq has committed to implement emission reduction measures, primarily with international support in technology and finance transfer. The agriculture and water sectors, meanwhile, are considered highly vulnerable to the impacts of climate change through the increasing frequency and intensity of extreme weather events, including drought, sand, and dust storms. Conflicts within Iraq have also heavily damaged these sectors' infrastructure, including water systems and irrigation facilities. Ongoing adaptation work in Iraq seeks to restore these systems and invest in climate resilient agriculture. The initial TNA report outlines each sector in greater detail, including their role in Iraq's climate vulnerability, GHG emissions, and Nationally Determined Contribution (NDC).

Further stakeholder participation throughout the TNA process considered various applicable technologies within each sector to decide on one to two primary options to be prioritized at this stage. A Multi-Criteria Analysis (MCA) was used to establish the most optimal technologies that align with the national context and provide added economic, social, and environmental value. This seven-step process – covered in depth in the TNA report – involved scoring of each technology according to a list of weighted evaluation criteria. Eight technologies, from the four sectors, were selected for the development of an adequate action plan (see Table 1). Technology prioritization is a cornerstone of Technology Action Plan (TAP) development.

Table 1: Technology Needs Assessment (TNA) – the list of prioritized technologies

Energy	Industry	Oil and Gas	Agriculture	Water Resources
On/Off-grid solar PV	Heat recycling in cement power plants	Vapor Recovery Units (VRU) for oil storage tanks	Agriculture water management – drought-resistant crop varieties	Probabilistic flood forecasting
		Use of associated gas for power generation	Conservation-friendly agriculture – drip feed irrigation	Flood risk mapping

1.2 TAP purpose and objectives

Following on from Iraq's initial TNA report, the prioritized technologies were analysed further, including analysis of barriers and enabling framework, market assessment, climate impacts and associated benefits, as well as specific project ideas that can be taken further by stakeholders to develop into specific project proposals. These various aspects are summarized in this Technology Action Plan (TAP) report. The purpose of a TAP is to propose an action plan for the uptake and diffusion of each prioritised technology that will contribute to the country's social, environmental, and economic development and to its climate mitigation and adaptation.

Each TAP contains a set of concrete actions and associated activities, to bridge the analysis of selected technologies with their practical and successful implementation. It includes estimates on human and financial resources, stakeholders, and activity timelines. This report for Iraq will also identify some of the barriers to developing these technologies and outline methods to address them through the creation of an enabling framework.

Both the TNA and TAP reports provide a reliable reference for supporting technology diffusion, project planning and funding, and national climate actions in Iraq.

1.3 Methodology

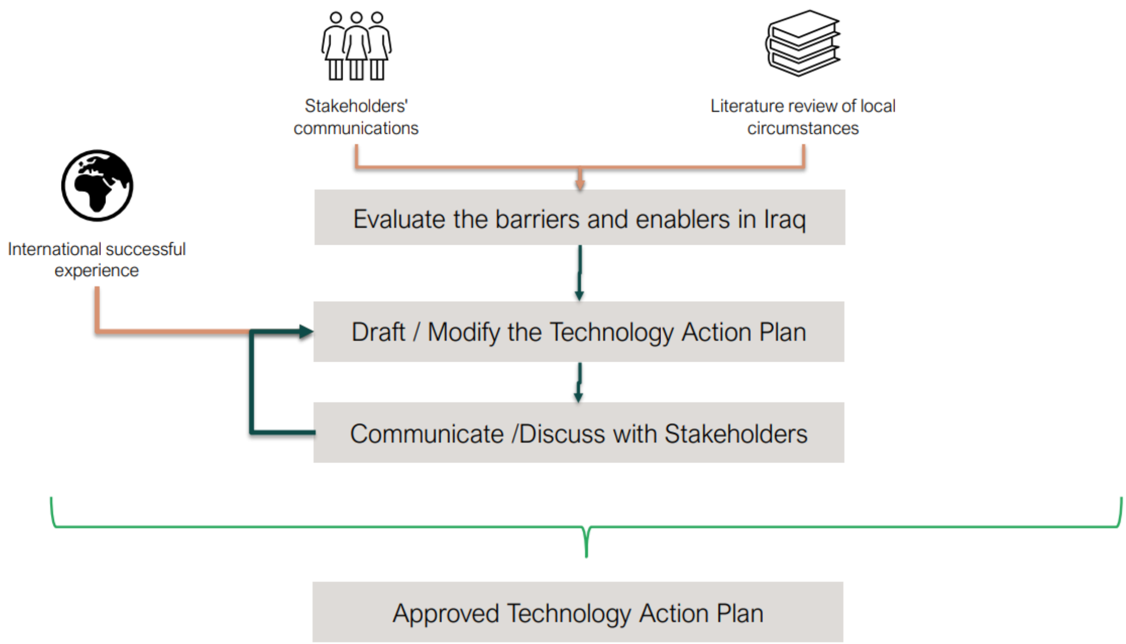
The preparation of the TAPs followed the same principles as the development of the prioritized technology list under the TNA, with deep engagement from local stakeholders and sector representatives' feedback to reflect the local conditions and ensure buy-in later on, especially at the technology deployment stage. The purpose is to develop an action plan adapted to the national context, aligned with the country priorities. The TAP methodology and engagement process are presented in Figure 1.

The first step in the development of the action plans was to identify the barriers that hinder the natural deployment of each of the eight prioritized technologies in the local market. A market mapping helped to localise the status of each technology in Iraq, including key players, existing value chains (or lack thereof), knowledge and experience with the technologies, including on pilot scale. Identified barriers define the obstacles that must be overcome by the actions detailed in the TAP, to foster the technology use in the country. Then, enablers for each barrier were considered in order to translate them into actions and activities. Barriers and associated enablers have been discussed in a number of stakeholder events throughout the project, including at the national stakeholder validation workshop where the TAP results were presented, as well as at the capacity building workshops for the private sector.

In the second step, the first draft of the technology action plans was developed by the consulting team based on international experience, as well as the feedback from local stakeholders, and the available national priorities and strategies. The first draft considered also actions implemented in other countries to overcome barriers similar to those identified in Iraq in step one. In several meetings with TNA Technical teams and designated focal points in different ministries, the early action plans were validated and further elaborated. Feedback was collected from the stakeholders, together with any project ideas already under early development and consideration within different sectors. This resulted in the second draft of the action plans, which were then presented to a broader group of stakeholders, including also other ministries, NGOs and private sector in a national validation workshop. The meeting also evaluated the synergies of each action plan across the different sectors. The outcomes of these discussions are presented in this report.

Gender aspects were considered during the methodology presented above, for the technology action plans to be aligned with Iraq constitution that preserve gender equality. Engagement with the national representatives englobed both men and women perspectives. The different inputs were assessed equally during consultation. In addition, the technology action plans were developed with a reflection on whether the deployment of each technology will enhance the lifestyle of both genders, provide equal work opportunities, and access to resources, and reduce the burden on woman, especially rural woman.

Figure 1: Technology action plans preparation methodology



Part I: Technology Action Plan for Mitigation Sectors

2 Energy Sector

2.1 Sector overview

Iraq's net electricity generation grew on average by 8% from 2008 to 2018, reaching approximately 80 TWh (IEA, 2019). The installed capacity is 32 GW, however the effective capacity is limited to 16 GW, due to extremely high transmission losses, with an average of 52% of the total electricity supply (EIA, 2021a)[1], and damaged or inefficient power plants.

Over 97% of electricity is generated from fossil fuels. The share of natural gas in power generation increased from 30% in 2016 to approximately 55% in 2018, primarily due to imports of Iranian gas rather than Iraq's own supplies. Due to the gas flaring in the oil sector in Iraq, the local market is short on natural gas and cannot cover the local needs. In addition, the country also imports 5% of its electricity from Iran (IEA, 2019).

On the other side, demand for electricity increased by 80% between 2012 and 2018, leading to unmatched supply and demand, even with the added generation capacity. The country's electricity consumption is very

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

seasonal and reaches its peak during the hot summer months. In general, power generation plants operate at low utilisation rates (with production capacity much lower than the installed capacity). This, together with high transmission and distribution losses, as well as damage to infrastructure, results in frequent power shortages, especially in the summer. To fill the gap estimated at 20% of the demand, the population is relying on neighbourhoods' diesel generators, adding to the consumption of liquid fossil fuels and associated emissions. It is essential to mention that, private generators' costs are several times higher than those of the conventional grid (IEA, 2019).

2.2 Preliminary targets

Iraq through its several national documents has expressed the will to improve and develop the energy sector in the country, as it will entail economic growth and development through the different sectors. Plus, a healthy power sector helps sustain higher standard of living for Iraq's population and decrease the risks of power outages especially during summer season. To reach its objectives, the country has set several targets. From the energy management side, Iraq aims to (Ministry of Planning, 2018):

- increase the power generation, including through renewable energy
- improve the efficiency of transmission and distribution system
- reduce consumption by 7% on an annual basis through energy efficiency measures

The renewable energy goals are also reflected in the main climate change document of the country – its first Nationally Determined Contribution (NDC), which was completed in 2021 (Iraq NDC, 2021):

- improve the generation mix, by increasing the share of renewable energy in the country and investment in clean energy with a focus on commercial projects
- reduce the carbon footprint of fuel-based power plants, through rehabilitation of power plant to increase the generation efficiency.

The targets are combined with a set of efforts in the country to update the legal framework and enact a new electricity law, as well as to improve the sector governance and encourage private sector participation.

2.3 Barrier analysis at the sector level

On the sectorial level, the energy sector in Iraq is facing major challenges. The barriers that hinder the development of the sector can be traced back to the lack of gas supply, damages to infrastructure and a weak transmission and distribution system. In its plan to decrease the footprint of its power generation, Iraq is trying to switch its oil power plants to natural gas. However, the oil and gas sector in Iraq does not have the capacity to cover the local gas demand, increasing the need to import from neighbouring countries. The focus on transition to renewable energy generation is limited due to relative novelty of the technologies in the country, lack of available funding and existence of already established fossil-fuel powered generation plants.

From the transmission side, the grid has deteriorated as a result for the unstable security situation in the country over the past years, and lack of maintenance. Rehabilitation of the national grid is highly expensive and has been threatened by persistent security concerns. Unreliability of the electricity supply from the national grid incentivizes the population to search for decentralized solutions, primarily diesel generators.

The lack of financing incentive for new technologies is also topped by petroleum products subsidies, making it difficult for alternative solutions to compete with fossil fuel-based power generation.

2.4 Enabling framework for the energy sector

In order to address some of the barriers outlined above, the country is taking several measures to provide an enabling framework for the development of an efficient and sustainable power sector. Several national documents stress on the importance to develop the power sector, as a key driver for economic development in the country. The draft of new electricity law currently being discussed in the parliament would bring the country one step closer to removing some of the regulatory barriers.

Iraq, due to its location, benefits from high solar irradiation levels, which can help transition away from the dependency on fossil fuels. Solar potential is estimated between 1600 to 1800 kWh/kWp for over 85% of Iraq's area (IRENA, 2021b). Other renewable energy can also be developed as part of the energy mix in the country. Wind energy potential in the northern mountainous regions can be significant and must be evaluated for commercial projects. The increase of renewable energy share would help lower gas imports, thus improving the financial status of the sector and country as a whole.

The rehabilitation of the national grid would boost the sector status and the deployment of new solutions, as it is the link between generation site and end user.

2.5 Action plan for on/off-grid rooftop solar PV systems

2.5.1 General description

Solar photovoltaic (PV) technology converts light photons from sunlight into direct current (DC) electricity through panels made of semiconductor material. The direct current (DC) is than converted to alternative current (AC), through an inverter to be used for households' equipment. The grid-connected system is only consisting of the PV array and the inverter. In this case the energy is directly used or fed to the national grid in case of excess generation, through a net-metering system. In an off-grid system, batteries are added to store the excess of energy generated for use during the periods of lower solar irradiation. Other auxiliary components are installed for safety and control purpose, known as balance of the system.

Figure 2: On-grid solar PV scheme

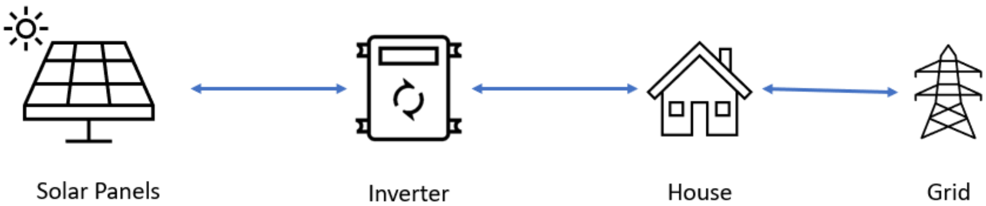
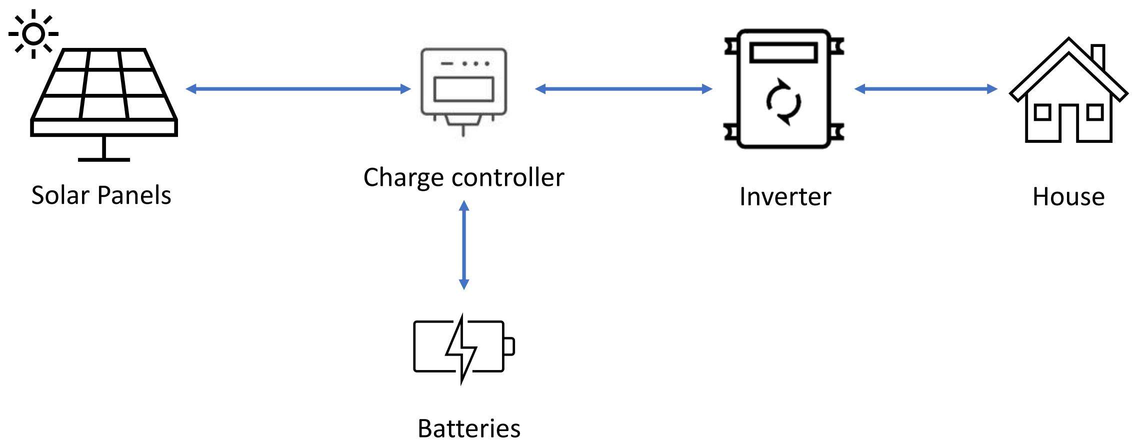


Figure 3: Off-grid solar PV scheme



PV systems can vary in scale. Small-scale PV refers mostly to household rooftop installations for personal use, limiting the total generation capacity to a few kilowatts (kW). Off-grid systems provide great flexibility and a reliable source of energy for users in rural areas often disconnected from the main electrical grid. Grid-connected systems are more useful in areas with more stable utility grid connection, decreasing capital costs. Both systems reduce the costs for the end user – either through lowering costs of fossil fuels needed to power local generator, or through lowering electricity bills for grid-connected users. Large-scale solar PV technology, on the other hand, has capacity in the megawatt (MW) range and usually comes in the form of grid-connected systems requiring significant capital investments. There are several large-scale projects currently in various stages of development or completion in Iraq.

The focus of the current action plan is on the small-scale rooftop solar PV installations, both connected to the grid, as well as off-grid with an integrated storage solution.

2.5.2 Ambition for technology transfer and diffusion

Iraq's climate and geographical location provides a multitude of benefits for solar PV installation. The country has high levels of year-round sun exposure; up to 85% of its area has an annual generation potential of 1600-1800 kWh/kWp and approximately 10% with a potential between 1800-1900 kWh/kWp, compared to a worldwide average of just 20% and 15% respectively (IRENA, 2021b).

Assuming the average roof size in Iraq to be around 150 m2 (PADCO, 2006), households can install a rooftop PV system with a capacity of 25 kWp, capable of generating around 40,000 kWh of electricity per year, almost two times the average cooling and heating household consumption in Iraq, which is approximately 19,000 kWh per year (Abbood et al., 2015). Similarly, commercial and municipal buildings, like schools, hospitals, shopping malls, etc., with rooftop areas much larger than those of residential buildings, have even higher potential for electricity generation and can also be targeted for deployment of solar PV. Adopting off-grid systems allows households, schools, hospitals, small businesses to become self-sufficient in their electricity production and consumption, while on-grid systems alleviate pressure on the national grid. Decentralising electricity generation through widespread deployment of solar PV technology across all governorates in Iraq, can help fill the growing gap between energy demand and current generation capacity, especially in rural areas.

Once the benefits of solar PV systems for personal and utility grid use have been well documented, their use can also be integrated into other sectors and industries. These could include irrigation systems and groundwater extraction for the agriculture and water sectors, or for use in the food and beverage industries where power demand is lower than other more energy-intensive industries, decreasing production costs. With the ability to adapt power supply to each end use, solar PV systems are a renewable, scalable solution to meeting Iraq's electricity demand needs.

2.5.3 Barrier analysis and enabling measures

The list of barriers for solar PV technology deployment were based on the national documents, international experience from other countries in the region, discussions with the sectoral stakeholders. The results are presented in Table 2.

Table 2: On/Off grid solar PV barriers and enabling framework in Iraq

Type	Barrier	Enabling Framework
Political	Low interest in small scale solar PV system	Provide studies that present the importance of small scale solar PV system, for individual application
Regulatory	Ambiguous legal framework (possibility to connect to the grid legally, with opposition from several parties due to technicalities)	Update the legal framework, to clarify the right to connect to the grid and provide a clear process for rooftop solar PV permits
Financial	Low competitiveness, due to the electricity subsidies by the government (90 to 95% of the electricity generation cost)	Develop a new tariff mechanism, where subsidies are removed gradually, with the possibility for regional application, but only after the grid reliability is improved
	High capital cost, long payback period	Enable and operationalize the Iraq Central Bank framework (see more information below) Explore other sources of climate and carbon funding
	Low private sector participation	Provide incentives such as profit tax exemptions, low interest offers by banks Build awareness and knowledge about technology
	Absence of incentive / Government support	Provide feed in tariff mechanism to alleviate the economic burden for private end-user
Technical (On-grid only)	Availability of reliable grid (24 hours of electricity supply)	Improve grid reliability to facilitate connection and efficient electricity transmission, and allow for net-metering

	Difficulties to control the connection to the grid (No net metering possibility)	
Technical	Lack of high-quality products	Develop a certification mechanism for PV system products entering the market Provide a list of accredited products and suppliers to the end-user
	Basic standards in place	Update the national standard for solar PV components
	Limited local production	Evaluate the need for national production for some solar PV components
	Limited linkage between research outputs in this domain and the industry	Enable the available research centres, and promote collaboration with other actors in the field, including the private sector Upgrade the solar Atlas developed with IRENA and develop ground-based measurement Atlas
Social	Low awareness of the end users, mainly in rural regions	Launch awareness campaign to reach the most needed groups of the population Develop pilot projects to prove the system efficiency Develop and make publicly available a tool to simulate the project cost and savings Publish the results of existing projects[2]

Iraq has started to take several measures to address some of the barriers. The Council of Ministers has enacted the decree No. 120, in March 2018, to exempt all renewable energy components, or materials that can be used for renewable energy manufacturing, from 99% of custom taxes. Solar panels, inverters, net/smart meters, and deep cycle batteries are included under this decree.

The Central Bank in Iraq has also launched a financing initiative to support the deployment of solar PV. The bank provides loans through private banks with 0% interest and for a period of 5 years. The initiative finances all kind of projects including residential, commercial, and industrial scale. For the residential sector, the loan amount can reach up to 18 million Iraqi Dinar. The system components should comply with a list of specifications, according to the International electrotechnical commission (IEC) standards set within the

[2] Several projects were implemented in Iraq as mentioned by the Ministry of Electricity, such as street lighting and Bayti residential projects. The results of these projects can be a showcase for the public to raise awareness about the advantages of solar PV technology

initiative. These specifications can serve as an entry point for the development of national standards. Unfortunately, the initiative is now on-hold according to MoE due to the difficulties with grid connection.

The International Renewable Energy Agency (IRENA) has also integrated Iraq's solar map into its Global Atlas tool to help identify the best solar locations and to serve as a database for solar system design. The map is based on satellite data. Three research centres in Iraq are complementing these efforts by providing research related to the performance of solar PV as well as the integration of PV technologies within other sectors and different applications. The three centres are:

1. Energy and renewable energy technologies centre – University of Technology (Established 2004)
2. Renewable energy research centre – University of Anbar (Established 2012)
3. Environment and renewable energy research centre – University of Karbala (Established 2013)

It would be beneficial for the research centres to update the solar map based on ground-based data, to reduce the uncertainty related to satellite data. The centres can also play a linking role between the different sectors and PV technology. Universities in Iraq also offer 19 academic programs for higher education related to solar energy, helping to provide the capacity needed for the sector development in the country.

The local industries are also involved in the solar technologies. The public manufacturer company, Al Zawraa Electric, is involved in several electric components manufacturing, such as electric transformers. The company also established partnership with international companies like Siemens, ABB, Matelec and others, and declared its capabilities to manufacturer of solar related components.

Information box 1: National Climatic Data Importance (UNDP, 2005)

Ground-based data is more accurate compared to satellite data, as it measures the parameters in the same conditions of future projects. For example, when measuring the solar irradiation, this helps consider the cloud coverage, dust effect, wind, and all other parameters, reflecting similar conditions of future projects, making it more accurate than satellite data. The ground-based data can be used to provide more accurate solar irradiations inputs per region, set up weather files for use in energy software, and to develop energy standards.

Once the data is collected, it can be used to develop climatic zoning in Iraq. Climatic zoning defines for each zone a set of climatic data (solar irradiation, wind…), This is a relevant input for the design of all energy systems, like cooling, heating, and solar PV. The methodology to build a climatic zoning follows these steps:

1. Evaluate the availability of relevant climatic data and complete by installing ground base climatic stations for missing parameters and regions
2. Review the climatic characteristics of Iraq
3. Selection of the representative climatic indicators that are relevant for PV system design and other renewable energy and energy efficiency use
4. Correlate the climatic data with the topographical data of the country (altitude)
5. Delimit the climate zoning taking into consideration the administrative lines in the country
6. Update the data on a regular time base (step to be defined based on the climate change effects)

Research centres in Iraq and mainly the one related to energy can have a major role in developing the climatic zoning for the country.

2.5.4 Actions and activities

The technology action plan's objective is to overcome the barriers identified above and provide a set of actions to develop the solar PV technology in Iraq. To reach this goal, a set of actions and activities are suggested across different areas and timelines. Table 3 presents the actions and activities identified for Iraq and validated with the stakeholders.

Table 3: On/Off-grid rooftop solar PV technology action plan

Short Term (< 2 years)	Medium Term (2 to 5 years)	Long Term (> 5 years)
1. Update the legal framework a. Develop an easy and clear permitting process with simple guidelines for PV system proposals 2. Develop financial incentives and incentivize the private sector engagement in the solar PV technology a. Reduce the profit taxes for PV suppliers/energy companies b. Analyse the need for local manufacturing of PV components (inverters, batteries, etc.) c. Enable and operationalize the Central Bank financing initiative and develop additional financing mechanisms to support small projects for households and small/medium enterprises, with low interest rate 3. Effective awareness program a. Prepare some national guidelines for design, installation, and maintenance b. Develop an open database tool to simulate residential On/Off-grid PV projects including their output and costs/savings (universities can play a major role in the capacity building actions) 4. Technical knowledge building	1. Develop financial incentives and incentivize the private sector engagement in the solar PV technology a. Adopt a national feed in tariff framework 2. Rehabilitate the national grid a. Ensure 24 hours electricity supply through the national grid b. Allow the possibility for private power generators to connect to the grid and for net-metering 3. Develop a Quality Control path to ensure good quality products in the market a. Upgrade the national standard/requirements for Solar PV components b. Prepare a certification scheme for the products in the country c. Prepare a certification scheme for suppliers and installers of PV system	1. Adjust the National Electricity Tariff a. Develop a subsides reform for fossil fuel power generation leading to a gradual phase out of subsidies. A region-based initiative can be considered, following the successful implementation of the adjust tariff in some regions. 2. Develop financial incentives and initiate the private sector to invest in the solar PV technology a. Develop a carbon market/tax

Short Term (< 2 years)	Medium Term (2 to 5 years)	Long Term (> 5 years)
a. Implement pilot projects and disseminate results about the results and lessons learned b. Focused practical training for engineers and graduates of technical programs c. Boost research in this domain using the existing centres in Iraq		

The information boxes below present some examples of specialised funding mechanisms for renewable energy that have recently been adopted in some of the neighbouring countries in the Middle East – Lebanon and Jordan. Not only such mechanisms helped significantly reduce the GHG emissions from electricity generation, but also provide substantial savings to the residential and industrial sectors in electricity costs and reliability of electricity supply (especially important for industries with continuous production processes).

Information box 2: National Energy Efficiency and Renewable Energy Action financing mechanism (NEEREA)

The National Energy Efficiency and Renewable Energy Action (NEEREA) is a Lebanese National financing mechanism dedicated to support energy efficiency and renewable energy measures, including solar PV. Launched in 2010, the mechanism provides loans at a very low interest rate (0.3 to 1.075%) for amounts ranging between 2,000 and 20 million USD. This helped NEEREA cover a wide range of projects from individual initiatives to large industrial projects. The loans are provided via commercial banks and supported by the Lebanese Central Bank. The projects are technically evaluated and followed by the Lebanese Centre for Energy Conservation (LCEC Team, 2016).

By June 2020, the mechanism had already financed more than 1,000 projects, with a total reimbursement exceeding 600 million USD. Seventy-six of these projects were for solar PV, covering mainly residential and commercial applications. The mechanism overall resulted in:

- 260,163,325 kWh of energy reduction
- 73,235,210 USD of annual savings
- 281,245 tCO2 of emissions abatement

More information is available on the mechanism's website.

Information box 3: Jordan Renewable Energy and Energy Efficiency fund (JREEEF)

Another relevant financing mechanism is from Iraq's neighbouring country, Jordan. JREEEF initiative was launched in 2015, with the objective to develop local renewable energy sources and energy efficiency projects through the provision of financial resources and technical assistance. JREEEF provides funding at subsidised interest rates.

The fund helped the deployment of clean technologies over different sectors and achieved the results below, by 2019:

Sector	Energy saving (MWh/year)	Emissions reduction (tCO_2)	Cost reduction (M JOD/year) *	Number of people
Residential	35,800	22,810	2.7	200,900
Industrial	2,000	2,180	0.6	643
Public and Government Building	25,000	9,000	3.1	500,000
Tourism	1,820	720	0.175	112,000

*M JOD: million Jordanian dinar

More information about JREEEF is found on their website.

