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Engineering
Net Zero
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OUR NET ZERO BLUEPRINT FOR THE FUTURE

Contents

LEADING A LOW CARBON FUTURE

The Net Zero Challenge

The recent release of the Intergovernmental Panel on Climate Change Working Group II Sixth Assessment Report[1] made clear that time is running out for governments and industries to take the required actions to reduce their emissions in line with commitments outlined in the Paris Agreement.

It stated that climate change is a threat to human well-being and that the world will face severe impacts even if global warming exceeds 1.5oC just temporarily. The report wrote that progress on adaptation has so far been uneven, with growing gaps between actions needed and actions taken to make deep cuts to greenhouse gas emissions.

Countries globally are implementing long-term strategies to reduce their greenhouse gas emissions, promote circular economy practices and ensure that their future-focused planning enables measures to minimise their carbon footprint. The question is whether planning has been done holistically and whether there is enough urgency in those plans.

Net Zero means achieving a balance between the levels of greenhouse gases emitted and the amount removed from the atmosphere. This can be achieved through multiple strategies and will need a mixture of approaches that each provide an incremental benefit to produce the transformational shift required.

The urgency for Gulf Cooperation Council (GCC) nations is to drive change that:

- reduces both their per capita greenhouse gas emissions – among the highest in the world throughout the bloc – and those of their heavy industries, such as metals manufacturing, oil & gas, conventional power generation, and water desalination.
- reduce its reliance on fossil-based road transport and demand side inefficiencies within the built environment, by decarbonising new infrastructure and reducing emissions from existing buildings and industrial facilities.

Capitalises on new technologies and skills as a long-term plan to replace oil & gas revenues.

Within the GCC, the UAE was the first country to commit to becoming Net Zero by 205 [2], making the announcement shortly before COP26 took place in Scotland, UK. It was quickly followed by the Kingdom of Saudi Arabia and Bahrain, both of which committed to a 2060 date. So far, the other GCC countries of Qatar, Oman and Kuwait have not announced commitments to Net Zero. It was also announced during COP26 and the upcoming two meetings would be held in the Middle East – Egypt in 2022 and the UAE in 2023, placing urgency on their respective governments to introduce decarbonisation initiatives.

Implementing net-zero carbon plans is a complicated engineering challenge that will require clear strategies, a willingness to invest in (and encourage) new technologies and an understanding of the various interdependencies across industries within each country. Remember that this region has a phenomenal ability to deliver when there is government commitment, and can implement complex projects and programmes at a pace that is the envy of the world.

This report is the first in the GCC to focus on three major interdependencies – energy, the built environment and transport, highlighting the opportunities, risks and recommendations for each. The recommendations are broad recognising that data isn't readily available publicly, and that given we are covering multiple countries, there isn't a one-size-fits-all recommendation. For reasons of space, it focuses mainly on Saudi Arabia and the UAE, but in most cases the opportunities, risks and recommendations made can be applied to all GCC countries.

Why are we, SNC-Lavalin, publishing this?

As a global and regional leader in fully integrated professional services and project management, SNC-Lavalin is at the forefront of 'Engineering Net Zero' (ENZ) in a number of countries, leading the engineering industry to achieve Net Zero Carbon as rapidly as possible, and helping clients manage climate risks and build climate resilience.

Energy

The nirvana of 100% clean energy for most nations is far off, including those in the GCC, despite the continued focus on solar (and in some cases nuclear and wind) power. The future electricity mix will require the integration of different forms of clean and renewable energy with reduced levels of fossil fuels to ensure that electricity grids remain stable and dependable for people and businesses, whilst also being affordable. This is what is known as the energy trilemma, and is covered in detail in our other Engineering Net Zero Reports.

The energy system, without doubt, gives the biggest opportunity for decarbonisation and there is hard interdependency between the energy system, transport and the built environment.. An obvious example is transport and government policies that increase electric vehicle use.

Transportation

Investment is required into cleaner public and industrial transport, such as interconnected and more extensive rail networks, metro and tram systems and bus lines. Where passengers and freight cannot use public transport, there must be greater emphasis on electrification for cars, last mile options such as active travel, micromobility, bus-on-demand and alternative fuels, such as hydrogen fuel cells for fleet or heavy vehicles (both land and marine). Investment in technology must also be accompanied by efforts to manage the demand for travel, to change public attitudes and nudge shifts in behaviour.

Built environment

Underpinning these transportation plans is a greater focus on sustainable master planning, for both cities and rural communities. The GCC has an advantage over much of the world in that a sizeable amount of planning in the region is still greenfield, providing the opportunity for master planners and governments to create mixed-use communities that can be accessed and navigated by walking, cycling and micromobility rather than by car, with more essential services within easy reach of those living or working in an area, better public transport connections and less focus on road networks. Enhanced building design and facilities management will ultimately reduce the overall national energy demand.

Net Zero targets

Meeting net-zero targets takes time, effective policies, engineering advancements and government will-power. Time is not a luxury on offer, but having target dates for Net Zero will motivate GCC countries to focus on planning schedules and accelerate build times, especially for energy systems. Carbon reduction strategies are required urgently to dent current emissions levels, which for the GCC are among the highest in the world on a per capita basis.

Significant levels of public and private investment will be required to meet Net Zero targets. This is likely to affect prices, either through governments looking to recoup some of their investment or through people and organisations needing to buy more efficient but more expensive alternative products as the less efficient or more carbon-heavy options are phased out. Therefore, a well-thought-out communications strategy explaining the importance, potential impacts, and financial subsidies or incentives should be coupled with any Net Zero drive.

To meet their Net Zero targets, the UAE and Saudi Arabian governments have each released strategies that provide key milestones at either a country or, for the UAE, emirate level. All GCC countries have also signed up to the Paris Climate Agreement, and five of the six countries in the bloc released updated Nationally Determined Contributions (NDC) to the UN Framework Convention on Climate Change (UNFCCC) in 2021. To some extent, the NDCs provide the targets, and the 2050/60 Net Zero strategies will provide the roadmaps of how countries will become low-carbon societies.

Saudi Arabian, UAE and Bahraini low carbon targets and strategies

Inevitably there is an overlap between the UNFCCC NDCs submitted and the individual Net Zero 2050/60 strategies.

Currently, Net Zero plans are in their early stages and broad brush, rather than detailed. We have included Bahrain's strategy, as this has also been announced.

	Nationally Determined Contributions
UAE [3]	Reduce greenhouse gas emissions by 23.5% by the end of 2030 compared to business as usual. This will remove approximately 73 million tonnes of emissions.
	Half of the country's installed power will be from renewable energy and nuclear by 2050; 75% of Dubai's electricity will be from clean energy sources by 2050.
	A 40% reduction in energy use by 2050 through improved demand side management efficiencies and building retrofit programmes managed by each emirate.
	Heavy industries, oil & gas, water, transport and waste management sectors will contribute to decarbonisation measures. For instance, Abu Dhabi National Oil Company (ADNOC) plans to cut its emissions by 25% by 2030, and under Dubai's Green Mobility Strategy, 2% of the emirate's road fleet, and 30% of government vehicles, will be electric or hybrid by 2030.
SAUDI	Remove 278 million tonnes of CO2e annually by 2030 compared with greenhouse gas emissions in 2019 - more than double the original NDC target of 130m tonnes of CO2e annually.
	Shift its power feedstock from a reliance on oil. By 2030 half of power generation will come from renewable sources, with the rest from natural gas. Renewables will be a mix of solar Photovoltaic (PV) and Concentrated Solar Power (CSP), wind, geothermal, waste-to-energy and green hydrogen.
	Reduce energy consumption through a major retrofit programme in 110,000 government buildings, 35,000 public schools, 100,000 mosques and 2,500 hospitals and clinics, plus 2 million streetlights.
BAHRAIN	5% of peak capacity will come from renewable energy by 2025 and 10% by 2035.
	Whilst these are all credible targets, all countries in region would benefit from having a holistic roadmap which encompasses the real link between demand side (transportation/infrastructure) and supply side of energy production, storage and distribution.

GCC commitments and 2050/60 Net Zero initiatives

Different ministries will develop their implementation plans, including those covering energy, economy, industry, infrastructure, transport, waste, agriculture, and the environment.

Clean energy will be one of the main pillars. To date, the UAE has invested about $40bn into the sector, and will spend about AED600bn by 2050. By 2030 it will produce 14GW of clean electricity, mainly solar and nuclear [6].

Carbon capture programmes will be continued. Some of the country's heavy industries will begin to decarbonise over the coming years.

The kingdom will invest $187bn to meet its Net Zero 2060 commitment, which it will reach by adopting a carbon circular economy. Its approach will include the use of carbon capture, increasing its use of renewable energy, green hydrogen production and through afforestation, by planting billions of trees.

A key milestone will be a 30% reduction in its methane emissions by 2030. Also by that date, 30% of cars in Riyadh will be electric and it will have halved the capital city's carbon emissions.

The kingdom will adopt a circular carbon economy, with atmospheric CO2 recycled, reused or removed, using technologies such as carbon capture and through afforestation, including quadrupling the size of its mangrove coverage.

By 2035, it will have reduced emissions by 30% and increased its renewable energy provision.

Government and industry leaders met in November 2021 in Glasgow, Scotland for the latest round of UNFCCC's Conference of the Parties (COP) meetings. These built on the 2016 Paris Climate Agreement, and discussed opportunities to meet 2050 goals, along with milestone targets.

Outcomes announced at COP26 were designed to reduce greenhouse gas emissions and improve climate and human health [7]. These included improvements in transport, energy and the built environment. Discussions and declarations also focused on access to finance, and different forms of investment, which are imperative to fund many of the planned initiatives [8].

Egypt will host COP27 in November 2022 and the UAE will host COP28 in November 2023.

The UAE government said it would make COP28 a "solutions COP" and involve the youth population in the negotiations to ensure actions and decisions will meet the needs of future generations [9]. It is expected that hosting COP28 will be a catalyst for new sustainability-focused initiatives in the UAE. Recent initiatives have included bans on single-use plastic bags being introduced in Dubai and Abu Dhabi [10, 11].

COP26 outcomes and opportunities for GCC countries

Actions discussed during COP26 will be met through combinations of sharing best practice standards and regulations, providing support to developing countries for the transition and promoting new skills and training that provide future employment, and working together on innovation and technology advancements.

The below declarations highlight where there are key opportunities or actions being taken by GCC countries.

ENERGY DECLARATIONS

The ongoing energy transition, as governments implement strategies to reduce their reliance on fossil fuels, is of particular relevance to GCC countries, both economically and due to their reliance on oil or gas for electricity generation.

Countries agreed to support clean energy transitions and to double the use of energy efficiency products by 2030, particularly high electricity consumers, such as air conditioning, motors and lighting. This aligns with the announced 2050/60 plans (see box 1) around buildings retrofits, which will reduce demand side management and create new opportunities for companies that offer facilities management services.

Working groups will collaborate to accelerate the commercialisation of clean energy technologies, including green hydrogen, sustainable aviation fuels, CO2 removal through direct air capture, and long-duration energy storage [12]. Economic plans within the GCC will see the region increasingly reliant on green hydrogen opportunities for export (see Hydrogen section) and cleaner aviation will be an important decarbonisation contribution due to the significant transport hubs in the region.

In addition, the Green Grids Initiative calls for more clean energy trading across borders, with efforts brought together through an interconnected global grid. This was endorsed by Oman, Saudi Arabia and the UAE [13], each of which shares electricity through the GCC Interconnected Grid. Saudi Arabia has also signed agreements to share electricity with Egypt and Jordan.