2.5.5 Stakeholders and management planning

As power sector is key for the Iraqi economy and everyday life of the population, the deployment of solar PV technology would require coordinated efforts of a number of stakeholders. The central role is assigned to the Ministry of Electricity (MoE) as it is the primary governor of activities within the power sector, with the overall management responsibility for a widespread roll-out of solar PV systems in Iraq. This includes overall planning of the activities, coordination and communication with all other involved parties, dissemination of lessons learned and adjustment of the implementation plan. The MoE also has several other key tasks to ensure the implementation of the action plan, including drafting of the new regulations, planning for future projects, maintaining the required databases, etc.

Other ministries can also play an important role: the Ministry of Industry's (MoI) support is needed to ensure a supply of local competitive products. Ministry of Higher Education (MoHE) needs to provide the capacities needed for design, maintenance, and operations of PV systems, in addition to the validation of the technology for new applications through research studies. Ministry of Finance (MoF) will need to coordinate the newly developed financing mechanism of the Central Bank, as well as any other future funding mechanisms and other financial incentives. All the other ministries are also responsible for the deployment of the technology within their field of work.

On the secondary level, non-governmental Organisation (NGOs) and local entities, such as municipalities, are essential to link the high-level activities to the end-user, through dissemination, capacity building, and awareness campaign. Through their local network and position they have the ability to reach a significant share of the population, over the different regions.

Commercial banks have a vital role to support financing projects at different level, starting from residential applications and up to industrial projects.

The timeline for implementation and intervention of each of the stakeholders listed, is highlighted in Table 3 above.

2.6 Project ideas for the energy sector

2.6.1 General project inputs

This section presents reference parameters related to PV technology. These parameters are used to assess the cost, mitigation potential and potential for any project idea that can be proposed in Iraq.

Table 4: Solar PV technology project design parameters

System	PV On-grid	PV Off-grid
PV energy generation potential in Iraq (kWh/kWp)	1600 to 1800[3]	
Mitigation Potential (kg CO_2/kWh)	0.8*[4]	
Cost (USD/kWp)	≈900[5]	≈1,700[6]
Operational Cost (USD/kW/year)	9	
Economic Lifetime	25 years[7] For off-grid systems, batteries economic lifetime is 5 to 15 years [8]	
Scalability potential	All regions mainly, urban areas	All regions, mainly, rural areas
Supplier	There is number of local suppliers in Iraq	

[3] (IRENA, 2021b)
[4] Considering that for the on-grid system, all energy produced is either used directly or injected to the grid. (Brander & Sood, 2011)
[5] (IRENA, 2021a)
[6] (Jabbour, 2021)
[7] (IRENA, 2021a)
[8] (Wrålsen & Faessler, 2022)

2.6.2 Project idea: On-grid solar system for primary public school in Baghdad

This section presents a project idea ready for implementation, and that can be used as an example to be further developed into a project concept note and full proposal for climate funding or other sources of financing. Green Climate Fund's (GCF) investment criteria[9] are considered in assessing this project opportunity, as GCF is one of the key funders of climate-related programs and projects. Although evaluation criteria for other donors might vary slightly, the key priorities are often very similar.

The project and all information presented was shared by the MoE as a case study.

Table 5: Baghdad primary school on-grid solar PV project idea

Project Idea			
Type	Project	Sector	Public - Education
Project rationale, objectives, and approach	Iraq suffered in late years from power outages due to the low production capacity. Despite an installed capacity of over 27,000 MW, the effective production does not exceed 13,000 MW, for several reasons related to maintenance, and fuel shortage. The available power is further reduced by transmission losses reaching up to 54%. The power outage negatively affected all the population, and students. Newspapers have reported high temperatures in exam rooms leading to several fainting cases, not to mention the physical and mental effects over students during education sessions and exam periods.		
Context and baseline	Power generation is one of the main sources of GHG emissions in Iraq and relies heavily on fossil fuels. This also means that the sector has a very significant potential for GHG emission reduction and thus is prioritized by the government in term of mitigation actions. There is a dedicated plan for the power sector mentioned directly in the NDC, including actions like awareness raising about energy efficiency and enacting the energy law (World Bank, 2018). Solar energy is abundant in Iraq and presents high potential up to 1800 kWh/kWp per year. PV is well aligned with the national policies and targets in term of climate change. It helps lower the energy deficit in the country, while mitigating an important part of its emissions. Presented project can serve as a pilot project to create awareness about the importance of this technology. In addition, decentralised systems help overcome some of the power sector problems like transmission losses in the country.		
Project/Programme description	The project aims to install 90.92 kWp of solar panels for a primary school in eastern Baghdad. The system consists of 209 PV modules covering a surface of 461.7 m^2 on the school's roof. The modules are than connected to 2 inverters to transform the generated energy into usable AC current. The energy generated can be used directly when needed or injected to the national grid via a net metering system installed. The system will help provide reliable source of electricity for the school and enhance the teaching standards for both workers and students. The reliance on solar energy will reduce the carbon footprint of the school by lowering its		

[9] More information is presented in the chapter related to Funding opportunities, as well as on the website of the Green Climate Fund: Investment framework | Green Climate Fund

	dependency on the national grid, and the fossil generated energy (including back-up diesel generators commonly used). Solar PV system requires low maintenance and operation costs, which reduces the fuel bill and alleviates the operation burdens of a private generator.		
Result Areas	<u>Mitigation</u> Energy access and power generation Buildings, cities and industries and appliances Climate and environment <u>Adaptation:</u> Most vulnerable people and communities Infrastructure and built environment		
Estimated mitigation impact (tCO2eq over lifespan)	2,707	Estimated adaptation impact (number of direct beneficiaries and % of population)	300 persons
Indicative total project cost	USD 99,394		
Payback Period (years)	18[10]	Estimated project/ Programme lifespan (years)	25
Expected project results	Solar energy project can improve the life of Iraq population, by granting them access to a reliable source of energy, to improve their life standards, working conditions and social status. The implementation of successful projects will lead the way for the deployment of this kind of energy in the country, benefiting from the abundant solar resources.		
Engagement among the NDA, AE, and/or other relevant stakeholders in the country	This project was prepared by the MoE, and it is aligned with the national policies enacted by the government.		
Financing by components			

Component/Output	Indicative cost (USD)
Solar Modules	54,549
Inverter	14,800
Steel frame	5,000
Balance of system (additional electric equipment)	25,000
Indicative total cost (USD)	**99,349**

[10] The payback period is calculated based on the current conditions, with subsidies electricity price, and absence of feed in tariff system.

Sustainability and replicability of the project (exit strategy)	This project is easily replicable for schools as they operate mainly during daytime, within daylight hours. But also, it can be a way forward for solar energy into different sectors including residential and industrial applications. The project is self-sustained, as it provides savings to the school, exceeding 1.6 million dinars during summer months. However due to the high upfront cost, the payback period is estimated at 18 years.

Based on the description above, the following key features of the project can be highlighted again the GCF criteria, in Table 6.

Table 6: project evaluation based on GCF criteria.

GCF criteria	Key project features
Impact potential	- 2,707 tonnes CO_2 reduced over project lifespan
Paradigm shift	- A successful pilot project will open the space for more application of on-grid solar PV for other commercial and municipal buildings - Capacity building of final users and players along the value chain
Needs of recipient	- Clean electricity to narrow the gap between power production and consumption in Iraq - The project will help provide adequate education services at this school - Project requires external financing due to large capital costs
Country ownership	- Solar energy is prioritized in national strategies - Solar PV prioritized as key mitigation technology for Energy in TNA stakeholder consultations
Efficiency and effectiveness	- The system is projected to achieve 76.8% performance ratio and produce more than 2 times the school energy needs, resulting in more than 1 M Iraqi dinar of saving, in summer season - Less than 5 USD/tonne CO_2 reduced
Sustainable development	- The project will help avoid 2,707 tonnes CO_2 over its lifespan - Access to stable electricity and better educational process - Environmental and health improvements from replacement of diesel generation

3 Industry Sector[11]

3.1 Sector overview

Being one of the largest oil producers in the world, Iraq's oil and gas sector is the dominating industry in the country, which has historically limited development of other sectors. The industrial sector is highly dependent on the revenues generated from the oil and gas sector (KAPITA & GIZ, 2020).

Data from 2018 indicates that the leading industrial enterprises 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 remaining share of the industries is widely diversified and includes clothes, wood, electronics, electrical equipment, construction materials, chemical, transportation, pharmaceutical and other type of industries. The most important players among large enterprises were the

[11] Kindly note that here and throughout this report industry sector excludes the oil and gas sector, which is analysed and presented separately.

manufacturers of refined petroleum and coke products with a total of 3,740,948,584 million IQD (KAPITA & GIZ, 2020).

The industrial sector is based on small-sized enterprises (25,747 enterprises in 2018, 96.9% of the total industries) with low share for medium and large-scale industries (198 and 627 companies respectively), however the latter employs most of the manpower working in the sector.

Cement production in Iraq is widespread across different regions, operated by both the public and private sectors. The Cement Producers Association in Iraq (CPAI) comprises 12 cement producers with a production capacity of 25 million tonnes of cement per year (WCA, 2022). The public company, Iraq Public Cement Company, consists of 18 cement factories distributed all over the country with a production capacity of 17 million tonnes of regular cement, in addition to other types[12].

3.2 Preliminary targets

In order to be less dependent on the oil sector revenues and diversify its economy in the long term, Iraq is giving more importance to the non-oil and gas industries. The government's climate mitigation efforts within the industrial sector include promotion of energy efficiency and renewable energy within the manufacturing processes across all relevant industries. This would help reduce GHG emissions, while at the same time, reducing the fuel costs which increases the products competitiveness. Under this goal, Iraq focuses on the integration of heat recycling, renewable energy, and energy efficiency across the sector, mainly for energy-intensive ones, like steel, cement, and brick production.

The second target looks to enlarge the industrial support network. This is mainly done through connecting industries with other sectors, encouraging the private sector to participate and invest in different industries, and attracting new sources of financing. The three pillars will help direct large amount of investment into the sector for its further development to ensure it can respond to the local market needs. Iraq's goal from this development is to increase the contribution of non-oil and gas industries to the gross domestic product (GDP) by 40%, as mentioned in the 2019 investment plan of Iraq s(National Investment Commission, 2019).

3.3 Barrier analysis at the sector level

Other industries are often neglected in Iraq and overshadowed by the oil and gas sector, as it is the main contributor to the country's GDP. The years of different conflicts resulted in severe damage to the infrastructure, combined with lack of financing which is hindering the potential of these industries.

The weak power sector adds on to the challenges of small industries, due to high costs of electricity and back-up generation needed for blackout periods. This increases the production cost and makes local product less attractive compared to the imported ones. Most of the industries are small-sized, and they lack the capacities to compete on the global market.

3.4 Enabling framework for the industry sector

The government strategy to develop other industries is the main driver and enabler for existing barriers. Raising awareness about clean energy and energy efficiency is a good policy for the manufacturers to be independent from the power sector struggles. This also entails low carbon and low-cost products that can compete on international market and boost the country's industrial exports. The solar resources in Iraq can

[12] Information shared by MoI. it is unclear if the Iraq public cement company's capacity is included in the CPAI total capacity or not.

be leveraged to cover the needs for electricity and heat for small and medium size industries. Energy efficient solutions can help the heavy industries to alleviate their challenges related to power and heat requirements.

The participation of private sector on the other hand, is required to cover the lack of financing and further develop the industries. To overcomes years of instability, the sector needs capital injection for rehabilitation of existing facilities and development of new ones.

3.5 Action plan for heat recycling in cement power plants

3.5.1 General description

Cement production is an energy-intensive process. As part of this process, raw materials, such as limestone, are burned in kilns at temperatures of up to 1,450 °C to be formed into cement clinker (IFC, 2014). The high temperatures involved in the process result in large amounts of wasted heat, mainly transmitted by exhaust gas. Between 20-50 % of industrial energy consumption is discharged as wasted heat (BCS, Incorporated, 2008). This energy can instead be recovered for use in other applications, including power generation.

Heat recovery technology relies on a heat exchanger to transfer energy from the exhaust gases to the working fluid inside, turbines, electric generators, condensers, and a working fluid cooling system, or to an intermediate heat transfer fluid (e.g., thermal transfer oil), depending on the type of WHR cycle. The type and size of the heat exchanger varies and can be custom designed based on the exhaust gas composition, flowrate, temperature, and type of liquid working fluid used – usually water, but sometimes either butane or pentane with better generation efficiencies at lower heat source temperatures, or a newer mixture of water and ammonia. The efficiency of the heat recovery system depends not only on the type of fluid but also on the thermal characteristics of materials used to build the heat exchanger, as the energy transporter between fluids, as well as on the flow design and certain other parameters. WHR is not new technology; it is well developed and technically proven. Various improvements are being made to overcome its primary limitation, relating to efficiency at low temperatures.

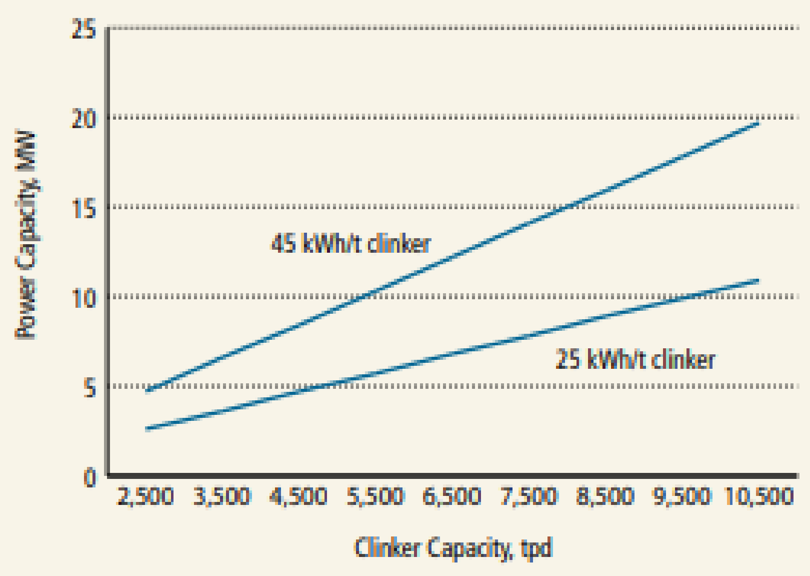
The adoption of heat recovery technology can boost the thermal efficiency of the cement industry while reducing operating costs at the facility level. It has the potential to provide 20-30 % of energy required in the production process, leading to a net operations income improvement of 10-15 % (IFC, 2014). Reducing fuel consumption during cement production not only mitigates greenhouse gas emissions but lowers the overall costs, making the product more market competitive.

3.5.2 Ambition for technology transfer and diffusion

Waste heat recovery technology has significant mitigation potential for cement production due to the high temperatures used during the production process. Figure 4 presents the power capacity (MW) per clinker capacity (tonnes per day, tpd), while Figure 5 shows the power generation potential relative to the preheater exhaust temperature. At a temperature of 300 °C and capacity of 2 500 tonnes per day, the potential power generation through heat recovery is estimated between 4 to 5 MW. In a 24-hour working power plant, this would avoid the consumption of 13 tonnes of natural gas per day.[13] The application of WHR systems can thus mitigate around 18 to 25 kg of CO_2 per MWh[14] of recovered heat, depending on the type of fuel used.

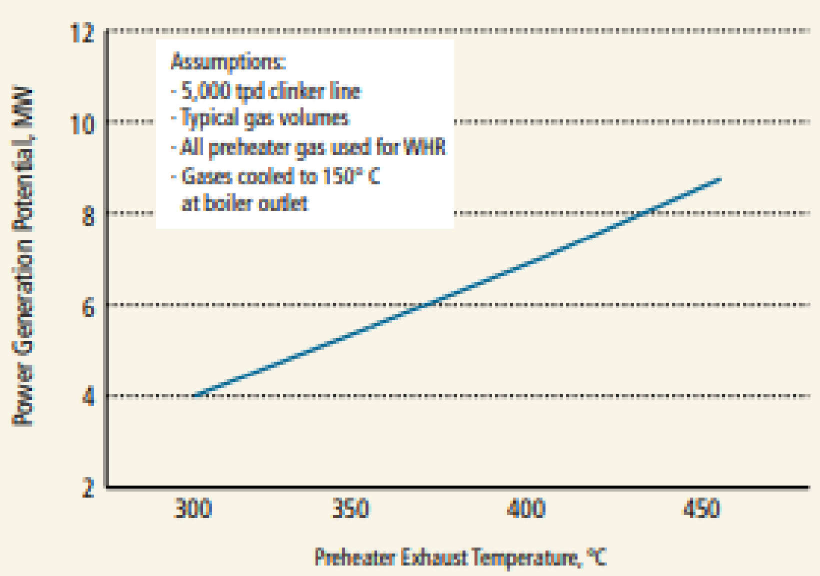
[13] Carbon Limits calculations on the energy content of natural gas
[14] Carbon Limits calculations on CO_2 emissions of natural gas from power generation

Figure 4: Waste heat power generation capacities (MW) relative to clinker capacity (tpd) (IFC, 2014)



Source: Based on OneStone Research, 2013

Figure 5: Power generation potential (MW) relative to preheater exhaust temperature (°C) (IFC, 2014)



Source: PENTA Engineering 2013

Iraq has a flourishing cement market – demand is expected to reach 28 million tonnes by 2026 (CemWeek group, 2021), providing vast opportunities for expanding national production and export capacity. In this growing market, WHR can play a major role both in reducing production costs, making local cement more competitive against its imported international equivalent, and reducing national energy consumption. Based on the current production capacity and the chart in Figure 4, WHR can provide between 120 and 150 MW of capacity on the national level[15], excluding possible waste heat use within the industry itself, making WHR an attractive option for the situation in Iraq. WHR technology also has wider potential for application in other industries, which is beyond the scope of this analysis.

Information box 4: WHR Potential – Egypt Case Study (IFC, 2014)

Egypt has important cement industry with 59 plants and a production capacity of 59 million tonnes per annum (Mta) of cement. In 2012, the country was exporting cement, as production exceeded consumption by 1.7 Mt.

The cement sector was publicly governed until 1995, when the private sector was allowed to enter the sector, which helped to inject new resources to develop the sector. In the recent years challenges arise, following the instability in the country, leading to a high fluctuation in demand, for a sector with high inertia, in other words, a low capacity for supply variation.

Adding to that, the removal of fuel subsidies for the industry created a problem with power supply. The power grid and natural gas supply was already a burden for cement plants due to issues with reliability. All these factors combined triggered the search for energy efficient measures and alternatives solutions.

WHR was evaluated by a group of stakeholders, as it presented a potential of 175 to 300 MW of additional power capacity. This resulted in a proposal to develop WHR projects under the Clean Development Mechanism (CDM) program in 2012.

3.5.3 Barrier analysis and enabling measures

Barriers of WHR technology were based on the analysis of the national documents, as well as international experiences of other countries, for example, Kazakhstan and Armenia. The list of barriers was then validated with industry representatives, and the Ministry of Industry. The results are presented in Table 7.

Table 7: Waste Heat Recovery barriers and enabling framework in Iraq

Type	Barriers	Enabler Framework
Regulatory	Absence of a supportive regulatory framework with a clear priority and plan for the WHR technology	The NDC presents an umbrella of options for the energy efficiency in the industrial sector
Technical	Limited data related to the characteristics of exhaust gases in cement production (moisture, composition, flowrate, temperature…)	Improve the environmental database developed by the Ministry of Industry to include all the different parameters needed to evaluate the applicability of WHR Expand the database to include all cement factories in the countries, including private sector ones Adopt a smart energy management system[16]

[15] Carbon Limits calculations
[16] According to ISO 50001, an energy management system includes setting energy policies, and developing energy targets and action plans to reach these targets.

	Uncertainty about the amount of recoverable heat[17]	Provide a wide range of products suitable for different heat quantities and with high efficiency Develop expertise to assess the potential of recoverable energy
	Limited space and transportability. Some facilities have limited physical space to access waste heat streams	Provide custom design services for waste heat recovery Research and development for adapted heat recovery systems
	Undeveloped local suppliers / Expertise	Develop waste heat recovery pilot projects, with the participation of local suppliers Create a cross-ministerial expertise exchange between the Ministries of Oil, Electricity, and Industry to utilize the existing knowledge
	Lack of standards and code for energy efficiency in the country	Adopt regulations and standards for minimum energy efficiency requirements
Financial	Fuel and electricity prices subsidies	Update the fuel subsidies for the industrial sector and link it to the energy efficiency within the industry
	High initial cost and long payback period	Launch additional initiatives, similar to the Central Bank financing scheme[18], dedicated to energy efficiency in the industrial sector Develop a carbon market in the country
Social	Awareness of the amount of energy lost by exhaust gases	Focused workshop for "niche" stakeholders in the cement industry Foster collaboration between the public and private sector

China presents a successful experience in deploying waste heat recovery in its cement sector, and can be used as an example for Iraq, in developing its national policies and incentives for the industry. Information box 5 highlights China's WHR story.

[17] The amount of recoverable heat depends on the exhaust gases' temperature and energy content, and the WHR system efficiency
[18] The Central Bank of Iraq has launched an initiative to support the industrial sector with low interest loan, as stated by MoI. A similar mechanism can be implemented to focus on energy efficiency in the industrial sector, including WHR systems.

Information box 5: Success Story – Waste heat recovery deployment in China (IFC, 2014)

In the 1970s, China transformed from small-scale county and commune cement production to large-scale integrated cement plants through an influx of private capital caused by market reforms. In the 2000s, China further pushed the sector with a series of regulation to promote production growth and improve efficiency. Production has jumped from 595 million tonnes per year in 2000 to 2,210 in 2012.

At the same quick pace, Waste Heat Recovery increased from less than 20 units in 2005 to 739 units in 2012, with a peak installation in 2009 at 180 WHR system during that year. The first installation was the result of cooperation with a Japanese manufacturer. And many projects were financed under the CDM programme[19]. The overall capacity installed was estimated at 6,575 MW in 2014, generally retrofitting most of the existing cement market in the country.

This development of WHR market was a result of several drivers:

- The energy conservation law, which encouraged industries to take energy efficient measures and facilitated the injection of surplus energy generated from waste heat, into the national grid
- Ministry of Industry required new production lines to be directly equipped with waste heat recovery systems
- China has included in its cement sector planning, a continuous promotion of energy efficient technologies and a focus on research and development of the energy efficiency equipment with a clear target for the future.

[19] Read more about CDM at: The Clean Development Mechanism | UNFCCC

3.5.4 Actions and activities

The technology action plan's objective is to overcomes the barriers identified above and provide a set of actions to develop the waste heat recovery in the cement industry in Iraq. To reach this goal, a set of actions and activities must be taken at different level and within different timeline. Table 8 present the actions and activities identified for Iraq and validated with the stakeholders.

Table 8: Waste Heat Recovery technology action plan

Short Term (< 2 years)	Medium Term (2 to 5 years)	Long Term (> 5 years)
1. Adopt an enabling legal framework o Develop a roadmap for WHR deployment in Iraq with a clear timeframe 2. Adopt national energy standards for the cement industry o Set a baseline for energy consumption in cement industry based on local conditions and international best practices 3. Facilitate WHR evaluation o Incorporate the missing data for WHR evaluation into the available environmental database o Provide a tool for preliminary assessment of WHR system o Develop industry expertise for in-depth evaluation of the heat recovery sources 4. Develop the local WHR manufacturing o Promote partnership between international and local mechanical industries, academic institutions and Ministries 5. Launch pilot projects o Implement pilot projects and disseminate their results 6. Facilitate investment in energy efficiency	1. Adopt an enabling legal framework o Transform the NDC document and WHR roadmap into concrete regulations/laws o Encourage regular energy audits for the cement industry 2. Adopt national energy standards for the cement industry o Set a standard for WHR systems in the industrial sector 3. Facilitate investment in energy efficiency o Build a financing mechanism, based on example of the Central Bank initiative 4. Implement pilot projects o Implement pilot projects started at the earlier stage and disseminate their results	1. Adopt an enabling legal framework o Facilitate the connection to the national grid in case of surplus power generated from waste heat and pressure 2. Adjust the fuel tariff o Develop a subsides reform for fossil fuels power generation leading to a gradual phase out of subsidies 3. Facilitate investment in energy efficiency o Develop a carbon market/tax

Short Term (< 2 years)	Medium Term (2 to 5 years)	Long Term (> 5 years)
○ Present/Test out new business model like design–bid–build (DBB) and build–operate–transfer (BOT) in pilot projects 7. Spread awareness ○ Deliver focused training for the cement industry stakeholders ○ Disseminate local projects results		

3.5.5 Stakeholders and management planning

Cement industry is niche sector with few big players present. Therefore, stakeholders' involvement is limited to key actors. Ministry of Industry is the main actor in the deployment of waste heat recovery in Iraq, given the size and significance of the national cement company. MoI is responsible for both governing and implementation of technology action plan at the same time. The Ministry has a regulatory duty to develop a roadmap, as well as laws and regulations for the use of energy efficient solutions. It can in addition develop and show case some pilot projects within the public company, to support the private sector in adoption of the waste heat recovery technology.

The other key institution is Cement Producers Association in Iraq (CPAI). The association, which includes many cement producers, has the potential to be the focal point for coordination with different stakeholders. CPAI can also leverage WHR within its members. The coordination between the Ministry of Industry and CPAI is essential for knowledge sharing, results dissemination, and capacity building.

Both CPAI and MoI could leverage the expertise existing in the country, and collaborate with both the Ministry of Higher education and Scientific Research and the Ministry of Science and Technology, to customise the technology to the local need, as well as develop the tools needed by the stakeholders to evaluate the potential of heat recovery in the cement industry and other sectors in the future.

International technology suppliers are also an important stakeholder group, as the local market cannot currently supply WHR systems. The connection can be through both the MoI and CPAI. The role of international players is not limited to technology transfer, but could also include capacity building on WHR evaluation, design, installation, operation, and maintenance, as well as data management.

Financial institutions also have a key role, as WHR projects require high capital investment. Iraq's Central Bank and commercial banks can provide financing for the implementation of identified projects. Cement producers can also reach out to international donors and specifically apply for climate finance instruments (see section 8, for more information).

WHR recovery projects require several months to be implemented. However, a set of steps can be done in the short term, presented in the previous section, to lay down an enabling environment for WHR deployment. In the long term, the deployment of WHR can be extended across the different energy-intensive industries, and not limited to the cement factories alone. Plus, the technology can also be deployed across agriculture and smaller industrial sectors, where more modest amount of heat exists.

3.6 Project ideas for the industry sector

3.6.1 General project inputs

This section presents reference parameters related to Waste Heat recovery technology. These parameters are used to assess the cost, mitigation potential and potential for any project idea that can be proposed in Iraq.