TRANSPORT DECLARATIONS

Road transport accounts for more than 10% of global greenhouse gas emissions according to the COP declarations and action plans called for a new normal by 2030 of making zero emissions vehicles "accessible, affordable and sustainable" globally [14].

Recent announcements by both Saudi Arabia and the UAE points to action here, particularly around government-owned fleet vehicles (see Electric Vehicles section). Governments, the car industry and investors will work towards more zero emissions vehicles being on the road by 2040 (and 2035 in leading markets) [15]. Saudi Arabia is working with electric and hydrogen vehicle manufacturers Lucid Motors and Gaussin within the kingdom towards this aim, creating significant opportunity for more low-carbon vehicles on its roads [16, 17].

The aviation sector, which plays a major economic role in the GCC, is actively exploring steps to decarbonise and COP26 commitments included actions to reduce CO2 emissions, with a commitment to be Net Zero by 2050 [18]. Airlines such as Abu Dhabi's Etihad are actively involved in research into use of sustainable aviation fuels and manufacturers of the fleets used are working towards low- and zero-carbon aircraft technologies (see Aviation section).

For maritime shipping, there was a commitment to clean fuels, zero-emissions vessels, alternative propulsion systems and landside infrastructure to support these changes. The declaration supports the development of green shipping corridors, where there are zero-emission routes between two or more ports [19].

BUILT ENVIRONMENT DECLARATIONS

COP26 agreed that by 2030, there will be at least 50 large-scale, urban-based integrated demonstration projects that provide a pathway for other cities to learn from and adopt net-zero carbon solutions. Saudi Arabia's giga city development plans will provide significant learnings and proof of concept around smart, sustainable cities in the coming decades.

The Urban Transitions Mission will cover housing, transport, energy and materials access, production and consumption, and industry, all important areas for the region. The GCC continues to be in a period of large-scale building. Some $60.2bn of construction projects – including new giga cities - are forecast to be awarded in 2022, led by Saudi Arabi and the UAE [20].

Saudi Arabia's Ministry of Energy will co-lead a working group that will investigate the use of Carbon Dioxide Removal technologies to reduce emissions by 100 million metric tonnes annually by 2030.

Two missions will also investigate how to decarbonise heavy industries, such as steel, cement and chemicals. These will investigate net-zero strategies and approaches, and use of biorefineries to supply the energy needed to generate the heat required by these industries [21]. The UAE already captures CO2 from its steel industry for use in Enhanced Oil Recovery, and there are ongoing strategies to manufacture green steel and aluminium using green hydrogen (see Hydrogen section).

GCC Opportunities for Decarbonising

For GCC countries, the government policies and strategies will greatly contribute to Net Zero or decarbonisation plans. The six countries have among the highest per capita carbon dioxide emissions in the world, highlighting the importance of government plans to reduce footprints.

World Bank data ranks Qatar, Kuwait, UAE and Bahrain in positions one-to-four for the highest per capita emissions, with Saudi Arabia 10th and Oman 12th. While Qatar's per capita emissions are the highest in the world, its small population means that total emissions are lower than those of Saudi Arabia and the UAE.

Saudi Arabia, along with other GCC countries, will continue to be reliant on oil & gas for their economic growth. In its submission to the UNFCCC, the Saudi Arabia made clear that it will continue to pump and export oil as it attempts to decarbonise at home. Those indirect emissions will not be included in its Net Zero targets.

Saudi Arabia is both the world's largest oil exporter and the region's highest oil consumer, giving the government significant leeway to introduce policies that cut use and bring down its greenhouse gas emissions

As the GCC's most populous country of almost 35 million people, its high CO2 emissions are exacerbated by its economic reliance on fossil fuels-related heavy industries, and continued high use of oil in its power stations, which accounts for 39% of the total feedstock [21].

Put simply, for countries to decarbonise, they first need a strategy of electrification and to build a low-carbon electricity system (which would include demand side reductions). Where it makes little sense to electrify, for instance with heavy or marine transport and heavy industrial processes, strategies should focus on alternative fuels such as hydrogen or a derivative. Where this is not possible, the strategy needs to include carbon capture and storage.

The UAE and Saudi Arabia's efforts to decarbonise are following this approach across energy, transport and the built environment, and this is presenting opportunities to reduce emissions as well as develop new technologies, skills and jobs. Along with Oman, they have developed long-term strategies for the upcoming hydrogen economy, with plans to build plants and export agreements being signed.

While carbon emissions in the UAE continue to be high, they are falling. The Dubai Carbon Abatement Strategy has reported that emissions fell two years in a row - by 22% in 2019, against a target of 16%, and by 33% in 2020, although this was with the backdrop of reduced travel due to the Covid-19 pandemi [23, 24]. That latest figure was achieved by increasing both the emirate's renewables capacity to 11.4% of its total energy mix and the use of district cooling, saving 650GWh of electricity, highlighting the role that both can play in a decarbonisation strategy in a hot climate.

The following pages detail opportunities to decarbonise across each of the interdependent areas.