Table 9: Waste heat recovery technology project design parameters

Technology	Waste Heat Recovery
Application Potential in Iraq (MW)	120 to 150[20]
Mitigation Potential (kg CO2/MWh)	18 to 25 [21]

[20] Carbon Limits conservative calculation based on Figure 4 and Iraq cement production capacity.
[21] Carbon Limits calculations, based on the CO_2 emissions from natural gas for energy generation.

Cost (USD/kWe)	2000 to 7000[22]
Annual Operational Cost (% of the capital costs)	2.5
Economic Lifetime	25 years
Scalability potential	Cement Industry, And possibility for scaling up into other industries
Supplier[23]	Kawasaki Plant Systems (Japan) CITIC Heavy Industries Co. (China) Transparent Energy Systems Private Limited (India) FLSmidth (Denmark) ORMAT (USA) Wasabi Energy (Australia)

3.6.2 Project idea: Mass Cement company waste heat recovery system

This section presents a success project for waste heat recovery in cement industry in Iraq. The project was implemented by Mass cement factory. The factory is established in 2008 in Kurdistan region. It consists of three lines of production with a capacity of two million tonnes each. The plant produces ordinary Portland cement, sulphate resistance cement and high fine grain Portland cement. The plant has recently implemented a waste heat recovery project, which the information is presented in Table 10 below. This information can be used for planning of potential new WHR projects in the industry, building on its lessons learned.

Table 10: Mass Cement company waste heat recovery – project concept example

Project Idea			
Type	Project	Sector	Industry - Cement
Project rationale, objectives, and approach	Cement industry is widespread across the different regions in Iraq. There are more than 12 producers in the market, including Iraq public cement company from the public sector. The industry relies on fossils fuel as the main energy source, as the national grid is not reliable. In this context, cement producers search to reduce their reliance on fossils fuels, to secure a reliable energy source and reduce emissions at the same time.		
Context and baseline	Cement production is an energy-intensive process. The chemical reactions to produce the clinker, cement raw material, require temperatures up to 1350°C. This process usually results in exhaust gases at high temperatures, which can reach 500°C in certain case. At the current stage, most of Iraq cement plants do not utilise the heat lost, and exhaust gases are directly emitted to the atmosphere, which represents a waste of valuable energy resource.		
Project/Programme description	Mass cement company in Northern Iraq, Kurdistan region, has commissioned in late 2021, their first WHR unit. The system is used to recover the heat from exhaust gas and redirect it to a steam turbine for power generation. Exhaust heat is recovered through two set of boilers installed in the system. The air quenching cooler boilers, handling the clinker exhaust gas at 400°C and the		

[22] (IFC, 2014)
[23] (IFC, 2014)

	Suspension preheater boilers used for preheater of the cement lines at 304ºC. The heat is then injected into a closed steam cycle. Steam generated in the boilers enters the steam turbine, at 285ºC and 11.7 bar, to produce electricity. At the turbine outlet, the water is directed to a condenser, for purification and cooling before being injected again in the boiler. The installed turbine has a capacity of 25 MW.		
Result Areas	Mitigation: • WHR system increased the energy production efficiency from 34% to 60% • Provide low-cost energy to the plant • Reduce GHG emissions from the factory and carbon footprint of the produced products		
Estimated mitigation impact	High	Estimated adaptation impact (number of direct beneficiaries and % of population)	Not applicable
Indicative total project cost	Confidential		
Payback Period (years)	Confidential	Estimated project/ Programme lifespan (years)	25
Expected project results	The project will help Mass cement plant to reduce its energy bill. This will be reflected in a cheaper production cost and more competitive product in the market. At the same time, emissions reduction, decrease the carbon footprint of produced cement, achieving a low carbon product compatible for exportations, if needed.		
Sustainability and replicability of the project (exit strategy)	The success of WHR in this application can be extended to similar cement plants in Iraq. At the same time, the technology is not limited to the cement industry, it can be replicated to all industry with wasted heat. Different unit sizes should be introduced to the market to cover the application of small and medium industries as well, like food and beverages.		

4 Oil and Gas sector

4.1 Sector overview

Iraq's oil and gas sector is the backbone of the country's economy. The sector generated 87 million USD of revenues in 2019 and accounted for 91% of the total governmental revenues in 2018 (EIA, 2021b). The country produced 4.1 million barrels of oil per day in 2021, ranking as the second largest producer in the Organization of the Petroleum Exporting Countries (OPEC), only behind Saudi Arabia. It also holds the world's fifth-largest proved oil reserves at 145,000 million barrels (BP, 2021).

In terms of natural gas, Iraq production is in deficit, as it produces 378,000 million standard cubic feet (MMscf) and consumes 636,000 MMscf, mainly for electricity generation. Two thirds of Iraq's natural gas come from the associated gas in super giant oil fields in the south of the country. Unfortunately, around 630,000 MMscf of the associated gas was still flared in 2021, making Iraq the largest flaring country behind Russia (The World Bank, 2022). Both the absolute amount of gas flared, as well as the flaring intensity (amount of gas flared per unit of oil produced) have remained rather stable over the past 5 years in Iraq.

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 elsewhere in the economy for productive purposes for example, power generation or transport. Hence the focus of the mitigation technologies within the oil and gas sector are on the latter category of emissions.

4.2 Preliminary target

While looking to diversify its economy, Iraq relies on its oil and gas sector to finance the development of other sectors. Therefore, the country aims to further develop and upgrade its oil and gas order to meet international standards, including those related to environment. National documents include several goals to increase capacity for oil production up to 6.5 million bpd, increase export and refining capacity. For natural gas, Iraq is looking to be self-sufficient, through increasing its proven gas reserves, boosting production capacity to 3,500 MMscf/d and utilizing the majority of its associated petroleum gas (APG) (Ministry of Planning, 2018).

The development of the sector is foreseen in a sustainable manner, with a great focus on reducing GHG emissions from the oil and gas sector. Iraq aims to reduce gas flaring and increase APG utilisation rate. Several specific technologies and practices are considered in the country's NDC, for example leak detection and repair (LDAR) to reduce direct methane leakage to the atmosphere, and Carbon Capture and Storage (CCS) (*Iraq NDC*, 2021).

4.3 Barrier analysis at the sector level

The structural challenge in Iraq starts with the framework conditions, within International Oil Companies (IOCs) contracts and the government. Under the technical service contracts (TSCs), IOCs shall finance the construction of gas handling facilities and will have the costs reimbursed (with interest). The taxes and fees, customs exemptions, and incentives are case-specific, each contract has its own conditions, rules, and concessions. The owner of the facilities will be a relevant Iraqi state-owned company which, in most cases, will also operate the gas handling facility. The incentives for the IOCs to actively pursue associated gas utilisation are limited. In addition, unclear requirements presented in the contracts, for instance, "flaring should be kept to an absolute minimum", without any supporting regulation to define this minimum, serve as an additional barrier to reduce resource waste.

The current internal gas price in Iraq is very low, and often the revenue stream from raw gas sales alone will not be sufficient to make the case financially viable for a potential investor. In addition, there is no preferential treatment of associated versus non-associated gas supplies when it comes to market access and price. This adds an economic barrier to APG utilization in the country.

The aging infrastructure is also one of the barriers for the sector's development. Upgraded processing and refining equipment, as well as transportation infrastructure can help increase the production capacity and align the quality of products with international standards.

4.4 Enabling framework for the Oil and Gas sector

The government through its different national plans has pledged to develop the sector and to lower the resulting GHG emissions, which incentivizes the government to provide financial support, update the regulations in place and raise awareness among its personnel to achieve the defined targets. The Ministry of Oil (MoO) is deploying several environmental training workshops, to spread awareness on the different types of pollutants/emissions and mitigation measures. In addition, the international commitments, like Zero Routine Flaring initiative or the Global Methane Pledge, to both of which Iraq is a signatory[24], are demonstrating the government's determination to find solutions to the issues within the sector.

Another enabler is the presence of highly experienced international oil companies (IOCs), helping provide technology transfer, capacity building for local manpower, and provide investment for future gas capture and utilisation projects. The accumulated experience available in Iraq, through the sector history, helps overcomes technical challenges.

The MoO presents in its plans economic and environmental targets, including utilization of associated gas, dry gas production and other type of fuels and materials. The implementation will be awarded to specialized IOCs and based on the Ministry's database of the associated gas production, utilization and flaring quantities.

4.5 Action plan for vapor recovery units (VRU) for oil storage tanks

4.5.1 General description

Vapour recovery units for crude oil storage tanks can be a powerful means to address climate change mitigation in the near term. Methane is a highly potent greenhouse gas with an ability to trap heat in the atmosphere is 84 times higher than CO_2 over a 20-year horizon. Recent research shows that human-induced methane emissions are responsible for at least one fourth of the global warming we experience today (Saunier & Haugland, 2021).

Vapour, consisting of methane and non-methane volatile organic compounds (VOCs) and other hazardous air pollutants (HAPs, such as benzene, toluene, and hydrogen sulphide), is released from liquid hydrocarbon products during storage and loading due to three different mechanisms: (i) flashing losses, (ii) working losses, and (iii) breathing losses, also known as standing or storage losses. Flashing losses occur when, for example, crude oil or condensate is exposed to temperature increases or pressure decreases during the transfer from production separators or heater equipment into an atmospheric storage tank. While stored, liquid hydrocarbons will continue to evaporate when fluid levels change or tank contents are agitated (working losses), typically during the loading and discharging of the tank. Breathing losses are caused by changes in ambient temperature and barometric pressure, resulting in expansion and contraction of the vapour space.[25] Emissions from storage tanks depend on the status of the tanks, at their highest when the

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[24] Zero Routine Flaring initiative: https://www.worldbank.org/en/programs/zero-routine-flaring-by-2030/endorsers, Global Methane Pledge: https://www.globalmethanepledge.org/#pledges

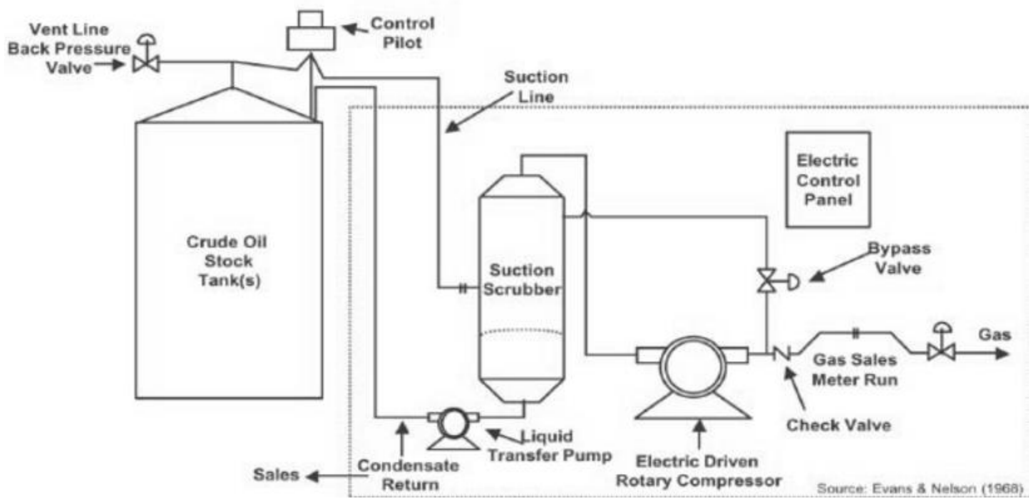
[25] The vapour release rate and composition from a storage tank or loading of a hydrocarbon product will vary over time and depend on fluid characteristics, facility design, and operational characteristics. Hydrocarbon vapour is often mixed with inert gases present in the tank (e.g., nitrogen and carbon dioxide), and the composition of the resultant gas mixture can vary considerably. The average share of methane can range from <1 Mol % up to >60 Mol % (with nmVOCs, HAPs, and inert gases making up the remainder), and can vary considerably over time, for example, during the loading period of a floating production, storage, and offloading units (FPSO) using inert gas as blanket gas. It is relatively common to vent to the atmosphere methane and nmVOCs emitted during storage and loading. It should be noted that the amount of methane vented through storage and loading operations upstream can be very limited in many instances and is highly dependent on the production process (e.g., the vapour pressure of the hydrocarbon liquid being stored).

tank is being filled and at their lowest (zero) when the tank is empty. When the tank is full, some remaining vapour is emitted mainly through evaporation.

A vapor recovery unit (VRU) can be installed to mitigate these emissions. Figure 6 illustrates a VRU installed on a single crude oil storage tank (multiple tank installations are also common). The VRU unit recovers the hydrocarbon vapor, which contains methane and other non-methane VOCs, at low pressure (around 2 PSI). The gas is then directed, to the suction scrubber, for purification. The separated liquid is pumped back to the storage tank, while the gases are compressed, metered, and supplied for the different end-use.

The compressor has two roles, it increases the gases pressure to be supplied to their destination and provides a low-pressure suction on the top of the storage tank, for the unit to ensure the vapor flow to the VRU. The units are equipped with control system to permit a back flow of the vapor to the storage tank, when oil level drops, to avoid vacuum. Control systems are sensitive equipment in the VRU application, as they have to operate at a very low-pressure difference, thus they must be very reliable[26](EPA, 2006).

Figure 6: Standard Stock Tank Vapour Recovery System (EPA, 2006)



Although vapour recovery system is a mature technology, a number of technical and economic considerations should be taken into account:

Technical

- Correct compressor selection in terms of type and sizing is key to handle the gas with uncommon compositions
- Pressure sensing and control system design is central to performance of VRUs, as the design is dependent on a functioning on/off state based on the pressure of vapours coming from storage tank vapor space
- Extreme variations in vapour pressure could lead to failure in VRU functioning

Economic

- The economic prospects of the project are sensitive to the amount of vapour to be recovered. Thus an accurate estimation of expected vents, including potential variations is required to mitigate the risks.

[26] More information on VRUs is available at:
http://www.gardnerdenver.com/; https://hy-bon.com/products/vru/; http://www.caltec.com/; http://platinumcontrol.com/

- The savings from condensate recovery compose the majority of the total prospective project revenues over the project lifetime. Therefore, it is important that a detailed compositional analysis of the vapours is carried out to confirm this figure.

It is thus very important to select a trusted technology partner, with significant experience in design, installation and operation of VRU systems, when implementing early VRU projects in Iraq. In addition, a through preparation for the project implementation, including quantification of vapours and analysis of their composition is needed in order to minimize economic risks during implementation.

4.5.2 Ambition for technology transfer and diffusion

VRUs can play an important role in reducing the sector's volatile organic compound (VOC) emissions, including methane and other non-methane VOCs. These emissions are known to not only be detrimental for the environment, but to also create safety hazards and lead to adverse health impacts[27]. In addition, the vapours from crude oil storage tanks are typically very rich and can be an important source of fuel – the natural gas liquids (NGLs) and gas separated from the vapours can be then reinjected into the gas transmission grid, or used for energy purposes on site. According to the IEA's Methane Tracker, 1 485 kt of methane is vented[28] every year during oil and gas operations in Iraq. Although these estimates rely solely on publicly available data and international emission factors, which makes them very uncertain, they indicate an extremely high potential for action on methane emissions in Iraq, which, in turn, can lead to significant climate mitigation in the short term. The IEA estimates that onshore VRUs for crude oil storage tanks can mitigate up to 1 165 kt of emissions, approximatively 80 % of methane vented from onshore oil fields, equivalent to 688 million cubic metres of natural gas. Of the VRU mitigation options, 87 % can be abated at a negative cost, which means that the resulting savings of vapour, which can be turned into additional revenue source, exceed the required investment and maintenance of the VRU infrastructure. Alongside other methane mitigation measures, this can help reduce the gap between natural gas demand and production in Iraq (IEA, 2022a). It should be noted that highest emission mitigation potential for VRUs present those storage tanks that contain unstabilized oil and are not equipped with a floating roof or a nitrogen blanket.

4.5.3 Barrier analysis and enabling measures

Identified barriers for this technology were based on the analysis of the national documents, as well as Carbon Limits' previous experience and communications with several NOCs and IOCs working in Iraq, as well as other international experience. It should be noted that methane emissions are a persistent problem of the oil and gas sector around the world and a large number of companies and countries are still early on in their methane mitigation journeys. The success stories of individual governments, as well as companies show that there are a number of ways to deal with this issue – through targeted regulations, appropriate financial incentive mechanisms, and others. The list of barriers was then validated with oil and gas representatives, and the Ministry of Oil. The results are presented below.

Table 11: Vapor recovery units' barriers and enabling framework in Iraq

Type	Barrier	Enabling Framework

[27] https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality

[28] According to IEA's definition, **vented** methane emissions are the result of intentional releases, often for safety reasons, due to the design of the facility or equipment (e.g. pneumatic controllers) or operational requirements (e.g. venting a pipeline for inspection and maintenance). In addition to methane emissions from venting, there are also unintended emission **leaks**, which occur due to aging infrastructure, improper maintenance, etc (for example, can result in faulty seal or leaking valve).

Regulatory	Absence of an action plan for the deployment of VRU for oil storage tanks in the oil and gas sector	Enact action plan for the deployment of VRUs within the different NOCs
	Lack of regulatory framework tackling direct methane emissions (both from venting and leaks)	Update the available regulations to include clear policies for methane mitigation (for example, consider including technical specifications for crude oil storage tanks to include a mitigation mechanism – floating roof, VRU, other) Set targets for methane reduction
	No methane measurement requirements	Enforce periodic LDAR that can help quantify the issue and help plan for mitigation
Financial	There are no taxes, or charges on venting emissions	Consider imposing taxes on avoidable venting from oil and gas facilities
	No emissions trading scheme or certified reduction	Develop an emissions trading scheme for CO_2 emissions[29]
	Despite the positive economic value of the technology (i.e. revenues from saved vapours exceed costs), it requires high capital costs	Assign part of the environmental budget within the Ministry of oil for VRU deployment
	Absence of loans/ grants from other parties	Explore other financing possibility through private banks and others international donors Create a plan for financing of climate mitigation projects from the oil and gas sector
Technical	No accurate estimates of emissions from oil storage tanks	Train the local NOCs and Ministry teams about methane emissions quantifications, including from oil storage tanks Develop a Tier 3 GHG inventory for the different facilities in Iraq
	Availability of service providers for measurement of methane emissions	Coordinate with IOCs for collaboration over LDAR technologies

[29] Methane emissions are typically not included in the national crediting mechanisms, as their quantification is often challenges and available emission estimates are highly uncertain.

		Equip the NOCs with LDAR equipment where possible
	Absence of venting and equipment standards	Develop a limit for emissions from storage tanks
	Absence of guidelines for the assessment and evaluation of VRU Technology Technical expertise to design the VRU system	Develop guidelines for the evaluation of VRU based on Iraq national conditions Conduct training for the employees at different NOCs
	Limited expertise for local manufacturing	Promote collaboration of international suppliers with local manufacturers
	Emissions variability / Methane content variability	Implement pilot projects with international technology providers to verify assumptions about methane content and build capacity about the VRU technology
	Efficiency of the system / VRU control system reliability	Ensure well-designed systems for the selected case through cooperation with trusted technology providers

4.5.4 Actions and activities

The technology action plan's objective is to overcomes the barriers identified above and provide a set of actions to deploy vapor recovery units for oil storage tanks in the oil and gas sector in Iraq. To reach this goal, a set of actions and activities must be taken at different level and within different timeline. Table 12 present the actions and activities identified for Iraq and validated with the stakeholders.

Table 12: Vapor recovery unit technology action plan

Short Term (< 2 years)	Medium Term (2 to 5 years)	Long Term (> 5 years)
1. **Capacity building:** o Promote expertise exchange related to VRU between IOCs and NOCs working in Iraq o Provide guidelines for the VRU design, installation, operation, and maintenance o Integration of environmental topics in the education curricula by the Ministry of Higher Education and Scientific research 2. **Provide a supporting financial environment:** o Clarify and promote the financing of VRU through the environmental budget allocated within the Ministry of Oil o Launch collaboration with private banks for private financing of environmental solutions o Provide a free open financial simulation tool for the VRU 3. **Build a national database of the emissions:** o Launch a methane measurement campaign in different regions of the country o Improve the national inventory using Tier 3 method 4. **Pilot projects and awareness:** o Launch pilot projects in different regions in Iraq and document the results 5. **Develop local production:**	1. **Capacity building:** o Build specialised teams / service provider for LDAR and menthane monitoring and mitigation within the NOCs 2. **Update the national regulations:** o Create a deployment plan and targets for VRU in Iraq o Enact methane regulations including setting targets for methane emissions and selecting instruments for methane mitigation (for example, consider including technical specifications for crude oil storage tanks to include a mitigation mechanism – floating roof, VRU, other) 3. **Provide a supporting financial environment:** o Simplify the contractual framework for IOCs to help with VRU and other gas capture technology deployment 4. **Build a national database of the emissions:** o Create projects database to keep track of all emission reduction	1. **Provide a promoting financial environment for the use of captured gas:** a. Develop a subsides reform for fossil fuels power generation leading to a gradual phase-out of subsidies b.

Short Term (< 2 years)	Medium Term (2 to 5 years)	Long Term (> 5 years)
○ Initiate a collaboration with the Ministry of Industry and Minerals for to analyse potential for developing local manufacturing of VRU units		

4.5.5 Stakeholders and management planning

The key stakeholder for this technology deployment is the Ministry of Oil (MoO), as well as associated National Oil Companies which report directly to the MoO[30]. These companies are responsible for the majority of oil production in the company, as well as refining and transportation of petroleum products, thus, a lot of the crude oil storage capacity (storage tank farms, where VRUs can be installed) are located at their facilities. The MoO will lead the process of implementing the actions and activities outlined above, involving other stakeholders, as required. The IOCs working in Iraq, have significant experience in deploying VRU units within their activities worldwide. The cooperation between IOCs and NOCs can help transfer this know-how between the companies and help facilitate VRU deployment in Iraq. The knowledge transfer can be initiated by sharing some of the standards and guidelines related to VRUs, and pursued at several levels, from system design to implementation, and operations and maintenance of the system. International technology providers can help develop specific concept solutions for the field operators, perform feasibility studies and finally install and operate (if needed) the VRUs. There are no local technology providers able to provide such solutions to the operators.

Capacity building and project development must be also complemented by national regulations and laws to encourage, and sometimes enforce gas utilisation. Different types of regulations can be adopted based on their suitability for the sector and the regulator capacities to enforce these regulations. Performance-based regulations, where the government sets a target for the emissions and provides some flexibility to the operator to select the best mitigations options to achieve this target. This kind of regulation is easy to monitor and follow-up from the regulator point of view. Prescriptive regulation, on the other side, sets a technical requirement at component level, for example, a flaring efficiency higher than 98%. A combination of both regulations can also be adopted within the same jurisdiction. The International Energy Agency (IEA) has developed a methane regulation database, that can be a starting point to review available policies worldwide[31].

Finally, national and international financial institutions, including large funders, like the World Bank, may play a role in increasing gas utilization in Iraq through providing loans or other financing instruments as part of financing of these expensive solutions.

4.6 Action plan for associated gas for power generation

4.6.1 General description

Associated petroleum gas (APG) is a by-product of oil production, often considered economically irrelevant due to the relatively low quantity produced and its marginal value compared to oil. The most common solutions to remove this gas during the production process are to directly vent it into the atmosphere or to combust it using a flare. Of these two options, the latter is more preferrable both from health, safety and environmental perspective, as the main component of the APG is methane, which, as described in the chapter above, is a strong greenhouse gas responsible for a significant share of global warming, with adverse health impacts. Flaring involves converting methane to carbon dioxide, lowering the potential onsite danger and the climate impact of the emissions. It is, however, still a resource waste, as flaring does not utilize any of the energy potential contained in the APG. The best solution for APG is to capture the gas, process it (depending on the chemical composition of the APG), and utilize it for energy purposes either on site or in a centralized facility. The use of natural gas can include generation of electricity, production of liquids, chemicals, etc. Figure 7 and presents the landscape of mitigation options available for associated gas flaring. There are many solutions available, but the selection of individual one will depend on a large number of factors.

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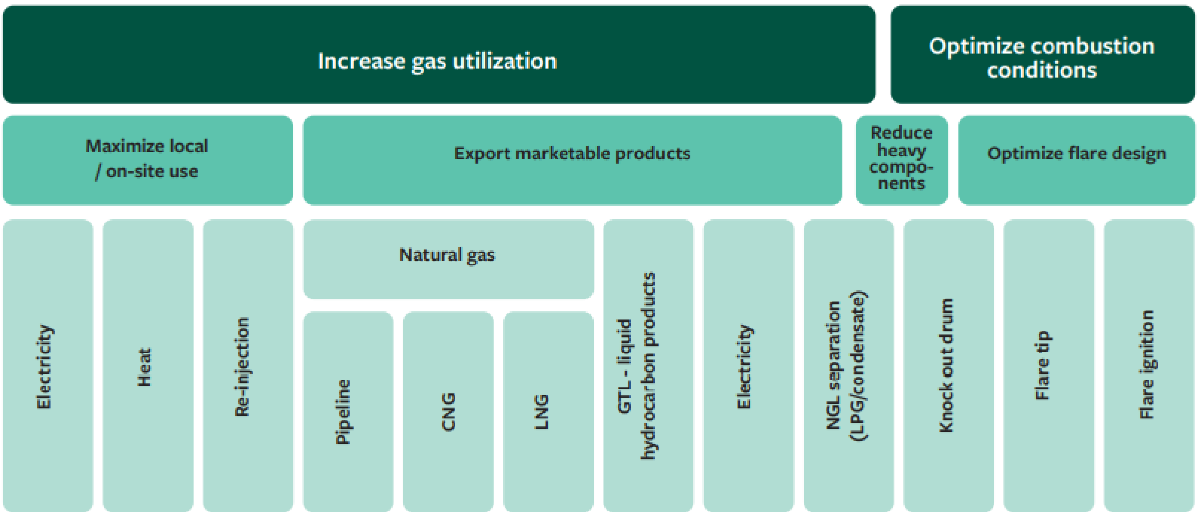
[30] These include: North Oil Company, Missan Oil Company, Midland Oil Company, Basra Oil Company (South Oil Company), Dhi Qar Oil Company, Iraqi Drilling Company, Oil Exploration Company, North Gas Company, North Gas Company, South Gas Company.

[31] Regulatory Toolkit – Driving Down Methane Leaks from the Oil and Gas Industry – Analysis - IEA

Figure 7: Overview of different ways of reducing associated gas flaring (Saunier et al., 2019)



The technology in question – gas-to-power – captures associated gas to use for heat and power generation either at the production site, as presented in Figure 8, or if the quantity exceeds on-site power needs, the gas can be transported via pipeline to nearby power plants, as shown in Figure 9. Although these solutions result in a similar final use of the gas, the required infrastructure and related costs can be rather different.

For both routes, prior to APG being used on-site or exported through pipeline to a centralized power plant, the gas must be gathered, processed and compressed[32]:

1. Flare gas gathering (and compression): This initial stage of gas recovery is required for any method of gas utilization that follows. In many cases, it is essential to gather scattered APG flare gas streams and cluster them centrally before treatment, compression, and export in order to achieve better economic feasibility. This step often represents a significant part of the overall project costs, particularly, if the flare locations are scattered and if the APG pressure is low and requires substantial compression.

2. Gas pre-treatment and conditioning: The associated gas always requires a certain degree of pre-treatment prior to being exported through infrastructure. This step removes impurities (e.g. H_2S, H_2O), but the level of treatment will depend upon site-specific conditions and specifications for the gas from the government. It should be noted that market specifications for natural gas are very strict in Iraq, so any gas that is supplied to the gas transmission system often needs to be treated further (see next step), which increases the costs of the project.

3. Separation of natural gas liquids (NGLs): As mentioned above, in order to be able to export the gas for any further use, including for power generation, the operator will need to further process the gas and, in particular, to remove the NGLs from dry gas. Separation will also allow for increased transportability of the dry gas. In case of on-site gas use for power generation, this step might not always be required (depending on the APG specifications).

After the gas is prepared for further use, it will need to be transported to the final user. For the technology described in this chapter, this will either be: (i) on-site power generation unit, or (ii) pipeline that leads to a

[32] This section is based on the report “Best available techniques economically achievable to address black carbon from gas flaring” prepared by Carbon Limits for a EU Action on Black Carbon in the Arctic project funded by the European Union: https://www.amap.no/documents/download/3827/inline

central power plant where gas will be used for power generation. In both cases a certain degree of pressurization is required, which will be dependent on the size of the pipeline, distance to be travelled, etc.

For the option including on-site power generation, additional equipment will be required – a small-scale gas turbine for energy generation. There are robust, heavy-duty internal combustion engines designed to run on APG and generate electrical power or combined heat and power (CHP) output. Available in unit sizes up to 30 megawatts (MW) and can achieve an electrical efficiency of above 45% (although with typical APG composition, efficiency is generally lower due to lower methane content), and under preferable circumstances can compete with gas turbines. Many gas engines can run on fuel with various gas composition, however, the typical nominal design point is the gas with at least 70–85% methane content (by volume). For many of the engines it could be possible to operate on gas with lower methane content, but performance malfunctions or reduced output can be expected (Darani, 2021). More information about this solution is available in a report prepared by Carbon Limits and Vygon Consulting for the World Bank.

Figure 8: Use of associated gas for onsite power generation scheme (Saunier et al., 2019)

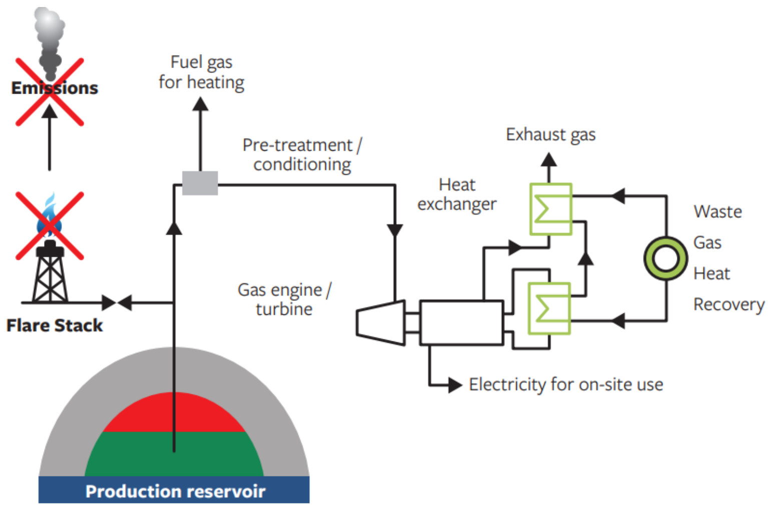
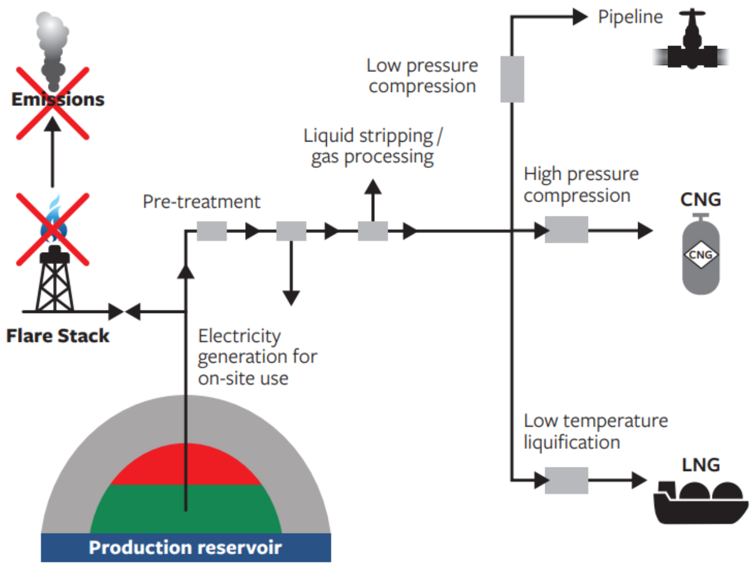


Figure 9: Transport of associated gas for other use scheme (Saunier et al., 2019)

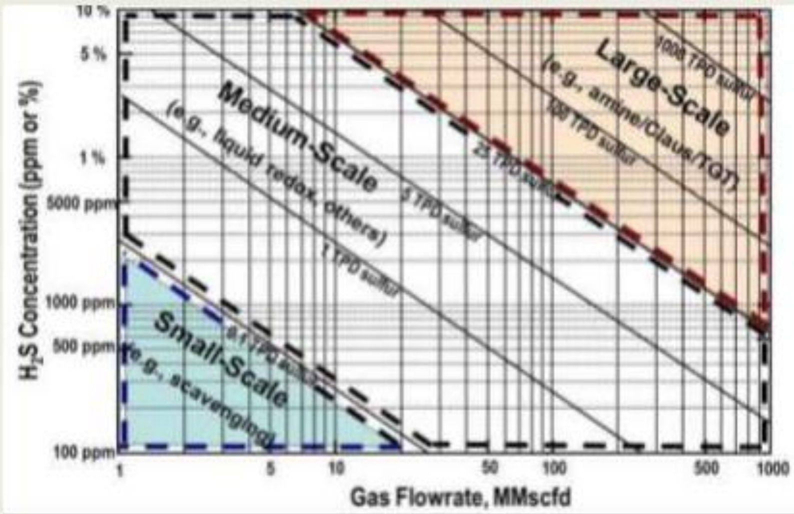


In the second option, gas is supplied to the national pipeline, and to power plants afterward. The supplier must treat the gas to comply with the pipeline specifications. This usually entails the installation of a gas processing unit, to adjust the concentrations of certain elements.
In case sulphur content in the associated gas produced is higher than the export requirement, a sulphur removal unit is required in the process to remove hydrogen sulphide (H_2S). Usually, gas supplier limits the concentration to 20 ppmv (GE Power Systems, 2002).

Information box 6: Sulphur removal unit[33]

The process to remove or scavenge hydrogen sulphide (H_2S) depends on the H_2S concentration and the gas flow rate. There are two main scavenging techniques:

- Injection of liquid H_2S scavenger (through oxidizing agents that react irreversibly with H_2S), normally injected in upstream surface facilities or in-plant gas streams. This method is relatively easy retrofit as it requires limited additional equipment. The drawback is the relative cost of the chemicals, and that this technology is limited to relatively low H_2S production.
- Solid bed H_2S scavengers, suited for moderate H2S production (100 kg / day). Solid bed scavengers process the gas separately from the oil in the crude separation plant downstream. The common approach uses filled pressure vessels in a "lead-lag" configuration to allow for the renewal of material in one bed while the other is in operation.



4.6.2 Ambition for technology transfer and diffusion

In 2021, around630,000 MMscf of gas was flared in Iraq with a total value exceeding 2 billion USD. This is in large part due to insufficient infrastructure to recover and transport APG from the production site. Two of the 12 largest detected flares globally (with a volume higher than 50 million cubic feet per day) are located in the country and are responsible for 10% of the total flared volume in the country. This quantity of energy loss could alternatively provide 360 terawatt-hours (TWh) of electricity[34]. Among the top 20 flaring countries, Iraq is ranked above average in terms of flare intensity (or amount of gas flared per unit of oil produced) - over twice as high as Russia and approximately four times higher than the USA. This implies that flaring can be substantially reduced through a limited number of large infrastructure investment schemes and/or

[33] Based on Carbon Limits previous communication with a number of technology providers (Frames, Honeywell, CECA, and Paqell).
[34] Carbon Limits calculation based on natural gas energy content.

through a clustered approach that allows for the utilisation of associated gas from different nearby fields (The World Bank, 2022).

At the same time, Iraq imported 857 MMscf per day of natural gas from Iran in 2019, equivalent to 312,000 MMscf per year (EIA, 2021b). As mentioned above, the gas flared in Iraq, if recovered, could instead provide 630,000 MMscf per year, approximatively double the actual import volume, thus transforming the national gas deficit into a surplus that can be exported, especially in times of high gas prices, as today. At a large flaring site, the gas recovered will usually exceed on-site energy needs, therefore also allowing any excess to be injected into the national gas pipeline or transported to a nearby power plant. For medium and small flares, gas gathering and processing at a common centralized facility (also knows as clustering approach) can be more suitable from the economic point view, providing larger gas quantities and economies of scale. However, higher capital cost might be needed to install the gathering pipeline network. Flared gas recovery is widely applicable technology to the Iraqi context, through an economic feasibility assessment on a case-by-case basis.

Utilization of associated gas is one of the MoO economic and environmental targets, therefore the Ministry has included in its current and future plans projects for associated gas utilisation and capacity building for its personnel regarded the environmental damage of associated gas emissions. The objective is to convert the associated gas into dry gas and other types of fuel. The dry gas will be mainly used to generate electricity at centralized power plants, at a subsidised rate. The Ministry already operates a database on the quantities of associated gas (produced, invested and burned). Based on these data, it will contract specialised IOCs.

4.6.3 Barrier analysis and enabling measures

Associated gas to power technology's barriers were based on the analysis of the national documents, as well as Carbon Limits previous experience and communications with several national oil companies and IOCs working in Iraq, as well as other international experience in the major oil and gas producing countries. The list of barriers was then validated with oil and gas representatives, and the Ministry of oil. The results are presented below.

Table 13: Associated gas to power barriers and enabling framework in Iraq

Type	Barrier	Enabling Framework
Regulatory		
	Very loose regulation when it comes to flaring stating that "routine flaring should be kept to a minimum"	Develop more clear and strict regulations concerning flaring, as well as a system for enforcement of this regulation
Financial	High investment cost	Launch collaboration with IOCs for the development of the oil and gas sector
	Absence of loans/ grants from other parties	Initiate other financing possibility through private banks and others international donors

	Very low gas price in the national market	Introduce a new tariff for the gas price, with low subsidies from the government
	Absence of carbon market	Develop a carbon market in the country
	Absence of taxes or charges on flaring	Introduce charges on routine flaring (or emissions related to such flaring)
Technical	High marketing specifications compared to international benchmark - Product quality requirements	Align the national specifications with best optimisation for health, quality, and utilisation of the associated gas
	Field layout: distribution of the flaring sites compared to the power demand	Incentivize on-site use, where possible Develop support for clustering approach that enables economies of scale through gathering of gas from several fields
	Gas exceeds site energy needs	Supply excess gas to the national pipeline to be transported to central power generation station
	Supply variability (variability in associated gas generation)	Promote clustering approach and gas gathering from different fields to reduce fluctuation of supply
	Absence of flaring standards	Develop standards for flaring and venting from oil and gas facilities

4.6.4 Actions and activities

The technology action plan's objective is to overcomes the barriers identified above and provide a set of actions to deploy associated gas to power technology in the oil and gas sector in Iraq. To reach this goal, a set of actions and activities must be taken at different level and within different timeline. Table belowTable 14 presents the actions and activities identified for Iraq and validated with the stakeholders.

Table 14: Associated gas to power technology action plan

Short Term (< 2 years)	Medium Term (2 to 5 years)	Long Term (> 5 years)
1. **Update national regulations:** a. Set targets for flaring reduction with a clear timeline, create measures for monitoring progress and address non-compliance 2. **Provide a promoting financial environment for the use of associated gas:** a. Clarify and promote the financing available through the environmental budget allocated within the Ministry of Oil b. Launch collaboration with private banks for private financing of environmental solutions 3. **Develop an accurate National inventory:** a. Assemble the database of associated gas specification and quantities to evaluate the possibility for investment (based on metering, where possible) b. Improve the national inventory using Tier 3 for GHG emissions 4. **Pilot Projects:** a. Launch pilot projects in the different regions in Iraq to prove the effectiveness of the technology and disseminate the results	1. **Update national regulations:** a. Review the national specifications of dry gas injected to the pipeline b. Include a clear regulation that limit flaring only for emergency cases c. Set requirements for a flaring permit in Iraq 2. **Provide a promoting financial environment for the use of associated gas:** a. Simplify the contractual framework for IOCs 3. **Optimise the infrastructure:** a. Develop a plan with gathering "hubs" for gas from nearby fields in each region 4. **Develop an accurate National inventory:** a. Create a project database to keep track of all emission reductions	2. **Provide a promoting financial environment for the use of associated gas:** a. Develop a subsides reform for fossil fuels power generation leading to a gradual phase-out of subsidies b. Develop a carbon market/tax

4.6.5 Stakeholders and management planning

The key stakeholder for this technology deployment is the Ministry of Oil (MoO), as well as associated National Oil Companies which report directly to the MoO[35]. These companies still operate a large number of fields where associated gas is not yet utilized due to various reasons – lack of infrastructure, declining production profiles, lack of financing, etc. The MoO will lead the process of implementing the actions and activities outlined above, involving other stakeholders, as required. In particular, an important role for wider use of associated gas to power is with international oil and gas companies (IOCs) that have not only already implemented some gas utilization projects in Iraq, but also have long experience with these issues in different areas of the world. They can provide technology transfer, know-how, technical expertise and capacity building to the local staff.

Another important stakeholder in the process to increase associated petroleum gas (APG) utilization through associated gas to power is the Ministry of Electricity, as the extra gas that will be captured and used for power generation will either be brought to existing power plants or used on-site in newly-built power generation units. In the second case, new connection to the national grid might be required, if the planned power generation unit will produce more electricity than is required on site. The Ministry will also need to coordinate natural gas needs at different existing power plants, so resources are distributed across the country.

International technology providers can help develop specific concept solutions for the field operators, perform feasibility studies and finally install and operate (if needed) the gas capture/processing units and gas turbines, will be required in order to implement this action plan, as there are no local technology providers able to provide such solutions to the operators.

Finally, national and international financial institutions, including large funders, like the World Bank, may play a role in increasing gas utilization in Iraq through providing loans or other financing instruments as part of financing of these expensive solutions.

4.7 Project ideas for the oil and gas sector

4.7.1 General project inputs

The tables below present some key information about the two technologies selected for the oil and gas sector. The information provided reflects generic values that will require further tailoring to specific cases in Iraq.

Table 15: Vapor recovery unit technology project design parameters

Technology	Vapor Recovery Unit
Application Potential in Iraq	All storage tanks containing unstabilized crude oil with fixed roof (High potential in Iraq)
Total Mitigation Potential in Iraq (thousand tonnes of methane)	1 165 (equivalent to over 29 Million tonnes of CO_{2eq} with global warming potential of 25 over 100 years horizon)[36]
Cost (kUSD/ tank farm)	200 to 1 000[37]

[35] These include: North Oil Company, Missan Oil Company, Midland Oil Company, Basra Oil Company (South Oil Company), Dhi Qar Oil Company, Iraqi Drilling Company, Oil Exploration Company, North Gas Company, North Gas Company, South Gas Company.
[36] (IEA, 2022b)
[37] The CAPEX estimate is extremely sensitive to the outlet pressure requirement; thus, a tie-in point with lower pressure would reduce the compressor size and therefore the Capex significantly. The cost presented is indicative only and based on Carbon Limits' experience in other countries

Annual Operational Cost (USD)	≈1%[38]
Economic Lifetime	15
Scalability Potential	The entire oil and gas sector in Iraq
Supplier	- Cimarron (USA) - Pioneer Engineer (USA) - Alma Group (France) - Cool Sorption (Denmark) - S&S technical (USA) - Flogistix (USA)

Table 16: Associated gas to power project design parameters[39]

Technology	Associated Gas to Power
Application Potential in Iraq	Majority of the oil fields with associated gas production. Different user cases can be envisaged: 1. Large oil fields connected to the gas transmission infrastructure – APG is processed on site and exported to pipeline to be used for power generation 2. Several medium-/small-scale oil fields located close to each other – cluster approach where APG will be gathered and processed centrally and then delivered to a pipeline for further use in power generation 3. Small oil fields where APG will be used for on-site power/heat generation With over 17 bcm of gas flared in Iraq annually (The World Bank, 2022), there is significant potential for each of these models to be deployed in Iraq. From economic perspective, the focus should be first and foremost on the large flares located close to existing infrastructure, which will help minimize the costs of gas transportation and maximize the economies of scale.
Mitigation Potential	Gas utilization through gas-to-power application significantly reduces emissions of CO2, particulate matter – PM, SOx, and heavy metals. The scale of emission reductions will depend on the gas composition and the amount of processing/transport that will be required for the gas to be delivered to final user. A typical gas utilization project can expect to reduce about 2,500-3,500 tonnes CO2 per million m3 of APG utilized. These values will,

[38] Based on Carbon Limits previous projects.
[39] See the following links for further information:
- On large-scale gas processing and export technologies: LNG Export, CNG, Re-Exports and Long-Term Natural Gas Applications
- APG Utilization Overview
- On-site gas use: Industrial Gas Turbine Utilization with Associated Gases
- Associated Gas Utilisation using Gas Turbine Engine Performance Implication
- Power Generation using Associated Gas

	however, vary a lot based on the specific gas composition, possible impurities, distance to market, etc.
Investment Cost (USD/MMscfd)	0.3-2.5 million USD/MMscfd[40] This would include: - Gas pre-processing & conditioning equipment (depending on APG composition & impurities) - NGL separation infrastructure depending on gas market specifications - Compressors for pipeline - Piping & related infrastructure
Annual Operational Cost	3-5% of CAPEX
Economic Lifetime	20-25 years
Supplier	Aggreko, Aerogas, Air Liquide Engineering & Construction, Aspen Engineering Services, BINGO Interests, Expansion Energy, GazSurf, GTUIT, MTR, Nacelle, Pioneer Energy, Siemens, Wartsila

4.7.2 Project idea 1: VRU on crude oil storage tanks

The following section presents an example of a project idea for a typical crude oil storage tank farm. Further details, including more detailed economic assessment of the project concept can be provided when a specific site is selected, and more detailed technical characteristics of the storage tanks are included.

Table 17: VRU for a crude oil storage tank farm – project idea[41]

Project Idea			
Type	Project	Sector	Public – Oil and gas
Project rationale, objectives, and approach	The project aims at capturing vapours that are currently being vented directly into the atmosphere through an open hatch and or specialized valves in a fixed roof of crude oil storage tanks. The VRU is typically installed at a storage tank farm, which includes several storage tanks. After capturing the vapours, they are rerouted to a system which separates the gas from the condensate and both products can be used on-site or exported as separate products, if infrastructure allows.		
Context and baseline	This project type is applicable for unstabilized crude oil storage tanks farms, not equipped to minimize the venting of vapours that build up in a storage tank as part of normal operations (for example, does not have a floating roof or already installed VRU). Emissions from storage tanks depend on the status of the tanks: they are highest when the tank is being filled and are null when the tank is empty. When the tank is full some remaining vapour are emitted, mainly due to evaporation.		
Project/Programme description	The project includes installation of a VRU unit at a small storage tank farm (assuming 7-8 storage tanks pf 5,000 m3 each and a single VRU unit) The VRU system includes the following elements – recovery of the vapours, liquid removal,		

[40] (Saunier et al., 2019)
[41] The data presented in the case study is based on Carbon Limits' experience in other countries. An aggregated storage tank farm facility is presented with average characteristics. Kindly note that technical specifications and related costs of the equipment will highly depend on the facility selected, its mode of operations (how often the storage is being filled, etc), ambient temperatures, etc.

	compression. The solution excludes long piping to the gas processing facilities. Additional piping on some tanks may be needed.		
Result Areas	<u>Mitigation</u> - Reduced emissions of VOCs, including methane (significant climate mitigation, as well as local air quality improvements) - Additional energy generation from previously wasted resource		
Estimated mitigation impact (tCO2eq over lifespan)	84 000[42]	Estimated adaptation impact (number of direct beneficiaries and % of population)	Not applicable
Indicative investment cost	350 – 650 000 USD		
Payback Period (years)	2.5-5 years	Estimated project/ Programme lifespan (years)	15 years
Expected project results	The project will lead to reduction of emissions of volatile organic compounds (VOCs) from the storage tank farm – between 80% and 95% of emissions can be expected to be captured depending on the efficiency of the design. The vapours will then be separated into gas and condensate, both of which can be either used on site for energy purposes, or marketed as separate products. If there is no available infrastructure for marketing condensate, it can be blended back with oil.		
Engagement among the NDA, AE, and/or other relevant stakeholders in the country	The facility operator (either a national or international oil company) will be the lead project implementer. It could be important to involve the Ministry of Oil in selecting the appropriate candidate for the project in order to be able to monitor closely the results and disperse lessons learned to a broader stakeholder group. It is also important to involve a reliable technology provider with proven track record in installing and operating VRU. A site visit by the technology provider with specific measurement equipment (hi-flow sampler, portable gas chromatograph, portable flash analyzer) in order to assess site-specific potential for vapour recovery and properly design the VRU unit is highly recommended.		
Financing by components	The total costs of the system can be broken down into the following components: - Capital costs (CAPEX) of the VRU system, including the following design components: ✓ Compressor And Associated Equipment ✓ Electric Motor ✓ Scrubber ✓ Heat Exchanger ✓ Electric Controls ✓ Instruments Total CAPEX: 350 – 650 000 USD - Installation cost: 10% of CAPEX - Maintenance costs: 3% of CAPEX		
Sustainability and replicability of the project	Oil storage tanks are commonly used by the oil and gas sector in order to store crude oil and other petroleum products prior to delivering them to market. Many of the storage tanks are part of the older infrastructure, which does not include a		

[42] Assuming global warming potential of 28 for methane (over 100 years horizon), 35% methane content in the vapours and 80% efficiency of the VRU system.

	floating roof or already installed VRU, which would limit the amount of losses during filling of the tanks or when ambient conditions change. Thus, the potential for replicability of the project is very significant in Iraq. Although the estimate is very uncertain, the IEA[43] estimates that over 1,000,000 tonnes CH4 can be reduced from oil storage in Iraq.

Based on the description above, the following key features of the project can be highlighted again the GCF criteria:

GCF criteria	Key project features
Impact potential	- Over 1 million m3 of vapour previously vented is captured, equal to ≈200 tonnes CH4 (or around 6,000 tonnes CO2[44]) reduced per year through capture of vapours - All of the captured vapours contain VOCs that have detrimental health impacts
Paradigm shift	- A successful pilot project will open the space for more application of VRU units on crude oil storage tanks with a total emission reduction potential of >1 000 000 tonnes CH4 from oil storage - Capacity building of final users and the Ministy of Oil - Removal of barriers (including financial) through showcasing new business models and potential revenue streams from such ventures
Needs of recipient	- Energy savings are needed to narrow the gap between power production and consumption in Iraq - Project requires external co-financing to test out and demonstrate new business models
Country ownership	- Energy efficiency in the oil and gas sector, as well as focus on increased gas utilization are both a key priority to Iraq's government - Iraq is a signatory of the Global Methane Pledge, with ambition to contribute to methane mitigation, including from the oil and gas sector
Efficiency and effectiveness	- VRU is considered the best available technology for reducing emissions from crude oil storage tanks - Low abatement costs (depending on gas and condensate prices assumed, it can be between -5 and +10 USD/tonne CO2 reduced)
Sustainable development	- The project will help avoid 3,000 tonnes CH4 over its lifespan (assuming 15 years lifetime) - Additional energy from captured vapours that are separated into natural gas and condensate - Improved local air quality and health improvements

[43] IEA methane tracker 2022
[44] Assuming global warming potential of 28 for methane (over 100 years horizon), 35% methane content in the vapours and 80% efficiency of the VRU system. This represents a small storage tank farm with 7-8 storage tanks pf 5,000 m3 each and a single VRU unit.

Part II: Technology Action Plan for Adaptation

5 Agriculture Sector

5.1 Sector overview

The Iraqi agriculture sector employs roughly 20% of the country's workforce and is the second largest contributor to the gross domestic product (GDP) after the oil sector, accounting for 5% of the GDP. Thus, agriculture development is critical to allow Iraq to achieve their vision of a more diversified economy, in addition to generating employment and boosting private sector engagement. Approximately 22% (9.5 million ha) of Iraq is suitable for agriculture production, yet only about 5 million ha are currently cultivated (*Agricultural Value Chain Study in Iraq*, 2021).