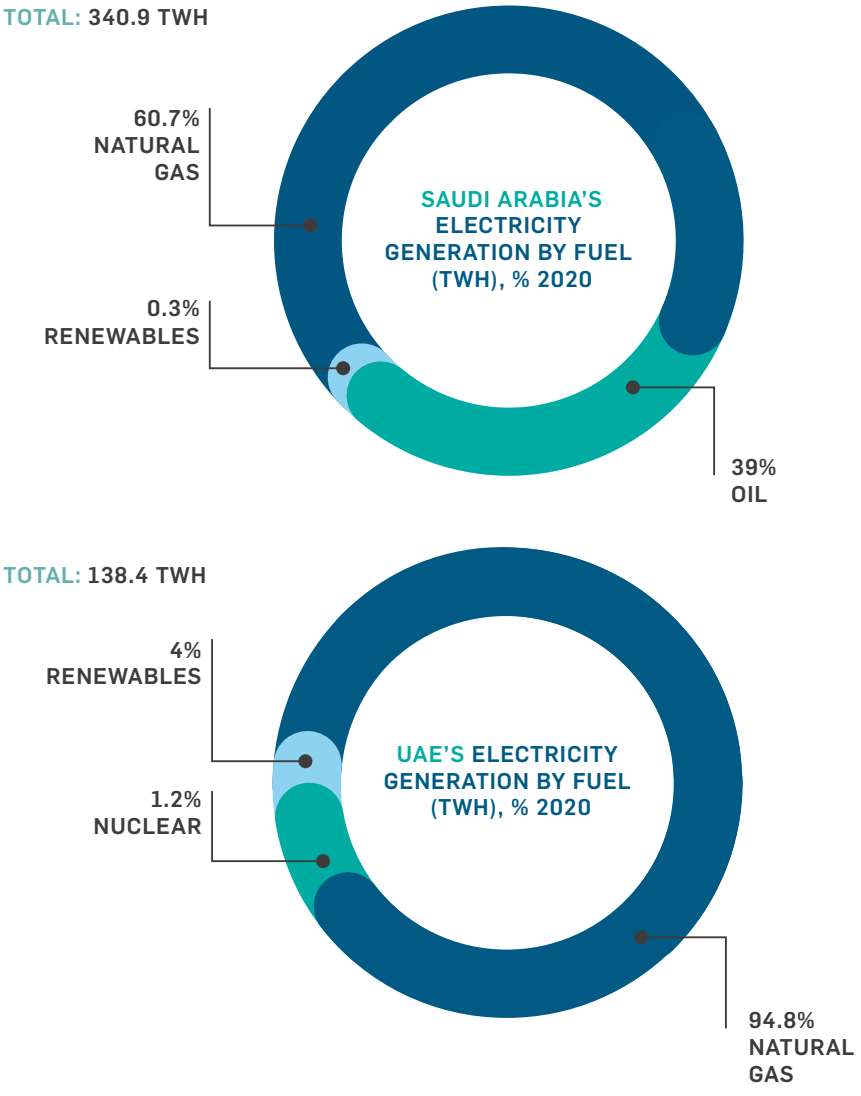
Tied to this of course, all GCC countries will be looking at what economic benefit from the massive oil and gas reserves can be delivered in a decarbonised world.

Energy

The ongoing energy transition within the GCC is the foundation of government Net Zero strategies.

Decisions around heavy industry, the built environment or transport, directly influence opportunities within the energy sector. This is reciprocal; a reliable and affordable energy system allows society to function. Creating an energy system of the right scale and the right time, needs close interaction with the users of that energy.

GCC countries are developing a mix of utility-scale solar, wind, waste-to-energy, and nuclear power as part of their planned low-carbon energy mix, although it is possible that build rates of both generation and grid integration projects (which must be considered in conjunction) may need to accelerate to meet government timelines. Today, the six countries are reliant on gas or oil as a feedstock for electricity generation and desalination, making clean approaches a priority if they are to meet their long-term decarbonisation goals. New thermal plants can make use of carbon capture technology. Whilst there is a cost to this, and generally a trade-off with electrical output, most developers (and reputable lenders) will not be able to develop or back new plants without a form of carbon capture in place, due to their green policies.



SOURCE: BP STATISTICAL REVIEW OF WORLD ENERGY 2021

RENEWABLE ENERGY

In the coming years, clean and renewable energy will increasingly decarbonise the region's energy mix. The Middle East is naturally an optimum region for solar technology.

The UAE has pushed ahead with solar projects, mainly PV with one concentrated solar plant, which due to its nature, provides an element of energy storage far better than traditional PV. Within Abu Dhabi, Taqa plans to increase its power capacity from 18GW to 30GW by 2030, of which 30% will be renewable energy [25]. Dubai is building the 5GW Mohammed bin Rashid Al Maktoum Solar Park (MBRSP). To date, 4GW of Abu Dhabi's clean energy schemes and 1.6GW of Dubai's solar plant are operational. Building is also underway in the UAE for several waste-to-energy plants.

For Saudi Arabia, the renewable energy opportunity also highlights one of the greatest risks to its plans. It is in the early phases of major development plans for new cities and improved services. Its investment plans are vast and include building swathes of energy infrastructure in the coming years. With such ambitious plans in place, it is likely that there will be competition for resources across projects internally as well as with GCC neighbours. Within Saudi Arabia's Vision 2030 strategy, the kingdom's energy consumption is expected to increase three-fold. It set an initial target of implementing 9.5GW of renewable energy by 2030 [26].

Perhaps the best-known upcoming giga city is NEOM, which will cover an area almost the size of Belgium. Plans call for it to be powered 100% from renewable energy. If energy projects run to schedule, by 2030 it will have an installed capacity of at least 16GW of solar PV and 7GW of onshore wind. That 16GW figure includes 4GW of PV solar and wind along with energy storage to supply its planned green hydrogen and ammonia plant, which is targeting a commissioning of 2025.

Schedules are in place for a further 1.3GW of wind and 2.6GW of solar PV, each across different projects. These have commissioning dates of 2026, leaving a further 4GW of wind and 11GW of solar PV projects to be announced and completed in the coming eight years.

Given that the announced projects each take typically 3-4 years to build post-award, the remaining capacity will need to be split into multiple contracts with their construction overlapping to meet the 2030 deadline.

The risk, if course, with large amounts of renewables is the energy storage requirements, which should not be underestimated. A city of 20 million people might need 300GWh of energy storage to enable it to be powered 24 hours. To put that in context, that would be 300 times larger than the worlds currently largest operational energy storage facility.

As the different cities develop, provision needs to be made for the competing demands and that electricity requirements have been accurately forecast. This then flows into implementation and tenders needed to properly planned and efficiently awarded, and enablers for the grid system (both within country and its neighbouring connections) to be able to react to this sizeable amount of intermittent renewable energy.

HYDROGEN

There is an upcoming rush globally to build the infrastructure required to produce green hydrogen and ammonia. Today, about 70-80 Mt (Mega tonnes) of hydrogen is produced worldwide annually, used mainly in fertiliser. US company Fitch forecasts this will rise by 15-25Mt/y by 2030. Green hydrogen is expected to be a 10Mt/y market by that date, accounting for about 10% of total production, compared to 0.7% today [27].

With the push for hydrogen, the above forecast seems conservative if all plans reach fruition. Recent announcements alone will total around 25Mt/y of green hydrogen in the coming years, suggesting production will quickly surpass the Fitch 2030 forecast (accepting that some companies have not announced a date for full production), and there will some sharp competition to the GCC in the production of green hydrogen, with countries like Australia, US and France announcing sizeable green hydrogen projects to be completed prior to 2030.

The UAE, Saudi Arabian and Omani governments have identified hydrogen as a major economic opportunity and are planning to build multiple production plants. This is understandable, given that the global hydrogen market, including blue and green, is forecast to be worth $700bn by 2050, according to Bloomberg [28].

Much of the hydrogen produced in the GCC will be converted to ammonia and exported globally. Strategically this is a major opportunity for this region to develop new workforce skills, build new infrastructure and diversify individual economies away from fossil fuels. Ultimately, green hydrogen and its derivatives could be a very credible source of national revenue in light of potential reducing revenues from oil & gas over the next 30 years.

The attention has been on green hydrogen plans, using water and renewable energy, although the UAE and Saudi Arabia will also produce some blue hydrogen, which uses conventional steam methane reforming of natural gas, but with carbon capture. The UAE has a stated target of 25% export market share for hydrogen and its derivatives in key markets by 2030, focusing on Japan, South Korean, India and Europe.

SAMPLE OF GREEN HYDROGEN PROJECTS AS COMPARATOR

SELECTED ANNOUNCED GREEN HYDROGEN PROJECTS	COUNTRY	PRODUCTION (m t/y)	CAPACITY (GW)	PRODUCTION DATE
NEOM/Helios Green Hydrogen plant	Saudi Arabia	0.24	4	2025
Green Energy Oman	Oman	1.8	25	2038
Fortescue Future Industries	Australia	15.0	200	2030
HyDeal Ambition	France	3.6	67	2030
Western Green Energy Hub	Australia	3	50	2030
Hydrogen City	USA	2.5	60	2026
National Development and Reform Commission	China	0.1-0.2	Not stated	2025

Overall, the GCC will have many competitors globally for the green hydrogen it produces. Several of the international schemes will produce significantly more than the planned plants in the GCC, with many due to begin production by 2030.

The electrolysers used in green hydrogen production can contribute to the energy mix though, and with the right engineering flexibility on production of hydrogen coupled with its storage, have the ability to act as a primary and secondary response reserve to the electrical grid. This means a facility could act as temporary batteries to help manage any grid fluctuations. This is an example of how the right engineering can push the boundaries of new and existing technologies, and help with grid stability as more renewables are added.

Including demonstration projects, there are seven planned hydrogen facilities in the UAE at various stages of development. Combined, they have an announced production capacity of 700,000t/y, of which 500,000t/y will be green.

The UAE's hydrogen plans are a major part of its Net Zero 2050 strategy, particularly for industries where decarbonisation is difficult. In addition to export, the hydrogen will be used for road, air and sea transport, power storage and steel production.

Both Emirates Steel Industries (ESI) and Emirates Global Aluminium (EGA) are investigating green hydrogen use for production of their respective metals. Taqa and ESI are examining the production of green steel, with the hydrogen feedstock produced using clean energy. Details have not been announced, but this may include solar and/or nuclear.

In addition to creating a new green steel revenue line for the company, it would also provide the potential opportunity to bottle the oxygen by-product, which could be sold to other industries such as glass production, steel, food & beverage manufacturing and healthcare. If the scheme is given the go-ahead, it would take about three years to build the hydrogen manufacturing facility. ESI will require numerous electrolysers to produce about 100,000t/y of hydrogen.

The energy required for aluminium production accounts for about 60% of the industry's greenhouse gas emissions. EGA is exploring whether it can replace natural gas with hydrogen-blended fuels for its 33 GE turbines, which together with a recent H-class combined cycle gas turbine unit supplied by Siemens, generate 5.2GW as part of its decarbonisation strategy. In addition, the company is exploring if it can integrate carbon capture and storage at its power plant. EGA is producing a small amount of green aluminium using solar power, taken from the MBRSP. It uses 560,000MWh of solar to produce 40,000 tonnes of green aluminium.

ADNOC produces 300,000 tons of blue hydrogen a year at its Ruwais Industrial Complex (with plans to expand production to 500,000t/y), and is building a facility in the Taziz Industrial Chemicals Zone in Ruwais that will produce 1 million t/y of ammonia. Start-up is slated for 2025.

There is also a demonstration project at MBRSP that is producing green hydrogen during daylight hours which is then used at night to produce electricity.

Saudi Arabia wants to be both the world's largest hydrogen exporter and produce the cheapest green hydrogen. If plans come to fruition, it will export 4M/y by 2030 [29].

Saudi Aramco is running pilot studies into the use of blue hydrogen for use in transport, working with Air Products and Toyota. To advance the use of hydrogen in vehicles, it also has a feasibility agreement with French clean transport company Gaussin, to manufacture on- and off-road hydrogen vehicles in the kingdom.

It is also producing blue ammonia for export, working with Saudi Basic Industries and the Institute of Energy Economics in Japan. From 2024, it plans to use gas from its Jafurah gas field to produce blue hydrogen, with large scale exports beginning from 2030.