If Iraq is to become more resilient towards food security, then agricultural change is required to enable continued (or even enhanced) levels of production given changes due to climate and impacts on access to water (e.g. see Figure 10). By far the largest crop (by yield) in Iraq comes from wheat (6.2 Million Tonnes produced in 2020) with the next largest crop being Barley (1.8 Million Tonnes in 2020) (see Figure 10 and (FAO, 2022)). Crop production is the major source of income for the majority (75 %) of farmers in Iraq (FAO 2021), while the rest depend on livestock or mixed crop and livestock enterprises (Lucani, 2011)

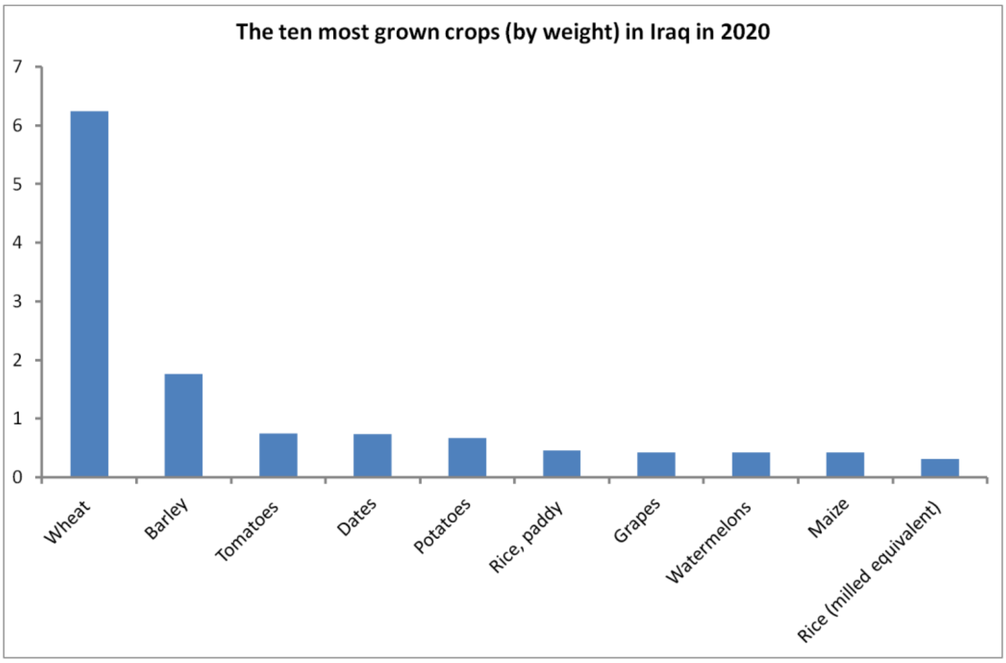
The two major focal areas for the agricultural action in Iraq were identified in the Technology Needs Assessment as 'Agricultural Water Management' and 'Conservation-friendly Agriculture'. Discussions with representatives of the Ministries of Agriculture, Environment and Water highlighted the importance of water management for agriculture as the primary objective in this sector. Iraq is the fifth most vulnerable country in the world to extreme temperatures and water shortages, according to the UN Environment Programme (The Arab Weekly, 2022).

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, reduces water loss (e.g. via use of mulching) 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 5.2). The use of 'conservation-friendly agriculture' was explored in two workshops and consensus was reached in both that this technology was not one of the two highest priorities in the sector.

5.2 Preliminary targets

A key target for Iraq is to continue to produce large quantities of staple foods (notably wheat which is by far the largest crop – see Figure 10) under demands caused by climatic conditions (especially lack of water) and other key factors (e.g. decreasing water supply from non-negotiated upstream management in other countries).

Figure 10: FAO agricultural statistics for latest year available in 2020 (as accessed on 30.06.22) shows the ten largest crops grown in Iraq by weight (y-axis shows tonnes in millions)



More specifically targets to achieve food security are facilitated by commitments and targets for example: (i) an increase in the contribution of Agriculture to 5.2% of the GDP by 2022; (ii) a clear recognition of the relationship between water-food-energy-and environmental security; (iii) raise the area of irrigated land by 17%; (iv) an increase of agriculture density (product per unit area) to 115%; (v) a reduction in the production of rice which requires substantial water for irrigation will enable more water to be diverted to other produce/crops [Investment Map of Iraq (2021), (Ministry of Agriculture) & National Development Plan 2018-2022; National Development Plan 2018-2023; Iraq Vision for Sustainable Development 2030 (2019); INDCs (2018)].

5.3 Barrier analysis at the sector level

There are a range of barriers including cultural issues with genetically modified crops (GMCs), lack of infrastructure for water transportation and a variety of other issues which we outline in more detail below.

5.3.1 Cultural barriers for new technologies and practices (e.g. crop diversification, use of genetically modified varieties)

Issues associated with Agricultural Water Management could be partially addressed by the use of Genetically Modified crops. Public perception of GMO is strongly negative as it is perceived as 'unnatural'. Views expressed at the workshop on 7th July 2022 included: 'they have negative effects on human health' and 'they contradict the going back to nature solution concept'. Currently GM crops cannot be legally grown in Iraq (see (ISAAA Inc, 2022)) and there is strong opposition to GM crops in Iraq (reported at stakeholder workshop on 07/07/22). Therefore, there are strong barriers to the use of GM crops in Iraq and it cannot be recommended as a viable option at the time of writing.

Table 18: Examples of non-GM varieties and GM varieties of example crops in Iraq

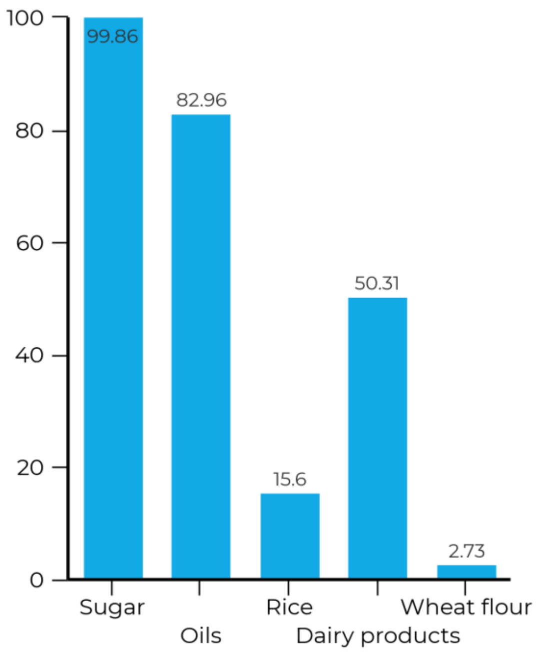
Crop	Drought resistant varieties in Iraq	Non-GM varieties	GM varieties
Maize	See (Oluwaranti & Ajani, 2016)	See (Castiglioni et al., 2008)	Nigerian crop: MON87460 exhibited an average yield benefit of 10.5% across four years of field trials (Castiglioni et al., 2008)
Wheat	New crop lines: Kalar1 and Kalar2 have been produced in Garmian region which are more productive (4.24 and 4.73 tonnes/hectare respectively) than local variety - Aras (2.83 tonnes/hectare) (Awtaq et al., 2021). However, the Garmian region is not wholly representative of the range of climates in Iraq. The 'Wafiyah' variety found to produce the highest yield when compared with 14 other varieties (see Al-Jiashi & Faisal 2020).	Crossing wild emmer wheat with bread wheat cv. Bar Nir produced a 59.3% higher yield in drought conditions (Merchuk-Ovnat et al., 2016)	EcoWheat ®, grown in Argentina increased yields by ~20% across ten years of field trials (Bioceres Crop Solutions Corp., 2020).
Barley	More drought tolerant varieties grown in Iraq have been identified: the germination rate of the drought tolerant ABN variety was 218% higher than the least drought tolerant variety identified (Black Garmiyan) (Lateef et al., 2021).	The reduction in grain yield for drought tolerant varieties (Cochise and Kopious) was double that of the drought resistant varieties (Solar and Solum) – 67.5% and 34.1% respectively (Carter et al., 2019).	Drought resistant genes have been identified in barley (Feng et al., 2020) however no GM drought tolerant barley varieties are available for commercial use
Dates	Dates are naturally drought resistant, limited research into making them more drought resistant...though drought is beginning to severely affect date palms		

5.3.2 Lack of infrastructure development and maintenance

5.3.3 The water and agriculture sectors are clearly linked already and with climate change these two sectors will become more strongly intertwined. 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 pollution ratio in irrigation water, low investments in water resource projects, and difficulties in controlling water reservoir and drainage through regulator dams. Other issues

FAO (2021) described how Iraq has transitioned from a being a smallholder-driven, food-producing country that can cover its needs to becoming a major food importer (see Figure 11). Several decades of sanctions, violent conflict, extreme weather events, water scarcity and competition from cheap imports, have disrupted value chains and distorted linkages between producers and markets. Furthermore, the so-called Islamic State of Iraq and the Levant (ISIL) crisis that began in 2014 spurred displacement of entire communities, limited access to inputs and markets and resulted in the targeted destruction of agricultural infrastructure by armed groups. The Ministry of Agriculture (MoA) estimates that Iraq lost approximately 40 percent of its agricultural production in the wake of the ISIL crisis, and the sector has yet to fully recover.

Figure 11: proportion of imports of key food stuffs into Iraq in 2015 (taken from National Strategy of Food Security in Iraq 2018)



5.4 Action plan for Agriculture water management – drought-resistant crop varieties

5.4.1 General description

Water management for agriculture is a key issue in Iraq given the rapidly changing climate leading to increasing temperatures and more erratic rainfall. No more than twenty per cent of irrigation water comes from groundwater sources in Iraq. Several key crops in Iraq require extensive irrigation (e.g. wheat and rice).

Whilst reducing the production area used of crops requiring substantial water to grow (e.g. rice) is proposed (in 2020 0.4 Million tonnes of rice were grown – FAO stats) 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 (e.g. see TNA report).

Agriculture in Iraq is associated with small-farming units (FAO Agriculture Sector Note 2011) 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 which can substantially increase yield (e.g. see Table 18). Drought-resistant crop varieties are those selected for their ability to withstand drought, for example: cultivars of wheat which are able to germinate and continue to grow under drought conditions (Al Azzawi et al., 2020).

5.4.2 Ambition for technology transfer and diffusion

Lack of water for agriculture is a limitation across Iraq and so technologies require implementation country-wide but there are regional differences (see below). Given the reliance on agriculture for many Iraqis this widespread approach is likely to yield co-benefits in terms of improvements in livelihoods for the rural poor. However, suitability in different regions is a key question and was addressed by FAO (2021) with the results set out below.

Broad targets of potential crops in different regions of Iraq were set out in the FAO (2021) report and are shown in Figure 12 below. The seven crops (shown in Figure 12) were analysed by FAO against the following six criteria that addressed economic, environmental, social and institutional issues:

- impact and relevance on the Small-Scale Farming System (SSFS);
- potential growth versus the unmet market demand as a clear indicator that the market should or will grow in the future;
- potential scaling up of target groups to participate in the value chain (in particular smallholder farmers);
- level of support that the public sector, the donor community, and other actors (i.e. NGOs, consulting companies and researchers) can or are providing to the subsector;
- environmental impact if the subsector grows after the interventions (in particular water availability, consumption, and related soil salinity); and
- role of the value chain in achieving food security and food sovereignty.

Based on the above criteria the FAO (2021) study selected wheat, tomatoes, grapes and dates as the most suitable to focus on in future with differences between potential suitability between regions shown in Figure 12.

Figure 12: Results of FAO (2021) multi-criteria decision analysis for seven crops in Iraq where each value chain was assessed as high, medium and low relevance/impact for four criteria in the three major agro-ecological zones: (1) Potential market growth and unmet demand; (2) Level of support available from

public, private, and non-governmental actors; (3) Environmental impact; (4) Contribution to food security and food sovereignty.

AREA	Wheat	Barley	Tomatoes	Potatoes	Grapes	Citrus	Dates
North	1. H	1. L	1. H	1. H	1. H	1. L	1. M
	2. H	2. M	2. H	2. H	2. H	2. L	2. L
	3. H	3. H	3. H	3. H	3. H	3. L	3. L
	4. H	4.M	4. H	4. H	4. H	4. L	4. L
Centre	1. H	1. L	1. H	1. M	1. M	1. H	1. H
	2. H	2. M	2. H	2. M	2. L	2. H	2. M
	3. H	3. H	3. H	3. M	3. L	3. H	3. M
	4. H	4. H	4. H	4. M	4. L	4. H	4. M
South	1. H	1. L	1. H	1. M	1. M	1. L	1. H
	2. H	2. M	2. H	2. M	2. L	2. L	2. H
	3. H	3. H	3. H	3. M	3. L	3. L	3. H
	4. H	4. M	4. H	4. M	4. L	4. L	4. H

5.4.3 Barrier analysis and enabling measures

Drought tolerant crops have been bred through conventional plant breeding techniques or biotechnology and continue to grow and produce even when rains fail. They've been around since the 20th century, but the last two decades have seen increases in drought tolerance research that targets staple crops like maize, rice and wheat (see (Ngumbi, 2019)).

There are some challenges involved, however. Breeding crops for drought tolerance takes time. On average, bringing new drought tolerant crops to market can take in the region of five years. Testing the seeds to accurately characterize the necessary traits can take many years and requires several locations. Another challenge is that significant investment is needed to breed drought tolerant crops and make them available to farmers.

5.4.4 Actions and activities

Broad actions: use of drought-resistant crops in Iraq requires cost-benefit analysis of the current varieties and the potential to use them in other localities versus development of new varieties. This needs to be done in conjunction with developments across the water sector.

Specific actions:

Capacity building in the use of appropriate technology to farmers (e.g. parameters under which drought-resistant crops can be grown) widely in pilot areas (north, middle and southern Iraq – see Based on the above criteria the FAO (2021) study selected wheat, tomatoes, grapes and dates as the most suitable to focus on in future with differences between potential suitability between regions shown in Figure 12.

- Figure 12 where dryland crops are prominent, through demonstrations, extension, research and training.
- 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.
- Evaluate adoption and impact of project technologies (e.g. early sowing) through socio-economic surveys and evaluation.
- Provide capacity development and training of Iraqi scientists.

- Undertake water footprint research across a range of crops in the agriculture sector.

Please see section 5.6 which provides details of project ideas.

5.4.5 Stakeholders and management planning

There are several entry points for close coordination and implementation. They include:

• the Ministries of Planning, Agriculture, Health, Environment, and Water Resources and FAO have established a multi-sectoral partnership for planning, implementation and monitoring for agriculture, water, and environment programmes and policies to improve coordination and outcomes for farmers;

• the Food Security and Emergency Livelihoods Humanitarian Clusters – and its members, and in particular the newly established Agricultural Working Group; and

• the Donor Coordination Group on Agriculture and Water – a forum where joint action can be considered supporting priority investment opportunities, closely coordinated with the Government of Iraq.

As the implementation expands, these core stakeholders can be progressively expanded upon to include NGOs, additional ministries such as the Ministry of Planning as well as the Ministry of Higher Education and Scientific Research, and relevant academic institutions. Provincial and local government will also become important stakeholders as the implementation progresses beyond national level.

The implementation time of the technology varies depending on the focus with some short term (e.g. rolling out of existing drought-resistant seeds) to medium/longer term (e.g. irrigation infrastructure; development of new drought-resistant cultivars).

See section 5.5.5 for how stakeholders can be involved in different stages of project development.

Drought-resistant crops are used nationwide in Iraq (as reported at workshop on 07/07/22), but they use mainly traditional irrigation methods. Some varieties have already been developed (e.g. see examples in Table 18). Therefore, infrastructure for development of improved, or new, varieties does exist. Examples of estimated costs are provided in section5.6.

Management of drought-resistant crop varieties will require a co-ordinated approach that weighs up the efficacy of different crop cultivars and also in different geographical locations to meet demand. The top-level of this approach is addressed by the Ministries of Planning, Agriculture, Health, Environment, and Water Resources and FAO multi-sectoral partnership for planning, implementation and monitoring for agriculture, water, and environment programmes and policies to improve coordination and outcomes for farmers. However, the key issue is the dissemination of this information to smaller administrative units and individual farmers.

5.5 Action plan use of conservation-friendly agriculture – drip feed irrigation

5.5.1 General description

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.

The water and nutrients are delivered across the field or through the protected crop structure via small diameter pipes which have drippers at regular intervals along their length. This technique is used in Iraq since the 1980s and it is currently widespread in the country (as reported in the workshop on 07/07/22).

Although the Ministry of Agriculture uses drip irrigation in its projects, most farmers still rely on conventional irrigation (as reported in the workshop on 07/07/22).

5.5.2 Ambition for technology transfer and diffusion

Lack of water for agriculture is a limitation across Iraq and so drip irrigation would be beneficial across the country in general.

5.5.3 Barrier analysis and enabling measures

With the agriculture sector being directly related to other sectors, such as the water sector (see section 0), failures within other sectors will have unavoidable repercussions on the former 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 (Idan and Hussein, 2021). The allocation of water for agriculture has been agreed to be reduced by 30% in 2035 despite the increased demand for irrigation.

Thus, the role of actions such as planting new crop composition that consume less water and raising the total irrigation efficiency using modern irrigation methods are crucial. 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.

The Iraqi Agrometeorological Centre has a significant weather station network that collects data on meteorological variables, and the focus of this data collection is for agricultural planning.

There is a requirement for a change in attitudes: a lack of awareness in Iraq of the magnitude of the climate change threat, along with the continuing use of age-old practices, are both factors limiting change.

5.5.4 Actions and activities

Specific actions:

- Quality control of the pipes used in drip irrigation
- Increasing farmer awareness on the use of the technology and best practice
- Capacity building for engineers and agriculture specialists
- Promote adoption of appropriate technology widely in pilot areas (north, middle and southern Iraq – see Figure 12) where dryland crops are prominent, through demonstrations, extension, research and training.
- Provide grant support to install "starter" drip and sprinkler irrigation systems for farmers operating small-scale farms and implement capacity building programmes across farming districts. The roll out would be envisaged at clusters of farms (e.g. twenty farms per year).

Please see section 5.6 which provides details of project ideas.

5.5.5 Stakeholders and management planning

There are several entry points for close coordination and implementation. They include:

- the Ministries of Planning, Agriculture, Health, Environment, and Water Resources and FAO have established a multi-sectoral partnership for planning, implementation and monitoring for agriculture, water, and environment programmes and policies to improve coordination and outcomes for farmers;
- the Food Security and Emergency Livelihoods Humanitarian Clusters – and its members, and in particular the newly established Agricultural Working Group; and

- the Donor Coordination Group on Agriculture and Water – a forum where joint action can be considered supporting priority investment opportunities, closely coordinated with the Government of Iraq.

As the implementation expands, these core stakeholders can be progressively expanded upon to include NGOs, additional ministries such as the Ministry of Planning as well as the Ministry of Higher Education and Scientific Research, and relevant academic institutions. Provincial and local government will also become important stakeholders as the implementation progresses beyond national level.

The implementation time of the technology varies depending on the focus with some short term (e.g. rolling out of existing technology in areas with reasonable infrastructure) to medium/longer term (e.g. irrigation infrastructure in poorly served areas).

See below for how stakeholders can be involved in different stages of project development.

Drip irrigation is limited in its use by the availability of water supply and harvesting infrastructure. Examples of estimated costs are provided in section 5.6.

Management of drip irrigation technology will require a well-planned roll out linked to existing infrastructure which is cognisant to future climate change. The top-level of this approach can be facilitated by the Ministries of Planning, Agriculture, Health, Environment, and Water Resources and FAO multi-sectoral partnership for planning, implementation and monitoring for agriculture, water, and environment programmes and policies to improve coordination and outcomes for farmers. However, a key issue is the dissemination of this information to smaller administrative units and individual farmers.

5.6 Project ideas for agricultural sector

5.6.1 Project ideas – water use efficiency in agricultural systems

Example of existing project for horticultural production using plastic housing to increase water efficiency

This project involves the use of plastic housing to make savings in water use for growing a range of intensive crops. In total 22103 plastic houses have been installed. The size of a typical plastic house is 450m^2 (an Iraqi Donum is equal to 2500 m^2). The total area for plastic housing for this project is 9,946,350 m^2 (4108 donum). The project involves 1940 farmers from 234 villages. Cost per one plastic house: 3200 USD. Type of crops that are grown include: tomatoes, cucumber, aubergine, paprika, lettuce, and other green leaved vegetables.

Quantity of water used in summer season is (4000 liter/house). Quantity of fertilizer used: 20 kg/house. Indicative levels of productivity: cucumber production in the spring season =10 tons/house; cucumber production in the autumn season = 5 tons/house, tomato production=8 tons/house.

These values compare favorably with water use in external areas and produce high yields.

Project Idea: building capacity for surface runoff water harvesting, sprinklers and drip irrigation systems

Action 1: surface runoff harvesting can provide water for farm needs and has potential in building resilience against prolonged drought especially in livestock-keeping regions. The strongest barrier for SRWH is inadequate capacity at local level to manage. There is also need to build incentives for private investment.

Action 2: provision of grants or subsidy to fund initial cost of installation of Sprinkler and Drip Irrigation Systems with solar PV and smart sensors for small and medium-sized farmers.

Examples of potential costs:

• Micro-Sprinkler Cost for purchase and installation of a micro-sprinkler irrigation system for a small (e.g. ¼ acre property) is cUS$150 to US$400.

• Drip Irrigation System Cost for purchase and installation of a drip irrigation system for a small (e.g. ¼ acre) farm is cUS$200 to US$500. Cost for 10 kW solar PV system approximately US$30,000 and US$250,000 for a 100-kW system.

• Cost for farmers to use rainwater harvesting and sprinkler and drip irrigation systems is estimated at cUS$200 per farmer.

Matching of this idea to GCF criteria:

- Impact potential (High)
- Paradigm shift (Low given it is existing technology)
- efficiency and effectiveness (potential to be high)
- country ownership (if in-country solutions developed this could be high)
- sustainable development (High as makes better use of scarce water resources to meet food security needs). Vulnerable farms in need of support would be identified through the relevant government departments and other agricultural support entities. Implement Solar Photovoltaic (PV) systems up to 10 kW each at ten (10) small farms (<1/4 acre) per year. Expand the project to implement 10-100kW PV systems at larger farms (¼ – 5 acres) per year. An example of the scale of impacts of such a scheme is provided by the estimates provided in the TAP for Jamaica: the intervention using sprinkler and SPV is estimated to avoid 753.6 metric tons of CO_2 equivalent from 74,056 gallons of diesel fuel for pumps; and generate 1,063.76 MWh from renewable energy over the project period (4 years).
- Need of recipients (High)
- The total amount needed for the project (per farm c$1000 with economies of scale for larger installations)
- The potential number of direct beneficiaries is high including farmers, government and NGOs.

5.6.2 Project ideas – drought resistant crop varieties

Project idea - Design and conduct field demonstration under different agro-ecological zones in Iraq.

Explore under field conditions the establishment and yield of a range of key crops and their cultivars (e.g. see Table 18) in a range of different regions (e.g. see Figure 12). Main aim is to explore the efficacy of lab work in field conditions (e.g. see Awtaq et al. 2021). This work will involve an element of demonstration platforms so that Iraqi farmers can visit the trials and see the results and the methods used.

Estimated time for trials 5 years. Costs c$800,000.

Matching of this idea to GCF criteria:

- Impact potential (medium with high potential downstream)
- Paradigm shift (Medium given it is existing technology)
- efficiency and effectiveness (potential to be high)
- country ownership (if in-country solutions developed this could be high)
- sustainable development (high as makes better use of scarce water resources to meet food security needs).
- Need of recipients (High)
- The total amount needed for the project (estimated to be $800,000)
- The potential number of direct beneficiaries is high including farmers, government and NGOs.

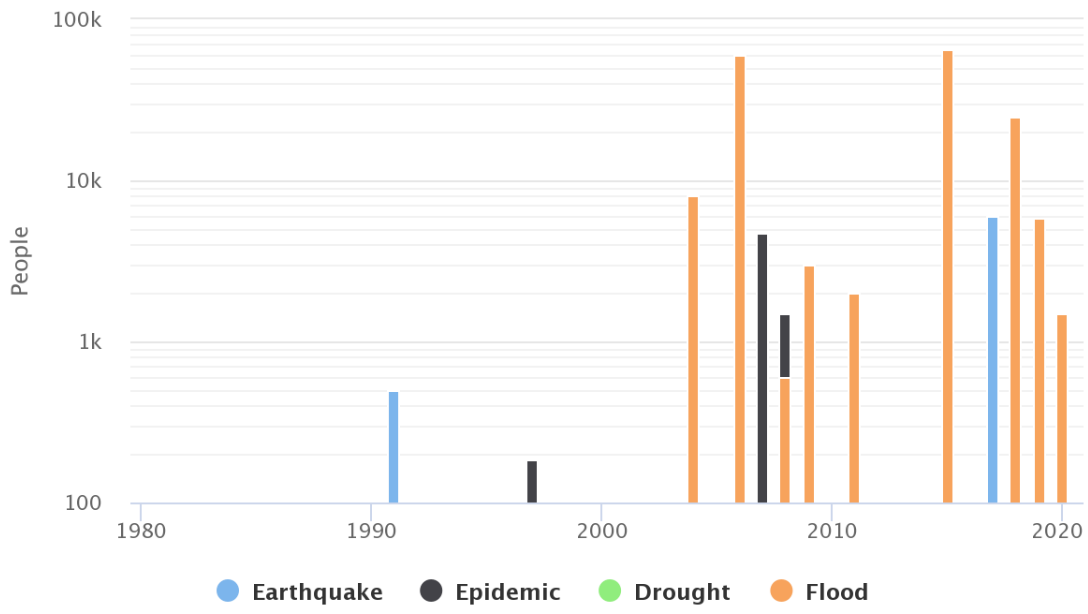
6 Water Sector

6.1 Sector overview

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 13), 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 13. 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 challenges are exacerbated by increasing demand for an increasingly scarce resource. 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. (Idan and Hussein, 2021). Despite the strategic 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.

6.2 Preliminary targets

The targets discussed below for flood risk management are derived from a broader water sector context. Iraq has identified three priorities for the sector, being: i) transboundary water negotiations; ii) efficient water use, and; water pollution. Although Iraq has been in negotiations with Turkey and Iran for many years in an attempt to contain water consumption in these upstream countries, concluding agreement on water allocations and consumption have not been reached. Iraq is therefore having to urgently address increasing water shortages in addition to keeping these negotiation channels open. Efficient water use is largely addressed by Iraq by targeting water intensive sectors. In terms of this project's sectors, both the agriculture and oil industries are understood to be highly water intensive, and the agriculture interventions envisaged under the agriculture section (section 6) for drought resilient crop varietals, as a crop selection objective and for water efficient irrigation are both targeted toward more efficient water use in the agriculture sector for example. The oil industry is also regarded as being water intensive. Water is needed for injection and cooling during the drilling process (Mehdi, 2020).

Both these sectors are central to the economy, and in the case of agriculture, to livelihoods. Although water use management has been effective, there is room for greater efficiencies. However, water dependencies will always be there and this is over and the issues that continue to plague Iraq around international water diplomacy. Put another way, Iraq has limited control over its surface and transboundary water availability, while it also has limited opportunity, at least in the short to medium term, for diversification into less water intensive economic sectors. The country is left with little option but to reduce losses and contamination of the resource wherever it can. Limiting the impacts of floods on both water availability and pollution is a viable opportunity through the selected technologies for this project, not least because Iraq is highly flood prone, and climate change is increasing flood risk through more frequent and intense flood events as a result of temperature rise and changes in rainfall variability.