RISKS TO HYDROGEN PRODUCTION

Building so much green hydrogen production capacity in so few years is a major engineering challenge that will require the installation of both significant amounts of clean energy capacity and additional manufacturing capacity for electrolysers. These schemes will use large amounts of desalinated and then polished water (it takes 9 litres of water to produce 1kg of green hydrogen, plus significant quantities again to cool the electrolysers). The desalination requirements create sizeable power and cost impacts to the economics of Hydrogen.

The rush of schemes has also highlighted a major bottleneck in the electrolysers. Today, the largest electrolysers are 20MW PEM and can produce about 3,200 tonnes of hydrogen a year, meaning for these large-scale plants many will be required. Although there is a research & development path to increase their capacity well above 20MW, this will take some years.

Currently there is insufficient electrolyser manufacturing capability to service UAE, Oman, Saudi and global schemes planned, which will mean governments and organisations competing for resources. The scheme planned by Australia's Fortescue Future Industries for instance will also see the company build an electrolyser facility to meet its 15mt/y production target.

IEA figures indicate that in 2020, the global electrolyser capacity was 3,000MW but that the pipeline could reach 17GW by 2026 [30]. Manufacturing capacity needs to ramp up rapidly to meet planned green hydrogen capacities.

Other risks exist around storage and transportation of Hydrogen, which involve costly heavily engineering equipment.

Green hydrogen is more expensive to produce than conventional hydrogen, and prices will need to fall for it to be more competitive. This will almost certainly happen as production scales and competition increases. Reported prices vary, but the production cost of green hydrogen globally is almost double that of blue. However, a recent report suggested for Gulf states, the opposite will be true in some countries. Blue hydrogen, the report stated, would cost between $4.66 and $4.80 per kilogram [31].

The UAE and Saudi Arabia turned solar energy prices on their head, rapidly driving down costs, and they could repeat this with green hydrogen using the solar plants either in place or being developed. The warning sign will be water desalination costs, as this region is reliant on desalinated sea water as feed to the electrolysers. Additional water will be required for cooling the electrolysers. This cooling water may be raw sea water or desalinated water depending on site specific factors.

This presents an opportunity for GCC countries to agree terms with manufacturers to build in-region facilities, creating new local jobs and skills, and a ready supply of electrolysers. The opportunity also exists to research and potentially invest in seawater to hydrogen electrolysers, cutting out or at least reducing the high-power need (and therefore cost) of desalinating water prior to conversion to hydrogen.

NUCLEAR

Nuclear offers a significant opportunity to meet GCC needs, providing clean baseload energy.

The UAE began construction on its four-unit Barakah nuclear reactor plant in 2012. Units 1 and 2 are both fully operational, with Units 3 and 4 expected within the next few years. Each reactor generates 1.4GW and the whole four-unit plant will meet approximately 25% of the UAE's electricity needs. The cost has been upwards of $20bn but these plants will generate clean baseload power for the next 60 to 80 years. Whilst the levelized cost of electricity (LCOE) may not look appealing on nuclear, focussing on LCOE is a false economy and should not be taken as a comparator in a complex energy system.

Given the size of the country, its population growth, urgent need to reduce its reliance on oil as a feedstock for electricity generation, and its access to coastal waters, nuclear would seem a good choice for Saudi Arabia.

After a decade of planning, the kingdom is now considering a twin unit reactor with a capacity of between 2GW and 3.2GW. Given the time it takes to build, license and commission a nuclear plant, even if the Saudis accelerate, it is unlikely that they will have grid-connected nuclear power before the mid-2030s.

There are significant advancements in smaller output reactors (small and medium modular reactors) and these are being developed globally, generally in the country of origin before preparing for the export market. It is likely that small modular reactors will be commercially available in a few years, with even more advanced reactors, such as high-temperature gas reactors, in the early 2030s.

If future plants are being considered in the UAE, differing technology should be reviewed, in particular emerging advanced reactors which could be used for process applications directly, as well as power.

Whilst not strictly 'nuclear', there is more research funding being pumped into fusion technology than ever before, and if the GCC aspires to become leaders in Net Zero technology, this technology should appear within any energy consideration, as there is no global supply chain in existence, and this can be fostered and developed in the region.

TRANSMISSION AND DISTRIBUTION

An often-overlooked aspect of decarbonisation is the transmission and distribution network essential to transport renewable and nuclear power to demand centres. Connection of renewable generation, nuclear power plants, large demand centres such as hydrogen plants and changes in demand profile offers several challenges.

Generation has often developed in and around load and demand centres for efficient transport of power. However newer renewable sources are often in more remote areas and in some cases offshore, requiring new transmission or distribution networks.

Intermittency of renewable generation sources and changing nature of loads such as battery storage, electric vehicles, embedded generation changes the load and generation profile of national power systems causing voltage, fault level, reverse flow and stability issues.

Integration of cross-country power networks and systems to provide greater stability and maximisation of renewable sources across networks requires longer transmission lines and cables requiring HVDC connection to reduce losses and cater for differing frequencies.

Single mega projects and cities such as NEOM require entirely new transmission and distribution systems to cater for the ambitious generation and demand connections.

Decarbonisation of oil and gas platforms by connection to the grid requires subsea HVDC connection for example ADNOC's HVDC sub-sea transmission between their offshore operations to Taqa's clean onshore power network.

Another important aspect is system operation and stability. Lessons that countries are observing right now, is showing that that power systems with high penetration of renewable generation display low fault levels and high rate of change of frequency issues impacting power systems stability, requiring changes in protection and control system capabilities as well as greater reactive compensation and back-up and operating reserve margins.

The opportunities in the T&D sector include network design and connection (substations, HVDC and AC cable and overhead lines) for large sources of power or demand, network reinforcements of the main transmission networks where constraints exist due to changing power flows, power systems analysis, regulatory and grid code expert services and advisory services for acquisitions and investments.

Transport and Mobility

GCC countries, in particular UAE, Saudi Arabia and Qatar, have invested heavily in their transport networks in the past decade, but there can be no denying that for internal travel all countries are still heavily reliant on petrol-based car ownership and use, as well as road-based freight. Among other reasons, this is due to the rapid growth of cities and communities that have been designed around the car. Many communities have no other option for travel of any distance.

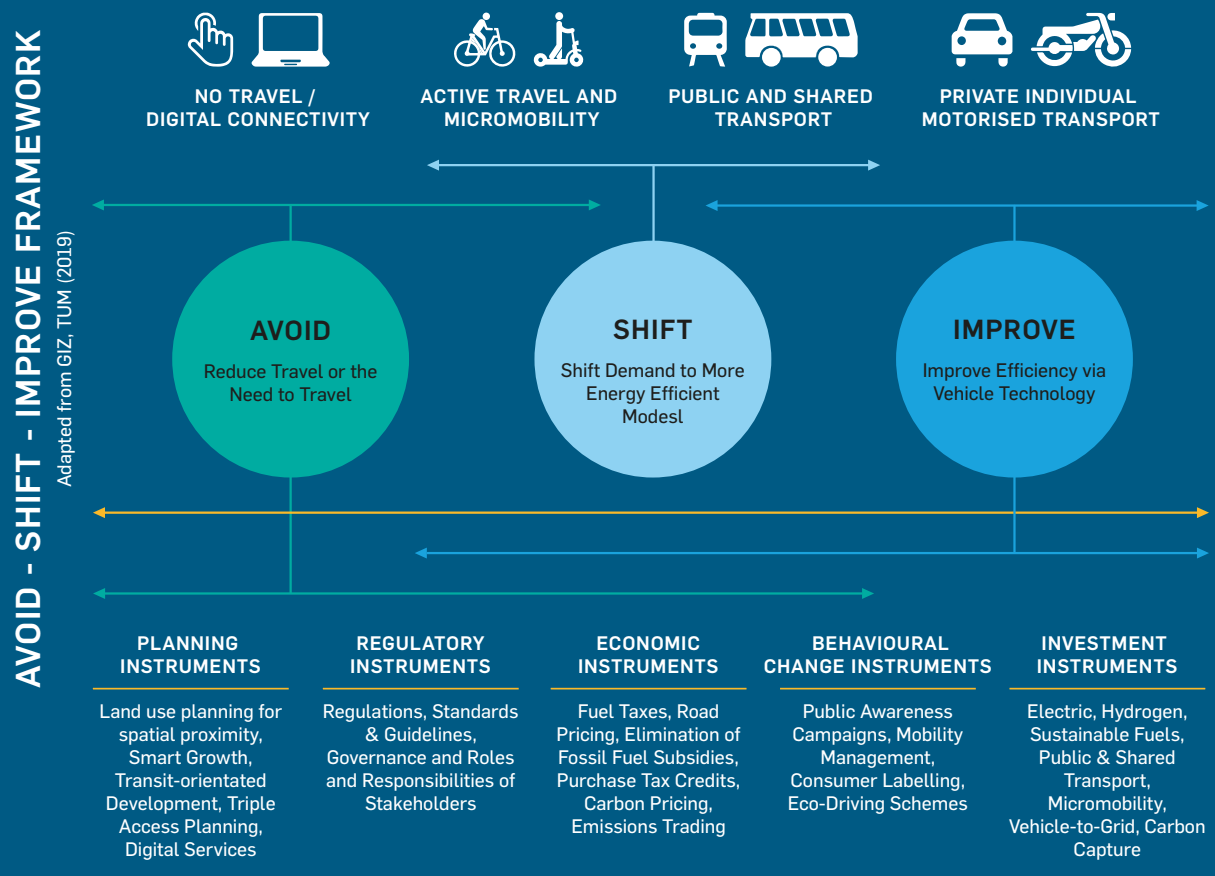
Changing long-held attitudes and behaviour towards land-based mobility will be difficult, and require a combination of encouragement and penalty, such as policies that incentivise Electric Vehicle (EV) purchase, reallocation of road space to other uses, increased parking fees or higher VAT on private vehicles with larger engines.

An approach that can be taken is that of Avoid, Shift and Improve. The first two options focus on behavioural change – getting people to think differently about how they travel or access transport services.

Avoid asks if the trip is necessary, for instance can it be replaced by a digital option such as an online meeting or internet shopping and delivery.

Shift seeks to make travel more sustainable, be that mass transit or an active mode such as cycling or walking. Where travel cannot be avoided or shifted,

Improve asks if it can it be done in a better way, for instance, by using an Electric Vehicle.



Active Travel (walking and cycling) is also an option for the built environment. Within the UAE, both Dubai and Abu Dhabi are investing in new cycling routes and encouraging cycling for recreation, sport and utility trips. But more needs to be done, proportionate regulation is required and effort must be put into raising public awareness of the health benefits from physical exercise. In addition, road traffic should be slowed down and citywide walking and cycling networks developed.

PUBLIC TRANSPORT

Land-based public transport networks remain limited, but through investment and expansion, will play a major role in Net Zero 2050/60 strategies.

Dubai's metro opened in 2009, Doha's in 2019 and Riyadh's is officially scheduled to begin operating in 2022. Dubai has a tramts and Qatar has recently opened its Lusail Tram. Existing metro and tram networks are not yet extensive, however, and new lines are needed that go to more locations if mass transit is to contribute significantly to a decarbonised transport network.

In addition, buses have seen improvements in scale and quality in recent years, but are not popular among many residents. These can become more important for short distance journeys, although culturally much work is needed to convince more people to use them. In terms of decarbonisation, Dubai has been piloting two electric buses on one of its routes, and there are longer-term opportunities for hydrogen, especially for long-distance coaches.