The preliminary target is to reduce the negative impact of flooding on the wellbeing of people in Iraq, as well as on infrastructure and socio-economic functioning. This will be achieved through improved flood forecasting and risk mapping for more effective flood management and response, as well as through improved development planning in flood-prone areas. The target is to ensure that the requisite skills and knowledge for effective flood management are institutionalised within relevant government bodies of Iraq, that local knowledge is integrated, and ownership is maintained, and that implementation is diffused from the national level down to the local level. All the highly vulnerable areas to flood risk in Iraq are targeted.

6.3 Barrier analysis at the sector level

Iraq still follows the traditional form of response to emergency with limited prior preparedness to such events. This is partly because of challenges related to governance and limited awareness to the importance of Disaster Risk reduction (DRR) strategies and partly because of the fact that natural disasters were not frequent in recent years. Thus, despite the legislation of multiple laws, application remains challenging. The general institutional context of the disasters still lacks essential communication and Early Warning Systems (EWS). Unfortunately, the draft of the first Disaster Risk Reduction Law has many limitations such as failure to define the type of disasters and disaster contingency planning that includes disaster mapping and vulnerability assessment. Additionally, the National Disaster Law only provides a framework for the national disaster plan, however, it needs to be complemented by including disaster management and emergency preparation plan.

The predominant barrier is that the existing institutional arrangement at national, regional and local levels focus on the post-disaster action without limited consideration for preparing for a pre-disaster phase such as prevention and mitigation planning. Therefore, Iraq is still lacking comprehensive disaster management systems based on analysis of risk, hazards, capacities and vulnerabilities of the affected population. Seemingly, Iraq needs strong infrastructural and technical capacities within the government and other stakeholder bodies to be able to respond to the future crisis. War and post-war conflict destroy infrastructure and leave the majority of institutions dysfunctional, thereby increasing the vulnerability of the population. Moreover, the poverty and displacement further make the country unable to respond to disasters. Although the international NGOs have a vital role in this response, they have no capacity to support complete disaster reduction and mitigation planning in Iraq without the effort of the local government. Nevertheless, overall, Iraq is making some steps in the right direction towards DRR and response and is slowly progressing.

6.4 Enabling framework for the water sector

On the first session of the Global Platform for Disaster Risk Reduction conference held at Geneva in 2007, the director of the Iraqi Ministry of Environment stated that the Iraqi government is making every effort to decrease the natural and man-made disasters in the country. In 2007, Iraq established the Natural Disaster Risk Committee which coordinates the response to natural and man-made disasters through preparedness, prevention and mitigation approach according to the Hyogo Framework for Action. Moreover, Iraq became part of the regional DRR programme. In 2008, Iraq endorsed the Arabian Centre for Earthquake Hazard and Natural Disaster Prevention programme. The aim of this programme is to form a system for the countries that share common borders to enable them to respond better to the natural calamities. According to this project, Iraq is committed to show scientific and technical cooperation with the other Arab countries in order to prevent, prepare, mitigate and respond to the effect of natural disasters. Furthermore, the mission of Iraq includes providing logistical and financial support, executing studies to evaluate the natural hazards, sharing the information with other centres in the region and mapping earthquakes and natural hazards.

6.5 Action plan for probabilistic flood forecasting technology

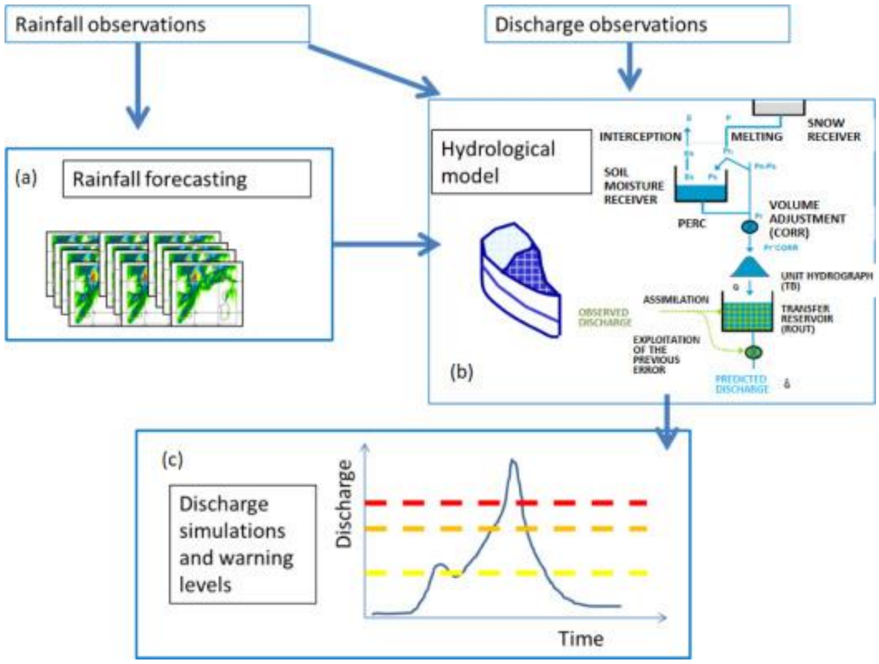
6.5.1 General description

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 Bayesian45 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).

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 (Figure 14). Application of a HUP postprocessor has been shown to improve performance for short-range forecasts.

[45] 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.

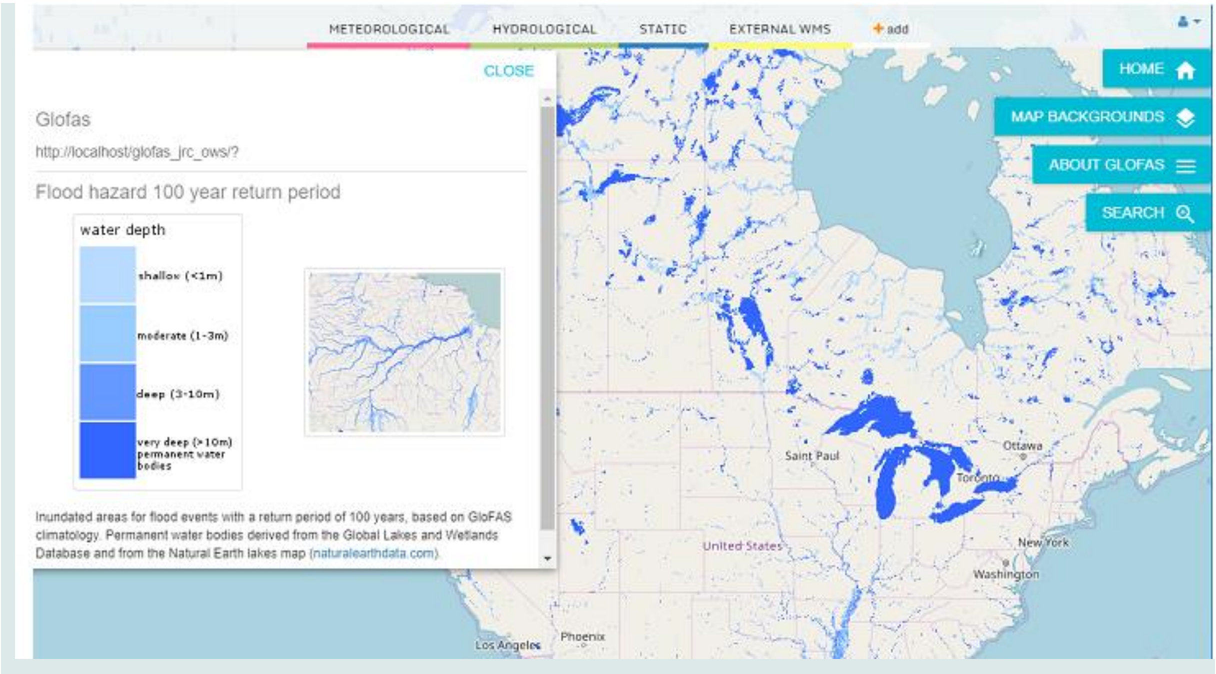
Figure 14. Example structure of information flows in a probabilistic flood forecasting system



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.

Information box 7: Probabilistic flood forecasting example, the Global Flood Awareness System

An example of probabilistic flood forecasting in implementation, the Global Flood Awareness System (GloFAS) produces probabilistic flood prediction possible up to two weeks in advance. GloFAS belongs to Copernicus' Emergency Management Service and was developed jointly by the European Commission and the European Centre for Medium-Range Weather Forecasts (ECMWF). Fully operational since April 2018, the web platform visualizes forecast products at 0.1° or ~11km resolution based on real-time weather forecasts and historical observations that enter a GIS-based spatially distributed hydrological model. GloFAS's interactive map allows separate visualization of forecasted meteorological data, predicted hydrological data, such as stream flows categorized by their probability of occurring (hydrological return-period), static maps of lakes and reservoirs included in the model and reporting points where additional forecast information is available.



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).

6.5.2 Ambition for technology transfer and diffusion

It is envisioned that the implementation of probabilistic flood forecasting will begin with priority river basins and floodplains within Iraq and gradually expand to the entire country. Priority basins will be selected based on several factors, such as historical flood risk and planned socio-economic development. These will serve as pilots for the implementation of the technology and allow for collaborative capacity development, skills transfer, and knowledge sharing. This will also allow the methods and procedures to be adapted to the context of Iraq's governmental management systems and structures to ensure that information feeds through the correct channels for effective flood management and response. Completion of implementation in the pilot basin/floodplain will establish a set of local best-practise for the Iraqi context and thus allow the expansion of the use of the technology to be refined and further adapted for improved suitability.

The technology can be implemented at a national level and as capacity is developed, this can be sub-divided to provincial and eventually district-level forecasting. These sub-divisions of forecasting can feed into a larger national forecasting and data collection system. It will be critical that the skills and knowledge for implementing probabilistic flood forecasting are institutionalised at all levels of government. Diffusion of skills and knowledge related to this technology down from national level will allow for a robust flood forecasting and management network to be established and will also allow for forecasting to take into consideration local needs and knowledge.

As the flood forecasting network becomes established within Iraq, there will be opportunities for establishment of and integration into regional and international frameworks and networks, such as the Black Sea and Middle East Flash Flood Guidance System (BSMEFFGS), through bodies such as the World Meteorological Organization (WMO) of which Iraq is a member. This will facilitate improved skills and capacity development as well as knowledge and lessons sharing. This will benefit Iraq by improving local forecasting as it will be kept up to date with new advancements and will allow the Iraqi network to contribute to global databases and forecasting systems. Given the cross-boundary nature of flood drivers and impacts, regional collaboration will be critical to ensuring effective flood forecasting, management, and response.

6.5.3 Barrier analysis and enabling measures

The primary barrier for implementation of probabilistic flood forecasting in Iraq is limited capacity. This encompasses a lack of sufficient technical skills and knowledge within the government institutions that are mandated to manage flood forecasts and response, as well insufficient resources in the form of workforce as well as technical resources.

The Iraqi Agrometeorological Centre has a significant weather station network that collects data on meteorological variables, and while the current context of this data collection is for agricultural planning, the data can be used to enable implementation of probabilistic flood forecasting. Historical records will be significantly useful as they will be used to strengthen variable selection and forecast reliability. Global databases such as those created by the WMO, the National Oceanic and Atmospheric Administration (NOAA), and Meteostat can be used to fill any gaps in historical records if needed, and to further strengthen the forecasts developed. There are several additional enabling measures in place in Iraq, with several flood management projects in Iraq that have been successfully implemented and can be used as foundations for the proposed forecasting. In recent years there has been an increased research output related flood mapping in Iraq using GIS-Mapping for river floods (Allafta and Opp, 2021), as well as flash floods (Al-Nassar and Kadhim, 2018). This research has provided valuable insights into understanding where floods are likely to occur, which can assist in allocating limited resources, effectively. While mapping is not incorporated within probabilistic mapping, it can inform the selection of variables and parameters for the forecasts.

6.5.4 Actions and activities

Probabilistic flood forecasting techniques and technologies that produce robust and reliable results (Iraq's articulated preference) reside in a few institutions around the world and are seldom imbedded in governments. At the time of writing this report, Iraq did not have the requisite skills or technologies, although the country had recently embarked on a training and capacity building process. This context is an important departure point in considering the actions and activities that need to be undertaken.

A key consideration is the extent to which Iraq needs to build these capabilities internally, and in which institutions capacities needs to be built. For instance, it will be very important for government officials to have the capacities and skills to interpret probabilistic flood forecasting results, but not necessarily to conduct the detailed modelling that underpins this technology. The modelling could be done by an academic institution that also has the advantage of access to post graduate students that can be dedicated to doing this work under supervision, and in partnership with the relevant government departments. Notably, the academic institution(s) concerned do not have to be Iraqi. There is value in Iraq partnering with international institutions that already have the requisite capabilities, at least in the early years of applying the technology.

With these and other considerations in mind, the below sets out a step-wise action plan.

a) Identify partner institutions

The Iraqi government could establish partnerships with institutions that have some experience in probabilistic flood forecasting (recommended) wither through existing networks, or through a more formal, and wider cast call for Expressions of Interest. Advertising such a call nationally and internationally would establish the existing capacity base, including in Iraq. This in turn would enable the Iraqi government to determine which international and national could support, and receive such capacity building. Experienced institutions would also have the knowledge of the most suitable modelling software and baseline qualifications.

b) Develop and transfer technical skills

These actions will revolve around developing the technical skills required for implementing this technology as well as establishing the requisite technical systems and governance systems for the effective running of a probabilistic flood forecasting system. International institutions could train local academic institutions and advise them on the system requirements. The Iraqi government would need to identify departments and officials that should be trained on the interpretation, application and dissemination of the forecasting results. The training should allow new individuals to implement the technology but should also include training on how to upskill and train people in the future to ensure the skills and knowledge are institutionalised for future upscaling. This will also require requisition and supply of physical facilities and equipment such as computers and software. There will need to be significant collaboration with the Iraqi Agrometeorological Centre for data sharing and establishment of constant data supply from the existing hydrometeorological monitoring network. Once this initial capacity building and structuring has been completed, the implementation of the technology can begin.

c) Procure the modelling software and platforms

Again, it will be important to determine early on in the process where this should be housed. It is recommended that an Iraqi academic institution be selected, through the Expression of Interest process, for skills transfer from more established capacities in international institutions. Government departments will however require sufficient software and platforms for accessing, reviewing, interpreting and disseminating the forecasting results. Government budget, along with any co-funding requirements, will need to be determined and made available for the procurement of both the modelling and software and skills transfer requirements in Iraq. It is expected that international institutions will have the modelling software and platforms, but that their time would need to be covered.

The Bayesian method, preferred by stakeholders and experts, requires detailed and complex hydrological modelling, through two processors. This equipment would be available through established institutions, but would require considerable financial and skills building outlay if Iraq chooses to do this in-country from the outset. Notably, going this route would also likely take more time in terms of producing an applying initial forecasts.

d) Establish the modelling parameters, gather the requisite data and model

For probabilistic flood forecasting it is first necessary to establish the geographies and their population demographics for the modelling. Following that, further data will need to be identified and collected, such as infrastructure data, water thresholds, historical flood event data and policy and regulatory data. On the latter for example, it may be necessary to revise regulations, for example for building within flood lines, following the results of the forecasting conducted.

To determine water-level thresholds and the probability thresholds and this information is typically available from the country's hydrometeorological data and stations. Water level thresholds refer 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 probability thresholds are 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.

e) Analysing and disseminating the results

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.

Once decisions have been made, both these and the underlying modelling results will need to be disseminated, by government and possibly through NGOs, to impacted communities. These communities may then have their own decisions to make, such as possible relocation of their homes and/or farms. Packaging this information in a way that is digestible for communities is a discrete skill and Iraq would benefit from learning from the lessons and best practice of other nations with relevant circumstances.

F) Monitoring the impact of further floods and flood forecasts

The Iraqi government will need to develop and implement a monitoring system, and report on its results. Questions the system should consider include among others:

- Is the forecasting knowledge being effectively used in decision making processes? By whom?
- Is the historical data of recent flood events aligned with the forecasts? If not, why not?
- Do wider geographical areas require flood forecasting to be conducted? Why?
- Would additional data (currently not available) enhance the forecast results? If yes, what data is needed and how could it be obtained?

6.5.5 Stakeholders and management planning

Critical stakeholders that will be involved in the implementation of probabilistic flood forecasting will be the respective government departments, such as the Ministry of Water Resources (for analysis and planning) , Ministry of Agriculture (for decision making and dissemination of results to farmers), and the Ministry of Municipalities and Public Works (for infrastructure and household level planning and decision making), in addition to NGOs that can support information dissemination to communities, and academic institutions that can support the Iraqi government in modelling and data collection. The Iraqi Agrometeorological Centre will play a vital role in this, particularly in providing historical data, and access to data from the hydrometeorological network in Iraq. Bodies and organisations responsible for emergency preparedness and response, which may require involvement from the Ministry of Defence, will also be required.

As the implementation expands, these core stakeholders can be progressively expanded upon to include further NGOs, additional ministries such as the Ministry of Planning as well as the Ministry of Higher Education and Scientific Research, and relevant academic institutions. International bodies such as the WMO may also be included with a vital role of supporting the implementation. Provincial and local government will also become important stakeholders as the implementation progresses beyond national level.

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.

6.5.6 Capacity needs and cost estimates

As noted within the Barriers, the primary capacity needs are related to skills, knowledge, human resources, and technical resources, including for communications and dissemination. Probabilistic flood forecasting requires specialised knowledge and skills and should be carried out by a qualified hydrologist who has the experience and expertise to do so correctly. The statistical modelling requires the hydrologist to understand Bayesian statistics so that they can adjust the model accordingly without compromising the results and allow them to interpret the results and convey them to decision-makers in an accessible format.

While these skills are present within Iraq, they are not institutionalised and remain siloed within academic institutions, and any expertise within government is held at the national level and has not yet been filtered down to the local level. Mentorship, training of trainers[46] (ToT) and similar programmes will allow the transfer of these skills and knowledge to the requisite government bodies and officials. It would eb beneficial for experts from intentional bodies such as the WMO to be involved in this process to ensure that the knowledge and skills shared are aligned with global best-practise. It will be critical to ensure that skills and knowledge are institutionalised within the Iraqi government bodies at all scales as this will ensure ownership of the developed systems.

In general, floods are local events – meaning they affect small communities, towns and sometimes cities. This means that measures taken to mitigate flood vulnerability are typically applied at the local level. While this makes sense, it also makes it more difficult to quantify the costs of these measures at a national level. However, data from several early warning system (EWS) programmes in Ireland provide valuable insight into the general costs of start-up and maintenance. The Munster Blackwater Mallow Initial Flood Forecasting System (IFFS) for example, runs a Unified River Basin Simulator that required an initial capital input of US$ 410 000 and costs US$ 280 000 annually to maintain (Environment Agency, 2021). The project was developed between 2005 and 2009 but is regularly updated (Environment Agency, 2021). This is just one of many such systems the country has in operation, each focusing on different fluvial or coastal systems, and each working with different kinds of technology. It is important to note that as extreme hydrological events like droughts and floods affect regions and countries differently, the levels of risk also vary. This means that countries (or local geographic areas) at a higher risk of floods require more advanced, more expensive forecasting equipment to better mitigate vulnerability.

Management of probabilistic flood forecasting will require a centralised body that is able to collate and process data, develop the forecasts, and disseminate the results. This needs to be carried out continuously

[46] The Training of Trainers (ToT) model is intended to engage master trainers in coaching new trainers that are less experienced with a particular topic or skill, or with training overall. A ToT workshop can build a pool of competent instructors who can then teach the material to other people.

and timeously as any delays in forecasting could result in a critical loss of valuable lead time during a flood event. This body should be housed in a critical ministry, such as the Ministry of Water Resources, but will require support from other stakeholder ministries outlined in the Stakeholders section above. Flood management and response is a complex process that requires a sufficient framework to synchronise the rapid responses of emergency response bodies.

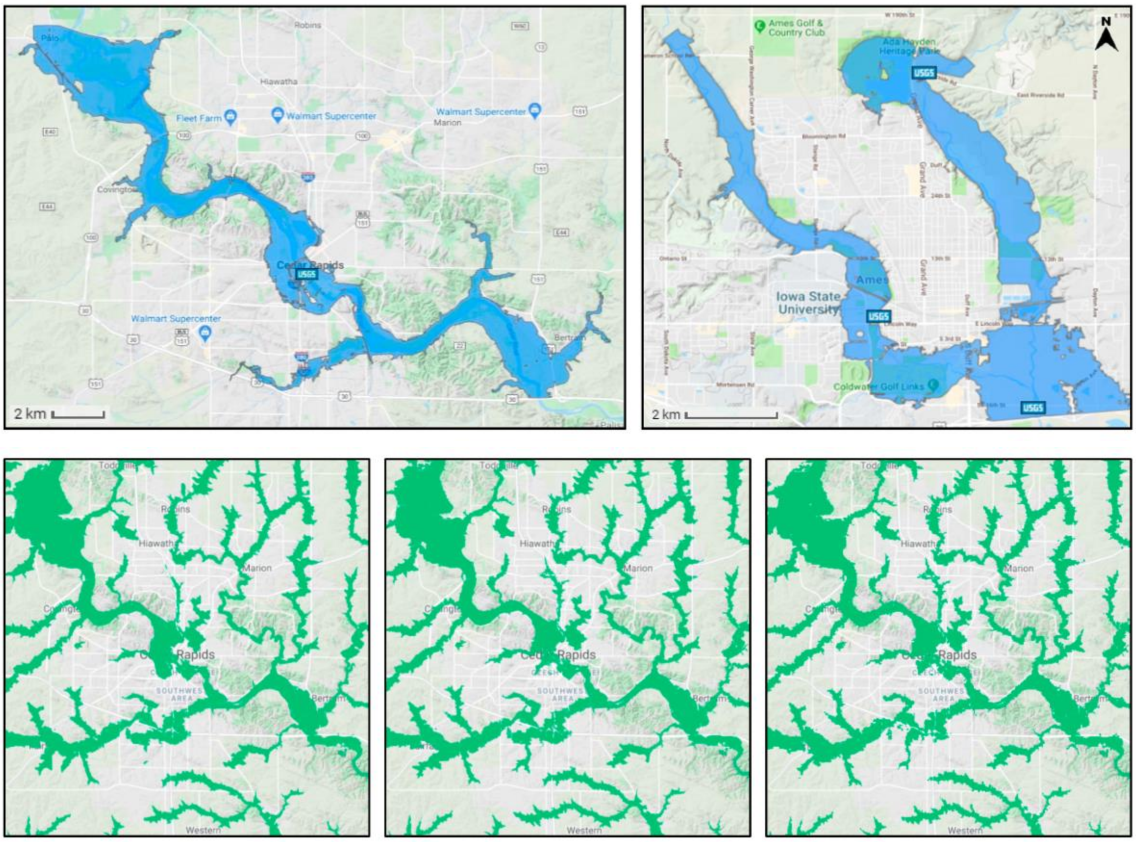
As the forecasting will likely build upon critical data gathered by the Iraqi Agrometeorological Centre, they will play a critical role in the management of the implementation of the technology. It will also be vital that human resources are sufficient to ensure that functioning is not compromised by absence of staff due to illness, vacation or turnover.

6.6 Action plan for flood risk mapping technology

6.6.1 General description

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 (Figure 15). As flood risk mapping does not cause a reduction in flood risk, it requires integration into other procedures.

Figure 15. Examples of flood risk maps



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 and 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.

6.6.2 Ambition for technology transfer and diffusion

The envisioned technology transfer and diffusion plan strongly mirrors that outlined for Probabilistic Flood Mapping. This is a result of the technologies being used in combination for effective flood risk management, with synergistic applications, as well as overlapping skills, knowledge and resource needs. Implementation of probabilistic flood risk mapping will begin with priority areas within Iraq and gradually expand to the entire country. Priority areas will be selected based on several factors, such as historical flood risk (Table 19) and planned socio-economic development.

The development of flood risk maps for specific areas and basins will serve as pilots for the implementation of the technology, and as maps need to be updated on a regular basis, these will form the start of a regular cycle of flood risk map generation. As with probabilistic flood forecasting, this of piloting within priority areas will allow for collaborative capacity development, skills transfer, and knowledge sharing. This will also allow the methods and procedures to be adapted to the context of Iraq's governmental management systems and structures to ensure that information feeds through the correct channels for effective flood management and response. Integration of flood risk maps into the proposed probabilistic flood forecasting systems will be critical to ensuring the two technologies are used to inform each other for more effective flood management and response. Completion of implementation in the pilot basins/floodplains will establish a set of local best-practise for the Iraqi context and thus allow the expansion of the use of the technology to be refined and further adapted for improved suitability.

Table 19: Significant flood events reported in Iraq over the last decade (FloodList, 2022)

Area	Month / Year	Reported Deaths	Description
Wasit / Dhi Qar	May, 2013	4	Heavy rainfall led to houses, public infrastructure and crops damaged or destroyed. The city of Kut in Wasit suffered from flooding coming directly from the Iranian highlands.
Southern and Central Iraq	November, 2013	11	Three days continued rainfall led to heavy rainfall throughout parts of southern and central Iraq. The Babel governate declared a state of emergency.
Multiple Areas in Iraq	October, 2015	7	Severe weather affected people in Baghdad, Mosul and Basra. Conditions wore worsened in IDP camps in Erbil and the Iraqi government declared a state of national emergency in order to deal with the damage.
Baghdad, Diyala Governante	November, 2015	58	Flash floods and water-related electrocution caused widespread damage and loss of life throughout Iraq, but particularly in the capital city. The flooding also increased the concerns of a potential cholera outbreak due to contaminated water.
Iraq / Kurdistan Region	February 2018	3 (one Turkish soldier)	Flooding and landslides were reported throughout the country, particularly within Baghdad. Some areas recorded over 400mm rain in 24 hours. 200 000 IDPs.
Duhok (KRI)	May, 2018	4	Flash floods struck Duhok city in the Kurdistan Region of Iraq damaging homes, cars and other property. Four died when two vehicles were swept away by the deluge.
Iraq (and regionally)	November, 2018	-	Unusually heavy rains affected Iraq, Iran and Kuwait.
Multiple areas in Iraq	November, 2018	21	Flash floods kill and injury many throughout Iraq – including in Mosul and Wasit.
Najaf province	January, 2019	-	50 homes swept away in flash floods
Multiplate areas in Iraq	March, 2019	0	Several governates flooding and damage to property, with over 1000 families displaced.
Ninevah Governate	March, 2019	5	Double the annual rainfall for that month fell in just 24 hours leading to widespread property damage, displacement, and death.
Erbil	October, 2021	-	Over 500 families were displaced after a short period of heavy rainfall led to flooding in the Kurdish region.
Erbil	December, 2021	8	Flash floods struck after a short period of heavy rainfall – cars, buses and trucks were all swept away during the inundation.

As with probabilistic flood forecasting, the technology can be implemented at a national level and as capacity is developed, this can be sub-divided to provincial and eventually district-level risk mapping. These sub-divisions of risk mapping can feed into a larger national forecasting and data collection system. It will be critical that the skills and knowledge for implementing flood risk mapping are institutionalised at all levels of government. Diffusion of skills and knowledge related to this technology down from national level will allow for a robust risk mapping and management network to be established and will also allow for mapping to take into consideration local needs and knowledge.

6.6.3 Barrier analysis and enabling measures

As with probabilistic flood forecasting, the primary barrier to effective implementation of flood risk mapping in Iraq is limited capacity. This encompasses a lack of sufficient technical skills and knowledge within the government institutions that are mandated to manage flood forecasts and response, as well insufficient resources in the form of workforce as well as technical resources.

Meteorological variables measured by the significant weather station network of Iraqi Agrometeorological Centre can be used to inform initial flood risk mapping processes. Tools such as ArcGIS (©Esri) have robust tools and resources for flood risk mapping as well as guidance materials for their application. There are several additional enabling measures in place in Iraq, as 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.

6.6.4 Actions and activities

Iraq has a greater level of the capacities and skills needed for this technology than for probabilistic flood forecasting. That said, the initial actions required will similarly focus on technical skills development as well as establishing the requisite physical systems and governance systems. Training will be needed to develop the technical skills and knowledge for flood risk mapping, and as with the previous technology this can be done in collaboration with academic professionals from within Iraq but may require international expertise to ensure that knowledge and skills are aligned with global best-practise. The training should institutionalise new skills for future upscaling. This will also require requisition and supply of physical facilities and equipment such as computers and the necessary software for mapping. Following the initial capacity building and structuring, the implementation of the technology can begin.

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

1. **Determine the partners and institutions** needed to effectively map flood risk, integrate the analysis with that for probabilistic flood forecasting, and to disseminate an communicate the results.
2. **Determine the study area** to establish what area to map. This can be determined by local knowledge and by examining high-risk areas based on previous flood occurrence, thus drawing on historical data from the meteorological services.
3. **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.
4. **Gather an collate data**: the data on the above characteristics must be gathered and collated against the causative factors identified.
5. **Standardize the data:** The standardization process makes the data dimensionless to facilitate the comparison of the different data points.
6. **Choose the method of assessing the flood hazard map and determine what modelling programmes would be used:** 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.

7. Implement the risk mapping
8. Interpret and analyse the results in conjunction with the flood forecasting outcomes.
9. Package and disseminate the information to all levels of decision makers.

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.

6.6.5 Stakeholders and management planning

The stakeholders for flood risk mapping strongly mirror those for the implementation of probabilistic flood forecasting as the technologies are envisioned to work in unison. Critical stakeholders will be the respective government departments, such as the Ministry of Water Resources (planning and risk mapping, policy guidance), Ministry of Agriculture (decision making, policy guidance), and the Ministry of Municipalities and Public Works (infrastructure planning and decision making, policy guidance, building specifications). As the implementation expands, these core stakeholders can be progressively expanded upon to include NGOs, additional ministries such as the Ministry of Planning as well as the Ministry of Higher Education and Scientific Research, and relevant academic institutions. Provincial and local government will also become important stakeholders as the implementation progresses beyond national level.

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.

As noted within the Barriers, the primary capacity needs are related to skills, knowledge, human resources and technical resources. Flood risk mapping requires specialised knowledge and skills and should be carried out by a qualified hydrologist who has the experience and expertise to do so correctly. The mapping requires the hydrologist to understand mapping results and convey them to decision-makers in an accessible format.

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.

6.6.6 Capacity needs and cost estimates

The capacity needs are the same as those for probabilistic flood forecasting as these skills are present within Iraq, but they are not institutionalised and remain siloed within academic institutions. Any expertise currently within government is held at the national level and has not yet been filtered down to the local level. Mentorship, ToT and similar programmes will allow the transfer of these skills and knowledge to the requisite government bodies and officials. It will be critical to ensure that skills and knowledge are institutionalised within the Iraqi government bodies at all scales as this will ensure ownership of the developed systems.

Flood risk mapping has significant technical demands in the form of computers with the processing power to run mapping software. Dissemination of the mapping results will require interpretation and translation of the outputs into an accessible resource for decision-makers and needs to be communicated timeously. As the extent of the technology's application across the floodplains and basins of Iraq expands, so the team needed to carry-out this work will need to expand, and the technology needs will also increase. The more extensive the mapping, the greater these needs will be, but this should be a gradual process. As the mapping process only needs to run on a five-year cycle and will not have persistent demands like those of probabilistic forecasting, the expansion of capacity needs will be far less extensive. Lessons can also be learned from previous projects that will allow the initial setup to be done in a way that is prepared for expansion in the future.

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.

Studies undertaken by the Federal Emergency Management Agency (FEMA of the United States found that updating their own flood hazard programme would lead to incremental costs of US$ 848 million over a 50-year period (Collins *et al.*, 2022). A more local-level case serves as a better example. In North Carolina, the total cost of a state-wide lidar survey (a crucial step in flood mapping) was estimated at US$ 27 million (Collins *et al.*, 2022) It is key to emphasise that the temporal factor contributes significantly to overall costs. As both technology and the climate change increasingly fast, flood risk maps become simultaneously easier to make, and more complex. Also, creating a risk map with no baseline is generally a much more expensive undertaking than just updating an existing one.

Similar to the management of probabilistic flood forecasting, flood risk mapping will require a centralised body that is able to gather the requisite data, develop the risk maps, disseminate the results and update the maps on a five-year cycle at minimum. It would be most effective for the central body that is responsible for flood forecasting to also house the flood risk mapping responsibilities, and thus the body should be housed in the same critical ministry, such as the Ministry of Water Resources, but will require support from other stakeholder ministries outlined in the Stakeholders section above.

6.7 Project ideas for the water sector

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 bring 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.

6.7.1 Project idea 1: Establishing a flood forecasting and early warning system

The project would introduce probabilistic flood forecasting and application of forecast information in adaptation initiatives to increase community resilience and to enhance preparedness against existing hazards, and to projected increases in flood risk.

The proposed project would involve developing integrated observation, forecasting and communication systems and procedures as well as enhancing institutional mechanisms and technical capacity for generating location-specific, user-relevant early warning information for integration in planning and decision-making in climate-sensitive sectors. Key activities include improving of observation system, establishing a data management system and web/GIS-based DRR/tools, building capacities to generate impact-based forecasts and response advisories, improving risk communication, training of technical staff and users, and demonstration of climate information application in select communities.

The project would have significant adaptation impacts and, given the worsening impacts of flooding under climate change, would align strongly with the climate context for international climate funding. The impacts of the project would increase resilience of most vulnerable people and communities; improve health and well-being, and food and water security; protect infrastructure and the built environment as well as ecosystems and ecosystem services.

Projected costs for a project of this nature are likely to be approximately US$10 million, with a timeline of 36 months.

6.7.2 Project idea 2: Improved flood risk management

This project would integrate flood risk mapping as part of a greater effort to improve flood risk management.

The project could address increasing vulnerability of communities and livelihoods to intensified climate-induced flood-related disasters. The project could establish an integrated approach to flood risk management (FRM), strengthen institutional, technical and financial capacity to implement long-term FRM strategies, including a combination of structural and non-structural measures and ecosystem-based approaches. The project could strengthen use of climate information, flood forecasting, early warning and emergency response systems to enhance adaptive capacity and resilience of at-risk communities.

The project would have significant adaptation impacts and, given the worsening impacts of flooding under climate change, would align strongly with the climate context for international climate funding. The impacts of the project would increase resilience of most vulnerable people and communities; improve health and well-being, and food and water security; protect infrastructure and the built environment as well as ecosystems and ecosystem services.

Projected costs for a project of this nature are likely to be approximately US$70 million, with a timeline of 10 years.

6.7.3 GCF Concept Notes

Links to GCF Concept Notes relevant to the water sector include:

- Enhancing resilience against floods and landslide in the coastal city of Limbe, Cameroon
- Strengthening climate resilience of water resources and supply in Southern Madagascar
- Climate Information and Early Warning Systems, One Pacific Programme

Finding GCF Concept Notes

The GCF has an extensive library of document related to past, current, and newly approved projects. These documents are hosted on the GCF website and can be accessed for reference and guidance when identifying the GCF as a potential funder to meet a need or challenge or to guide the project development process. These documents can be accessed by following the steps below:

1. Access the GCF website: https://www.greenclimate.fund/
2. Select the 'Data and Resources' tab and then select 'Operational Documents'
3. The list of documents can the be filtered to show Concept Notes only by viewing the 'Filter by Type' section and selecting the 'Concept Note' filter.

7 Programmatic Approaches

Programmatic funding proposals could be developed based on combining some technologies elaborated in this report, to address key sector and cross sectoral needs. Etc. Suggestions for developing programmatic project concept notes, for example to develop into funding proposals for the GCF are outlined in this section, with a brief rationale.

7.1 Programmatic concept 1

Project title:

Promoting water and climate resilient technologies and practices in Iraq's most drought and flood prone areas.

Project description:

The project will implement technologies and build institutional and household capacities for effective drought and flood risk management in geographies/areas that experience extreme climate variability as a result of climate change. Technologies will be implemented at household level, benefitting Iraq's most vulnerable populations, including women and children. Technologies will include drought resilient crop varietals, water efficient irrigation systems and flood forecasts and flood risk maps, disseminated to and used by key stakeholders in decision making processes. The project components and sub components include:

1. Highly accurate flood and drought risk mapping and forecast information is available to key stakeholders
    a. The relevant government departments have access to flood forecasting technologies and capacities
    b. The relevant government departments have access to/can effectively map flood risk
    c. Farmers, households and other key decision makers have access to climate information in real-time
    d. Farmers, households and other key decision makers respond effectively to real-time climate information
2. Agriculture in high-risk areas is climate resilient
    a. Drought resilient crop varietals are deployed by > 70 percent of farmers in high-risk areas
    b. > 70 percent of farmers use water efficient irrigation systems
    c. > 60 percent of farmers, households and infrastructure developers are aware of, and responsive to flood risk
3. Institutional capacities are established to support climate resilient agriculture and climate information systems
    a. The capacities of relevant Iraqi Government departments are established
    b. The capacities of farmers (e.g. through cooperatives) are established to adopt climate resilient agriculture practices and technologies
    c. The capacities of government departments and NGOs are established to package and disseminate climate information
    d. The capacities of farmers and households to apply the climate information are established

7.2 Programmatic concept 2

Project title:

Accelerating renewable energy technologies for enhanced agricultural productivity

Project description:

The project will implement technologies that can increase agricultural productivity and value addition. Agricultural productivity needs to be maintained and enhanced to ensure food security in times of extreme events as well as in the face of incremental climate changes. Renewable energy powered technologies will be implemented at the farm level to reduce dependence on rainfed agriculture, increase food storage to mitigate the impacts of floods and droughts and to enable productive agribusinesses,

The project components and sub components include:

1. Renewable energy technologies are available to and understood by farmers in drought and flood prone areas
    a. Renewable energy technologies for productive use in the agriculture sector are understood and available
    b. Farmers deploy renewable energy technologies at scale in high climate risk areas
    c. Farmer input costs for electricity are reduced
2. Renewable energy technologies in agriculture high-risk areas maintains/enhances productivity
    a. Farmer dependence on rainfed agriculture is reduced

   b. Farmer incomes are increased, including through enhanced crop yields and storage capacities
   c. Food security is increased in high climate risk areas
   d. Farmer incomes are diversified
3. Institutional capacities and arrangements are developed to support/enable accelerated uptake of renewable energy technologies for productive use.
   a. The capacities of farmer cooperatives are enhanced to support the uptake and deployment of renewable energy technologies
   b. The capacities of relevant government departments are enhanced to package information on effective renewable energy technologies for farmers
   c. Cross sectoral institutional, collaborative arrangements are established between key sectors and departments to plan for and support renewable energy uptake, e.g. agriculture, energy and water

8 Means of implementation

In line with the international climate diplomacy efforts, various means of implementation of the technologies outlined in this report are available to Iraq. These include:

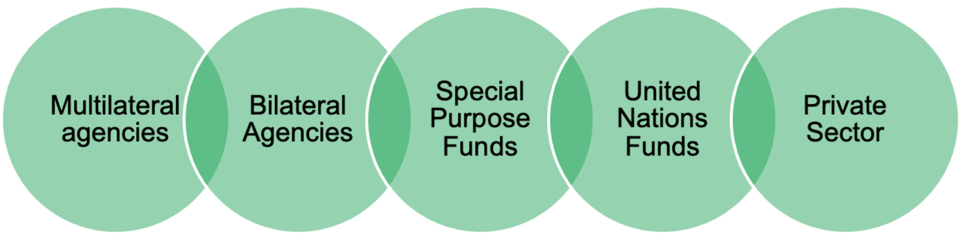
- Policies, actions, or measures that can help address and overcome barriers for technologies from multiple sectors, including national and international policies
- Multi-stakeholder partnerships
- Social inclusion, such as of women, children and the disabled
- Capacity building and skills transfer
- Funding sources and finance mechanisms

The funding sources and financing mechanisms aspects are further elaborated in the section that follows.

8.1 Sources of finance and funding mechanisms

As part of developing TAPs, a key aspect is to identify the resources required to develop and implement the various technologies. It is thus important to consider the available funding sources; a distinction is made here between carbon and climate finance, with the former more relevant for mitigation projects and the latter for both mitigation and adaptation. A complex multi-funder and multi-scale finance landscape is applicable, as demonstrated in Figure 16 below:

Figure 16: A multi-funder landscape

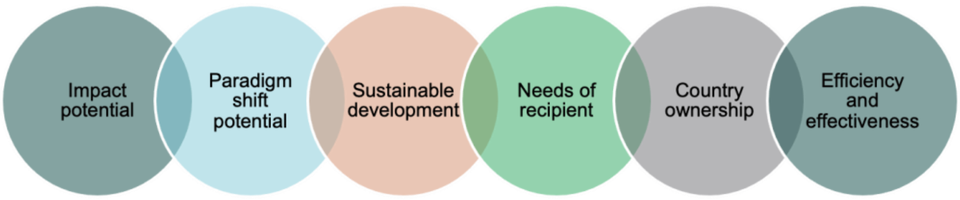


Accompanying this landscape are funding criteria, which vary from funder to funder, but which typically include core criteria such as:

- Implementation and management capabilities
- Efficiency and effectiveness
- Impact
- Sustainability
- Monitoring and evaluation
- Climate change additionality

The Green Climate Fund (GCF) has stringent investment criteria, which each project must meet, outline in Figure x below. These criteria constitute the GCF's mandate, or license to fund and operate, hence a high level of scrutiny is afforded to funding proposals by the GCF.

Figure 17: GCF investment criteria



The tables that follow outline the primary funders, descriptions thereof, and the funding mechanisms of each funder described, across the categories of funder outlined in Figure 17 above. The section that follows provides a brief description of these, and other funding mechanisms available.

Table 20: Multilateral funds

Fund/Funder	Description	Funding mechanisms
	Multilateral Special Purpose Funds	
Adaptation Fund	Governments can access through accredited entities Implementing Entities can submit a concept or project proposals.	Grants: Readiness Grants, Innovation Grants Concessional Finance only
Green Climate Fund	Climate adaptation and mitigation activities against the eight GCF results areas of: •Health, food and water security •Livelihoods of people and communities •Energy generation and access •Transport •Infrastructure and built environment •Ecosystems and ecosystem services	Grants Loans Concessional Finance only

	•Buildings, cities, industries and appliances •Forests and land use	
Global Environment Facility	Environment project in developing countries and countries with economies in transition to meet the objectives of the international environmental conventions and agreements.	Grants Concessional Finance only

Table 21: Development Finance Institutions

Fund/Funder	Description	Funding mechanisms
Development Finance Institutions		
International Bank for Reconstruction and Development -- World Bank Group	Infrastructure and water security Climate change adaptation and mitigation Transition to low carbon economy	Grants Loans
Islamic Development Bank (IsDB)	Infrastructure Climate change adaptation and mitigation Enabling access to climate finance	Grants Loans
Bahrain Development Bank Emirates Development Bank, etc. (nine in the Middle East)		

Table 22: Bilateral Agencies

Fund/Funder	Description	Funding mechanisms
Bilateral Agencies		
China Import/Export Bank	Infrastructure and water, energy and food security	Grants Loans
Kreditanstalt fuer Wiederaufbau(KfW) - Germany	Infrastructure Climate change adaptation and mitigation	Grants Loans
Bilateral development agencies (e.g. GIZ, SIDA, Norad, FGEF, Netherlands Embassy, Enabel (Belgian Development Agency), UKAid (etc.)		

Table 23: United Nations (UN) Agencies

Fund/Funder	Description	Funding mechanisms
	UN Agencies	
UNDP & UNEP	Eradicating Poverty; Governance; Crisis prevention & resilience; Environment- NbS for development; Clean, affordable energy; Women's empowerment, gender equality	Grants
UNICEF & UN Woman	Women, children, community empowerment, livelihoods Political Empowerment; Economic Empowerment for achieving women's economic and political empowerment and the Sustainable Development Goals	Grants
Climate Technology Centre & Network (CTCN	Promotes the accelerated development and transfer of climate technologies at the request of developing countries for energy-efficient, low-carbon and climate-resilient development. It provides technology solutions, capacity building and advice on policy, legal and regulatory frameworks tailored to the needs of individual countries.	Grants

Table 24: Private Sector

Fund/Funder	Description	Funding mechanisms
	Private Sector	
Commercial Banks	ESG activities, service delivery (sanitation, electricity, water etc), disaster risk management	Loans
Large Corporates with high carbon, energy, land use, and water footprints Automotive Industry Mining Industry Food and Beverage Industry Manufacturing industry (including agri processing) Energy sector Coca-Cola AB InBEV Nestle	Promotes the accelerated development and transfer of climate technologies at the request of developing countries for energy-efficient, low-carbon and climate-resilient development. It provides technology solutions, capacity building and advice on policy, legal and regulatory frameworks tailored to the needs of individual countries. Community projects/localised projects with impact. Largely infrastructure projects or projects with tangible outcome.	Grants

A range of funders and mechanisms are available. Funder selection can be informed by matching a need/challenge to the programmatic areas of funding of a funder. For example, the GCF has two themes of work, adaptation and mitigation, with specific definitions that projects seeking funding must align to. This is further broken down into the eight GCF result areas for projects, for adaptation: 1) Health, food and water security; 2) Livelihoods of people and communities; 3) infrastructure and the built environment; 4) ecosystems and ecosystem services; and for mitigation: 5) energy generation and access; 6) transport; 7) Buildings, cities, industries and appliances; and 8) forests and land use. Similarly, the GEF has focal areas defined for each funding replenishment that define the investment priorities, and within these there are specific objects that projects should be aligned with when seeking funding. The broad GEF focal areas and impacts programmes are: i) Biodiversity; ii) Chemicals and waste; iii) Climate change; iv) International waters; v) Land degradation; vi) Food security; vii) Sustainable forest management; and ix) Sustainable cities. Alignment of projects to funders can be further informed by identifying existing projects that address a similar need or challenge and identifying the funders involved in the project within its current scope.

It is always important to understand funder criteria and to select a funder(s) because the project or programme aligns with these criteria. The project idea and objectives, and the country climate finance agenda should drive the funding. The funding criteria should not drive the project.

Careful selection of a funder is important. A single funding application cannot be submitted to multiple donors as each funding source has set requirements, templates, and procedures for projects. This requires proposals and applications to be developed in a tailored way for a specific funder. While there is some overlap between the scope of projects financed by different funders, there are often specific requirements that make it best to target the funder most appropriately matched to the project as this allows for the greatest likelihood of approval. This also ensures and pairing with the funder with the most suitable support mechanisms for the process.

It is also important to ensure that the scope of project applications is matched to the capacity of the country to manage active projects. While most proposals will include capacity development and support, the effective coordination and management of these projects is critical to their success. A rapid influx of capacity development could unintentionally hinder proper assimilation of the support. NDAs and AEs need to be considered within this too, as their capacity will be a limiting factor to the number of active projects that can be managed effectively. Many funders also have specific requirements for funding to ensure that duplicated efforts are avoided, and this requires effective coordination and tracking of project development to ensure that applications are not rejected on the grounds of duplication. Funers will not finance projects that they perceive to be double counting.

Funding proposals take time and skills to prepare. The time it takes to prepare a proposal through to approval and disbursement of funds can be upwards of a year. The GCF, as a multilateral fund, has among the longer processing and approval processes, and different GCF windows are briefly described below for illustrative purposes.

The GCF has recognised that developing countries may face capacity constraints in developing climate finance proposals, and so has developed the Project Preparation Facility (PPF) to provide financial and technical assistance for the preparation of project and programme funding proposals. The PPF allows for applications of funding up to USD 1.5 million, proportionate to the activities included in the PPF application. Simplified PPF Funding is also available for support up to USD 300,000. All Accredited Entities (AEs) are eligible to apply The Project Preparation Facility, though it is especially designed to support Direct Access Entities for projects in the micro and small-sized category.

The PPF can support one or more of the following activities which contribute directly to the development of a project, and PPF deliverables must be submitted as part of the funding proposal package:

Support is available through two modalities: 1. PPF funding; and 2. PPF service; and both modalities require the AE to be responsible for oversight, quality assurance and funding proposal submission to the GCF.

PPF funding:

AEs can receive funding in the form of grants, repayable grants or equity to undertake project preparation activities by themselves. This requires AEs to organize the procurement and implementation process directly and be accountable for the oversight and reporting of the approved funding and activities. Generally, if a PPF results in a feasible project with income generation potential, the PPF amount financed by the GCF should be repayable at financial close of the funded activity. PPF funding from the GCF should be repaid within the financial structure of the Funding Proposal, with terms and conditions to be determined at the Funding Proposal development and review process, prior to submission to the GCF Board.

PPF service:

The GCF provides project preparation services directly to AEs through a roster of independent consultancy firms, ensuring fast and quality delivery to AEs who do not wish to take on the procurement and project management of PPF activities by themselves. As is the case for all types of GCF projects, Accredited Entities may seek PPF financial resources to prepare funding proposals for consideration under the Simplified Approval Process, based on a high potential concept note.

PPF Process

Accredited Entities submit a project/programme Concept Note either prior to, or together with, a PPF application. It is strongly recommended that the concept note be submitted before the PPF application to make sure the PPF applications mirrors the feedback provided by the GCF on the concept note. The objective of a PPF application is to finance the preparation of a Funding Proposal package based on the Concept Note. All PPF applications must provide sufficient justification of the AEs need for project preparation funding from the GCF, as well as detailed budget breakdown. Once the Concept Note is cleared, the PPF application Note will be reviewed and approved by the GCF Secretariat. The process steps described below reflect the differences between the PPF funding and the PPF service. Funding Proposals developed with PPF resources should be submitted to the GCF Board within two years of PPF application approval.

GCF SAP

The Simplified Approval Process (SAP) is an application process offered by the GCF for projects or programmes that are expected to possess significant climate impact potential. SAP proposals are expected to be ready for scaling up and have the potential for transformation and promoting a paradigm shift to low-emission and climate-resilient development. GCF contributions for SAP projects are limited to up to USD 25 million and must have minimal environmental and social risks and impacts. The SAP simplifies the process and documentation required for project development through: i) simplification of key documents; ii) shorter proposal length; and iii) simpler questions and clear guidelines in project forms. Accredited Entities, National Designated Authorities (NDAs) or Focal Points can submit Concept Notes under the SAP, and Direct Access Entities are particularly targeted for this funding avenue.

8.2 Description of Funding Mechanisms

This section provides details about the types of funding mechanisms, examples of which are presented in the section above.

Carbon finance is "payment in exchange for transfer and ownership of verified greenhouse gas emission reductions, which can potentially be used to meet the purchasing country's emission reduction obligations". This applies to Iraq's mitigation projects, which may earn revenues from delivery and sales of emission reductions to a carbon market (or through bilateral trades) in addition to other revenues generated. The principal source of carbon finance is now Article 6 of the Paris Agreement, previously the Clean Development Mechanism (CDM) of the Kyoto Protocol. Article 6 outlines mechanisms by which countries can cooperate on a voluntary basis in the implementation of their NDCs, including through the transfer of Internationally Transferred Mitigation Outcomes (ITMOs). Outside of the Paris Agreement is the voluntary carbon market, covering primarily sales of emission reductions to entities that voluntarily choose to reduce emissions using offsets. Unlike Article 6 and the CDM, emission reduction projects are not reviewed by UNFCCC institutions but by independent governing bodies. There are different standards for approval, but it is typically selective with respect to project types and eligible sectors. A large portion of offsets brought to the voluntary market come from renewable energy and forestry while very little, if any, come from the oil and gas sector.

Climate finance, on the other hand, are the broader "financial flows directed towards low-carbon and climate-resilient development interventions with direct or indirect greenhouse gas mitigation or adaptation benefits". This covers both public and private sources with concessional or commercially based terms. A large part of this finance comes from the UNFCCC to support developing countries for climate change mitigation and adaptation. Both before and following COP26, the UN has supported Iraq in mitigating and adapting to climate change, through the design of sustainable projects that focus on livelihoods creation, medium and long-term development, investments in efficient water and wastewater infrastructure, irrigation, management of water consumption, as well as the use of renewable energy such as solar power.

Concessional finance is below market rate finance provided by major financial institutions, such as development banks and multilateral funds, to developing countries to accelerate development objectives. The GCF for example extends concessional finance as a multilateral fund, to enable traction of climate resilience building and reduced greenhouse gas activities, that would otherwise not be funded.

Bilateral funding from developed countries is the most important source of climate financing, including national development agencies and finance institutions. This category also comprises funding to the Green Climate Fund (GCF) and the Global Environmental Facility (GEF).

Multilateral Development Bank, with their mandate to enable innovative projects that are outside of the business or development as usual realm, and are thus considered to be high risk by commercial funders, are a prominent funding source, with the World Bank Group and the Asian Development Bank being the most relevant funding sources for Iraq. The World Bank Group's Maximizing Finance for Development (MFD) framework proposes a method for development banks to help countries systematically leverage all sources of finance, expertise, and solutions for development.[47] Iraq, alongside Egypt and Jordan, was identified as a pilot for this approach in the Arab region. It assesses the financing requirements of each project to promote, first, a sustainable private sector solution that limits public debt and contingent liabilities. If unavailable, it examines whether this is due to policy or regulatory gaps, or perhaps the project risk profile, to seek support for policy and regulatory reforms or risk mitigation tools. If none of these options are possible, then public funding is pursued.

Iraq is also one of the main beneficiaries of net official development assistance (ODA) from all sources. Arab recipients received about USD 12 billion annually from 1990 to 2014, representing nearly 5 % of total net ODA to all developing countries. A major portion of Arab donors' aid goes to other Arab countries, reflecting the significant role of other Arab institutions in funding development efforts in Iraq.

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[47] https://www.greenfinanceplatform.org/research/financing-sustainable-development-arab-countries

Table 25: Examples of current UN-supported climate-related projects in Iraq and relevant funding sources[48]

Activity name	Contributing partner
Development and enforcement of evidence-based, gender-responsive renewable energy policies and legislation in Iraq	UN Women, Global Environment Facility (GEF)
Generating green energy (solar energy) for operating water pumps in selected communities	Bureau of Population Refugees USA Department of State, European Commission, Government of Germany, others to be identified
Improved resilience to transboundary sand and dust storms in Kuwait and Iraq (hard pipeline project)	Kuwait Fund for Arab Economic Development
Strengthening climate resilience of vulnerable agricultural livelihoods	Ministry of Health, Ministry of Agriculture
Strengthen Iraq's capacity to access global climate financing through a Nationally Determined Contribution (NDC)	Green Climate Fund (GCF), United Nations Development Programme (UNDP)
Guidance materials developed to establish range of ecosystem-based adaptation technologies options, and practices suitable for marshlands	UNDP
Support capacity building of climate change negotiations under UNFCCC and Paris Agreement	UNDP
Knowledge on energy and environment in building sector of Iraq is developed according to global best practices, and impact of regulatory and institutional framework is regularly monitored and evaluated	GEF
Environmental survey conducted for all governorates	Government of Canada, Government of Czech Republic, Government of Germany, Government of Japan
Enhancing the climate action ecosystem in Iraq in order to support tackling climate change challenges	Government of Germany, Government of Qatar, UNDP
Strength Iraq's capacity to access the Readiness Fund for REDD+ (UN Programme on Reducing Emissions from Deforestation & Forest Degradation)	International Committee of the Red Cross
Strengthen Iraq's capacity to adopt Nationally Appropriate Mitigation Actions (NAMA)	United States Agency for International Development
Develop policy to support the transformation of Iraq's industries towards sustainability	GCF
Support climate change and biodiversity nexus: Nature-based solutions and economic evaluation for the socio-ecological sites and ecosystem services in Iraq	GEF
Rehabilitation of water network infrastructure in conflict-affected areas	European Union Trust Fund

Other UN project funding partners in Iraq, primarily focused on post-conflict restoration under the SDG goal for 'Sustainable Cities and Communities' in addition to those mentioned above, include the European Union, Adaptation Fund, Al Waleed Foundation, MADAD Fund, Kreditanstalt für Wiederaufbau, World Bank Iraq

[48] Iraq.un.org

Trust Fund (ITF), Belgian Development Agency, Government of Norway, Government of South Korea, Government of Sweden, United Kingdom Department for International Development.

The third important category under UNFCCC Climate Finance is private finance mobilised by public climate finance. Iraq's private sector has played an important in land restoration and the utilisation of smart irrigation systems that may have positive impacts for water and food security. Fadak Farm, for example, was established in 2016 by the Shia Endowment Authority as part of an agricultural initiative launched by the Iraqi Ministry of Agriculture, exhibiting how the government can combat management and institutional capacity issues by collaborating with other sectors. Al Babteen farm, a land-reclamation project developed by a private investor from Kuwait, uses advanced systems to desalinise groundwater for irrigation—indicating the high potential for regional collaboration to combat agricultural and water sector issues in Iraq, including desertification and saltwater intrusion. The recent rise in agriculture projects funded by the private sector present a plausible approach for strengthening Iraq's climate change response while keeping direct costs relatively low.[49] Compared to other parts of the world, the Arab region has low rates of private capital mobilisation for financing larger infrastructure projects. Out of a world total of USD 2.5 trillion by 2014, private participation in infrastructure in the Arab region (excluding high income countries such as Bahrain, United Arab Emirates, Saudi Arabia, Qatar, Kuwait, and Oman) reached only USD 113.5 billion between 1990 and 2014—less than 5 percent of global PPP activity.[50] However, Iraq has the fourth largest share of PPP activities in the region, with 9 % of its total.

Other climate finance consists of a broad range of public and private funding sources and funds allocated to investments in both developed and developing countries. Green Bonds are any type of bond instrument where the proceeds are exclusively applied to finance or re-finance, in part or in full, new or existing eligible climate projects. Investments in renewable energy are by far the largest components of this type of climate financing; they are also straight forward to define and account for compared to other projects where the financing is much harder to quantify. Domestic climate financing also falls under this category. Relevant national ministries can play a huge role in financing Iraq's mitigation and adaptation technology projects.

9 Dissemination strategy for TAP

As part of the project supported by GCF/UNIDO, the consulting team has delivered a number of regional workshops to inform key identified stakeholders in different parts of Iraq about the project, and most importantly, about its results. The team has presented the action plans for eight prioritized technologies in Baghdad, Erbil, Sulaymaniyah and Dhi Qar, with participants from the regional governments, large local industries and other industry groups present to the workshops. Useful feedback with respect to the regional challenges of deployment of technologies was received, and discussions were initiated regarding the best approaches in involving regional stakeholders in implementation of the TAPs. The Ministry of Environment participated to all of the regional workshops and will remain the key coordinator in bringing the TAPs forward, including collecting feedback from the various stakeholders, initiating the process of

Further dissemination of the TAP report and key project findings is envisaged through the project stakeholders that have been part of the TNA projects and participated in various workshops/exchanges, etc. Over a hundred stakeholders have been included in the TNA process and they represent important institutions, organizations and companies in Iraq that will benefit from the results of the analysis and could be able to take it forward. In addition, the results of the project will be made publicly available both through

[49] https://timep.org/commentary/analysis/iraqs-climate-change-response-the-private-sector-and-civil-society/
[50] https://www.greenfinanceplatform.org/research/financing-sustainable-development-arab-countries

Ministry of Environment's designated web page, as well as through CTCN's network, and consultants. The project management unit within the Ministry of Environment, established for the project, will remain the key focal point in disseminating the project results, as well as communicating its outcomes to other relevant processes within the country – namely, the ongoing work on the National Adaptation Plan, as well as any further revisions of the country's climate strategy, including under the NDC.

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Annexes

Annex 1: Solar PV technology Policy brief

Technical description

Solar photovoltaic (PV) technology converts light photons from sunlight into direct current (DC) electricity through panels made of semiconductor material. The direct current (DC) is than converted to alternative current (AC), through an inverter to be used in households' equipment. The on-grid system is only composed of the PV array and the inverter, in this case the energy is directly used, or fed to the national grid in case of excess. In an off-grid system, batteries are added to store the excess of energy generated for use during the night or on cloudy days. Other auxiliary components are installed for safety and control purpose, known as balance of the system.

PV systems can be either small or large-scale. Small-scale refers mostly to household rooftop installation for personal use, limiting the total generation capacity to a few kilowatts (kW). These systems, usually off-grid and battery powered, provide huge flexibility and a reliable source of energy for users in rural areas often disconnected from the main electrical grid. On-grid systems are more useful in areas with more stable utility grid connection, decreasing capital costs and thus reducing electricity bills for the end user. Large-scale solar PV technology, on the other hand, generates electricity in the megawatt (MW) range and usually comes in the form of on-grid systems requiring huge investments. There are a few of these projects currently in various stages of development or completion in Iraq.

Current technology readiness level or commercial readiness index

PV technology is very well developed and deployed worldwide in all types on and off grid solutions and at different scale, small/large scales. Technology readiness is classified at level 8 (system complete and qualified), for the existence of wide international experience. However, on the commercial level in Iraq, it stands at level 3 (commercial scale up), as the first commercial projects are starting to appear in the country.

Climate rationale of the technology

Iraq's climate and geographical location pose a multitude of benefits for solar PV installation. The country has high levels of year-round sun exposure; up to 85% of its area has an annual generation potential of 1600-1800 kWh/kWp and approximately 10% with a potential between 1800-1900 kWh/kWp, compared to a worldwide average of just 20% and 15% respectively. While providing a reliable source of energy, PV systems will reduce the reliance of the population on the national grid and help mitigate GHG emissions. For every kWh avoided from the national grid, it reduces 0.8 kg of CO_2 emissions.

Estimating the average roof size in Iraq to be around 150 m2, households can install a rooftop PV system with a capacity of 25 kWp, capable of generating around 40000 kWh of electricity per year. For comparison, the average household in Iraq consumes approximately 16000 kWh per year, thus PV systems can help provide energy security for Iraqi households. The abatement potential could range between 12.8 tCO_2 and 32 tCO_2 per household, considering the input above.

Ambition for the technology

Adopting off-grid systems allows households to become self-sustained in their electricity production and consumption, while on-grid systems alleviate pressure on the national grid. Decentralising electricity generation through widespread solar PV technology deployment across all governorates in Iraq can help fill the growing gap between energy demand and current electricity supply, especially in rural areas.

Once the benefits of solar PV systems for personal and utility grid use have been well documented, their use can also be integrated into other sectors and industries. These could include irrigation systems and groundwater extraction for agriculture and water sectors, covering energy needs in commercial facilities, or for use in the light industries (for example food and beverage), where power demand is lower than other more energy-intensive industries. The introduction of solar PV to the industrial sectors helps cut production expenses and make the local products more competitive. With the ability to adapt power supply to each end use, solar PV systems are a renewable, scalable solution to meeting Iraq's electricity demand needs.

An initial target for decentralised solar PV can be set in order of "**hundreds of MW**" based on a detailed assessment of the country potential.

Scale for the implementation and timeline

The deployment of PV solar systems can happen within **weeks or months** based on the system size, as the components are already available in the Iraqi market. Still to accelerate the deployment of the technology, the policy/decision makers should provide a fostering environment for this technology. Most of the enabling activities can happen within less than **2 years** and this include:

- Capacity building
- Providing financial support
- Raising awareness
- Pilot deployment of both on grid and off grid solar PV systems

Few other activities require more time to be achieved. Reform of electricity subsidies for example is not feasible on the short term due to the additional burden that will have an impact on the citizens, within the current circumstances. However, it is one of the key elements for PV deployment and should be planned to be implemented in the long term.

Expected impact of the technology

PV deployment would result in the following impacts in Iraq:

- Provide a reliable source of energy to the population, and help them ensure a higher standard of living
- Create job opportunities within the new energy sector, to design, install and maintain the PV systems, in addition to its positive effects on the productivity of other sectors, like industry and agriculture, which will create indirect job as well
- Fill the gap between the power generation and energy consumption in Iraq
- Reduce energy bill for industrial, agriculture and commercial sector, improving the competitivity of Iraqi products
- Increase the quality, of educational, medical and other services relying on energy
- Reduction of GHG emissions in power generation that mainly relies on fossil fuels in Iraq

Policy actions for technology implementation

Existing policies

- Ministry of Electricity Plan for and Renewable Energy Plan: the plan stresses on the importance of rehabilitation of the power sector, which includes converting open cycle gas turbine plants into the combined cycle with a capacity estimated of 5 GW. It also tackles renewable energy and encourages the deployment of solar PV technology "only" on a commercial scale with 13 potential projects identified.

Proposed policies to enhance technology implementation

1. Update the legal framework: Develop an easy and clear permitting process with simple guidelines for PV systems proposals
2. Develop financial incentives and initiate the private sector to invest in the solar PV technology: Enable the Central Bank financing initiative and develop additional financing mechanisms to support small project for household, with low interest rate.
3. Rehabilitate the national grid: Ensure reliable transmission of electricity through the national grid
4. Effective awareness and use program: Prepare some national guidelines for design, installation, and maintenance
5. Develop a quality control path to ensure good quality products in the market: Prepare a certification scheme for the products in the country and disseminate the certified products to the public
6. Capacity building: Focused practical training for engineers and technical graduates

Key figures

Table 26 presents solar PV technology key figures for Iraq, that can be used for project planning.

Table 26: Solar Technology key figures.

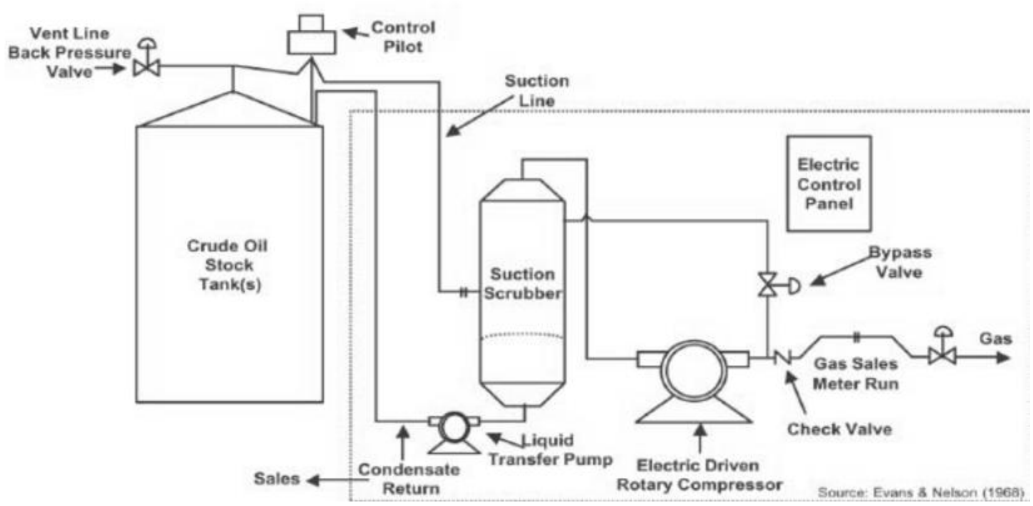
System	PV Ongrid	PV Offgrid
PV energy generation potential in Iraq (kWh/kWp)	1600 to 1800	
Mitigation Potential (kg CO_2/kWh)	0.8	
Cost (USD/kWp)	883	1,651
Operational Cost (USD/kW/year)	9	
Economic Lifetime	25 years For off-grid systems, batteries economic lifetime is 5 to 15 years	
Scalability potential	All regions mainly, Urban areas	All regions, mainly, rural areas

Annex 2: Vapor recovery unit policy brief

Technical description

Vapour, consisting of methane and non-methane volatile organic compounds (VOCs) and other hazardous air pollutants (HAPs, such as benzene, toluene, and hydrogen sulphide), is released from liquid hydrocarbon products during storage and loading due to three different mechanisms: (i) flashing losses, (ii) working losses, and (iii) breathing losses, also known as standing or storage losses. Flashing losses occur when, for example, crude oil or condensate is exposed to temperature increases or pressure decreases during the transfer from production separators or heater equipment into an atmospheric storage tank. While stored, liquid hydrocarbons will continue to evaporate when fluid levels change or tank contents are agitated (working losses), typically during the loading and discharging of the tank. Breathing losses are caused by changes in ambient temperature and barometric pressure, resulting in expansion and contraction of the vapour space.[51] Emissions from storage tanks depend on the status of the tanks, at their highest when the tank is being filled and at their lowest (zero) when the tank is empty. When the tank is full, some remaining vapour is emitted mainly through evaporation.

Figure 18: Vapor Recovery Unit Scheme



A vapor recovery unit (VRU) can be installed to mitigate these emissions. The Figure 18 above illustrates a VRU installed on a single crude oil storage tank (multiple tank installations are also common). Hydrocarbon vapour is drawn out of the storage (stock) tank under low pressure, typically between four ounces and two psi, and is first piped to a separator (suction scrubber) to collect any liquids that condense out. The liquids are usually recycled back to the storage tank. From the separator, the vapors flow through a compressor that provides the low-pressure suction for the VRU system (to prevent the creation of a vacuum in the top

[51] The vapour release rate and composition from a storage tank or loading of a hydrocarbon product will vary over time and depend on fluid characteristics, facility design, and operational characteristics. Hydrocarbon vapour is often mixed with inert gases present in the tank (e.g., nitrogen and carbon dioxide), and the composition of the resultant gas mixture can vary considerably. The average share of methane can range from <1 Mol % up to >60 Mol % (with nmVOCs, HAPs, and inert gases making up the remainder), and can vary considerably over time, for example, during the loading period of a floating production, storage, and offloading units (FPSO) using inert gas as blanket gas. It is relatively common to vent to the atmosphere methane and nmVOCs emitted during storage and loading. It should be noted that the amount of methane vented through storage and loading operations upstream can be very limited in many instances and is highly dependent on the production process (e.g., the vapour pressure of the hydrocarbon liquid being stored).

of a tank when oil is withdrawn and the oil level drops, VRUs are equipped with a control pilot to shut down the compressor and permit the backflow of vapors into the tank). The vapors are then metered and removed from the VRU system for pipeline sale or onsite fuel supply. It is very important to choose reliable, sensitive control systems because the automated gas flow valves must be opened and closed on very low-pressure differences.

Current technology readiness level or commercial readiness index

Vapor Recovery Unit is a commercialized technology and deployed in the oil and gas sector in developed countries. Technology readiness is classified at level 8 (system complete and qualified), for the existence of wide international experience. However, on the commercial level in Iraq, it stands at level 1 (Hypothetical commercial proposition), as until this day there is no vapor recovery unit installed in Iraq.

Climate rationale of the technology

VRU can play an important role in collecting vapour vented from storage tanks, separating it and then using the natural gas liquids (NGLs) and natural gas as valuable products, supplying additional energy on site and to the market. It is estimated that 1 485 kt of methane is vented every year during operations in Iraq, namely oil and gas[52].

The IEA estimates that onshore VRUs can mitigate 1 165 kt of emissions, approximatively 80 % of methane vented from onshore oil fields in Iraq, equivalent to 688 million cubic metres of natural gas. Of the VRU mitigation options, 87% can be abated at a negative cost. Although these estimates are characterized by high level of uncertainty due to unavailability of a detailed national inventory of methane emissions in the country, they give a good understanding of the possible scale of the issue and potential to reduce it.

Ambition for the technology

Iraq holds the world's fifth-largest proven oil reserves, with 145 million barrels totalling 8% of global reserves. In 2019, daily production averaged 4.7 million barrels, the majority of which from onshore oil fields. The oil industry contributes 91 % of Iraq's total government revenues, equivalent to 87 billion USD. Vapour recovery units can be installed on the majority of standard crude oil storage tanks that are not equipped with a floating roof. Emission reduction potential will be highest when installed on tanks with unstabilized crude oil.

Scale for the implementation and timeline

VRUs can be deployed all along the oil and gas sector in Iraq, within the different NOCs and for the different sizes of storage tanks. The deployment of the units from the technical perspective can happen within **months**. However, the governance hierarchy available in Iraq can hinder the deployment and increase the required time, together with lack of required funding. Several key actions can be taken to ensure an enabling environment on the short term **(up to 2 years),** for example:

- Capacity building and pilot projects
- Provide financial support
- Improve the methane emissions database

Expected impact of the technology

[52] IEA Methane Tracker 2022

VRUs impacts exceed the environmental side and can positively affect the country's economy, which is highly reliant on the oil and gas sector. Alongside other methane mitigation measures, this can help reduce the gap between natural gas demand and production. In addition, volatile organic compounds (VOCs) that make up the content of the vapour are known to have detrimental health impacts on people exposed to them over long period of time. Capturing vapours from storage tanks can thus limit the number of VOCs at and around the oil and gas facilities, yielding positive health impacts for the facility staff and communities around it. Some of the expected impacts are:

- Reduction of methane emissions in Iraq and associated burden on the environment and climate
- Increase the NGLs and gas production in the country, which in turn, can be translated in better electricity generation, availability of cooking and transport gas and better livings standards
- Cut costs on imported gas from neighbouring countries
- Generate revenues to the government budget
- Improved health due to reduction of VOCs emitted

Policy actions for technology implementation

Existing policies

- Iraq's Nationally Determined Contributions (NDC): The policy aims to maximise the use of associated petroleum gas (APG), in power generation and other sectors like transport and industry. It also encourages deployment of energy efficiency measures and means of reducing waste gas, which are the nature of VRU technology.

Proposed policies to enhance technology implementation

- Capacity building: Promote expertise exchange related to VRU between international and national oil and gas companies operating in Iraq (for example, through OGCI – Oil and Gas Climate Initiative, Global Methane Initiative, etc).
- Update the national regulations: Enact methane regulations including setting targets for methane emissions.
- Provide a supporting financial environment: Clarify and promote the financing of VRU through the environmental budget allocated within the Ministry of Oil and international markets
- Build national database of methane emissions: Improve the national inventory using Tier 3 method
- Pilot projects and awareness: Launch pilot projects in different regions in Iraq

Key figures

Table 27 presents vapor recovery unit technology key figures for Iraq, that can be used for project planning.

Table 27: Vapor Recovery Unit key figures.

Technology	Vapor Recovery Unit
Application Potential in Iraq	All storage tanks with fixed roof (High potential in Iraq)
Mitigation Potential (kt of methane)	1 165
Cost (kUSD/ tank farm)	200 to 1 000
Annual Operational Cost (USD)	1-5%
Economic Lifetime	15
Scalability Potential	The entire oil and gas sector in Iraq

Annex 3: Probabilistic flood forecasting Policy brief

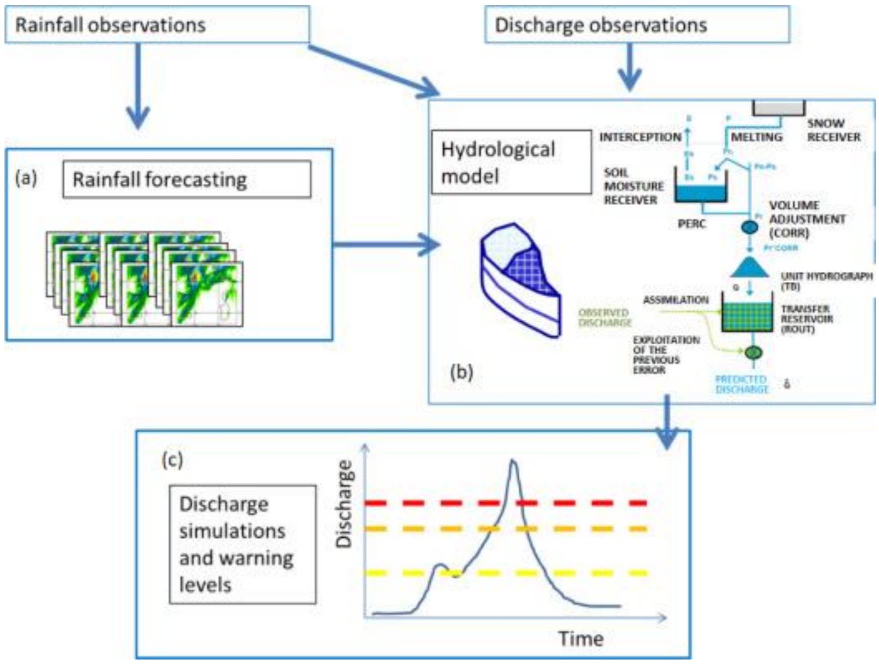
Technical description

Probabilistic flood forecasts provide a range of possible forecast outcomes that indicate the probability of a flood occurring. 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. These will include differences in water levels, rainfall intensities, wind speed, and other meteorological variables to reflect the uncertainty involved in the forecasting. The ensemble of the forecasts is then run through forecasting systems that generate an overall probabilistic forecast through Bayesian[53] systems based upon a robust theoretical framework used for probabilistic forecast through deterministic hydrologic model of any complexity. 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.

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). 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.

[53] 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.

Figure 19: Example structure of information flows in a probabilistic 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.

Current technology readiness level or commercial readiness index

Probabilistic flood forecasting is deployed in developed countries, the United Kingdom for instance. The technology itself stands at technology readiness level TRL 8 (system development), still on the commercial side, in Iraq it is still at commercial readiness index CRI 1 (hypothetical commercial proposition).

Climate rationale of the technology

Iraq is witnessing frequent flooding in the last few years, as a direct effect of climate change. Floods are recurring more often in the northern region and in the Wasit governorates. The ability to foresee floodings can help reduce the damages resulting from floods, including on the agriculture sector and livelihoods of thousands of people.

Ambition for the technology

It is envisioned that the implementation of probabilistic flood forecasting will begin with priority river basins and floodplains within Iraq and gradually expand to the entire country. Priority basins will be selected based on several factors, such as historical flood risk and planned socio-economic development. These will serve as pilots for the implementation of the technology and allow for collaborative capacity development, skills transfer, and knowledge sharing. This will also allow the methods and procedures to be adapted to the context of Iraq's governmental management systems and structures to ensure that information feeds through the correct channels for effective flood management and response. Completion of implementation in the pilot basin/floodplain will establish a set of local best-practice for the Iraqi context and thus allow the expansion of the use of the technology to be refined and further adapted for improved suitability.

The technology can be implemented at a national level and as capacity is developed, this can be sub-divided to provincial and eventually district-level forecasting. These sub-divisions of forecasting can feed into a larger national forecasting and data collection system. It will be critical that the skills and knowledge for implementing probabilistic flood forecasting are institutionalized at all levels of government. Diffusion of skills and knowledge related to this technology down from the national level will allow for a robust flood forecasting and management network to be established and will also allow for forecasting to take into consideration local needs and knowledge.

Scale for the implementation and timeline

As explained above, the technology can be developed at different scales and preferably starting with the priority region. The deployment can be done in short to medium term. The time-consuming part can be to build capacity with the institutions' personnel and provide reliable data as inputs. Projected costs for a project of this nature are likely to be approximately US$10 million, with a timeline of >36 months.

Expected impact of the technology

Flood forecasting presents several advantages:

- Save lives, by issuing an early warning in areas with high flood probability
- Initiate protective measures to counter-floods and early mobilisation of flood management resources
- Decrease the losses resulting from floods, like the loss of crops, and material damage
- Help enhance the water resources management

Policy actions for technology implementation

Existing policies

- National Development Plan 2018-2027: the document reflects several targets related to water management, such as providing potable water according to international standards, laying water networks, preparing a plan for water resources management

- Nationally Determined Contribution of Iraq: the NDC lays out key objective for the water sector of increasing the resilience of the country's water resources through the adoption of an integrated approach that addresses the growing future demand for water, reduces the potential deficit by developing water uses in line with the challenges of climate change.

Proposed policies to enhance technology implementation

- Develop technical skills: collaboration with academic professionals at the local and international level
- Establish technical systems: requisition of physical facilities and equipment (computers and software), data collection systems
- Ensure governance systems for the effective running of probabilistic flood forecasting: provide a clear communications procedure between the experts and decision makers