Rail networks are extremely limited across the region. Saudi Arabia has the most extensive rail network in the GCC, offering freight and passenger services across three lines. The longest at 2,800km is the Northern Train Network, running from Riyadh to Jordan. The East Train is the oldest line, and the 450km-long Haramain high-speed line opened in 2018. The kingdom has a long-term master plan for the extension of passenger and freight rail in key corridors, with the government stating in January 2022 that it planned to lay 8,000km of track [32]. Saudi Arabia is also building its portion of the GCC Rail Network and the Saudi Landbridge.

A four-line metro is also being developed in Mecca. The Makkah Public Transport Programme is a long-term development plan, that once complete will have 180km of track and 88 stations. A bus network is also being developed as part of the strategy.

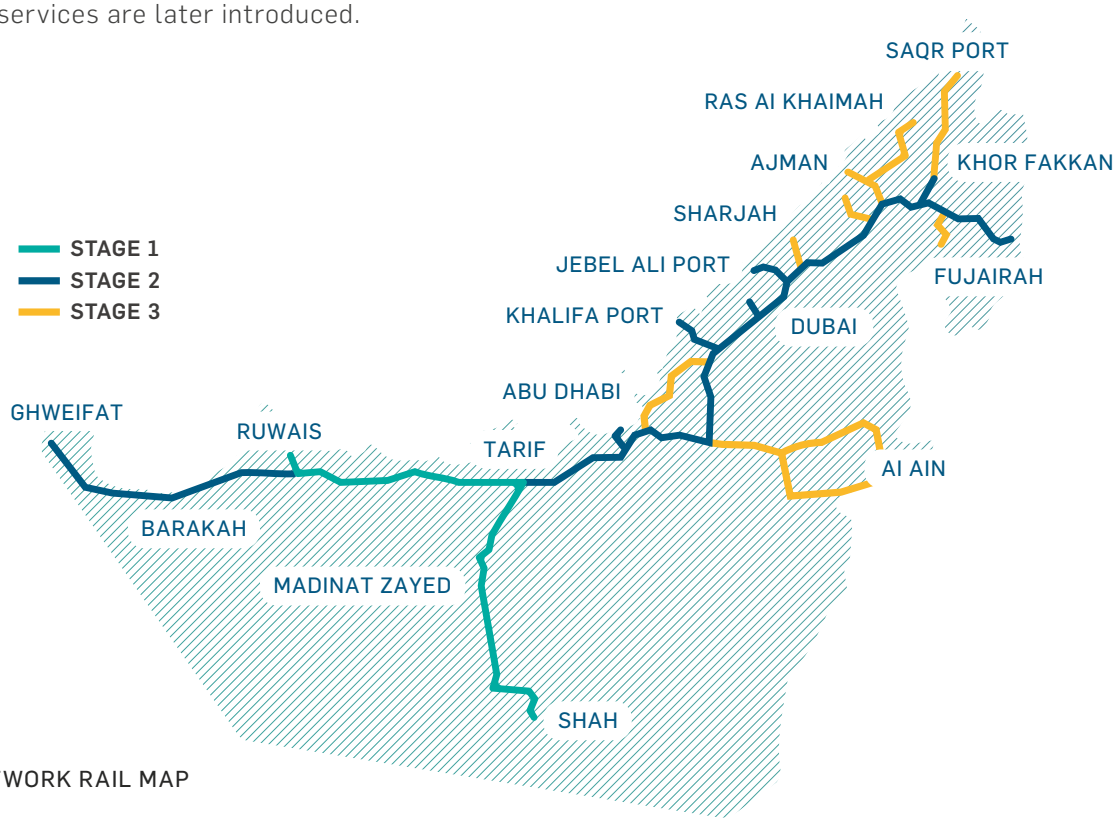
Within the UAE, the Etihad Rail element of the GCC network will stretch across 1,200km and run to the borders of Saudi Arabia and Oman. Stage one, a line to transport sulphur, has been operational since 2016 and the connection between Abu Dhabi and Dubai was completed in March 2022. Stage 2 is nearing completion and will provide a step-change in national rail connectivity, including early passenger services. More is needed, however, including additional rail freight connections, consideration of High-Speed Rail in some corridors and closer integration of rail connectivity with regional and local land use planning.

Once construction has been completed, the delayed GCC Rail Network will connect major cities across all six GCC countries and taking a sizeable chunk of heavy goods vehicles off the roads.

Passenger and freight rail transport will become more widespread as progress is made on various elements of the network. In addition, over the coming decades other technology options such as Hyperloop and maglev could feature. These technologies induce much less friction than conventional rail systems, and theoretically require less power to cover the same distance. The electric power for these systems, if they ever come to fruition, will need to come from clean sources for them to contribute to being a low carbon transport system.

A Hyperloop proposal has been floated to connect major cities across the GCC, with an initial connection between Riyadh and Abu Dhabi [33]. It was suggested in 2021 that commercial freight operations could be launched between Dubai and Abu Dhabi in the mid-2020s which is very ambitious, particularly given the time it traditionally takes to build a transport network. This region has grown on the back of ambitious projects and timelines, so even if this target is missed the project could prove a testing ground for viable travel by Hyperloop before passenger services are later introduced.

Overall, today's lack of rail and metro networks limits passenger options for travel in the region and means movement of produce, goods and construction materials is reliant on diesel trucks and road networks. This is creating a challenge for government Net Zero transport plans that will continue into the 2030s and beyond. Cities are still being master planned or built in the region and mass transit requires significant investment. Any decisions in the coming years to extend metro, rail or tram infrastructure options will need around 7-10 years to plan, design, build and test before they become operational.



ETIHAD NETWORK RAIL MAP

ELECTRIC VEHICLES

Many GCC communities have been developed or expanded around road infrastructure. Getting people to shift en masse to public transport would be a significant task that is unlikely to be effective within the region. In general, communities do not suit car-free families, and often local amenities, shops or schools are walkable for only the few.

Harsh summer temperatures are often cited as a reason for high car usage. If people will not abandon their cars, then the region needs a policy of electrification, be that battery electric vehicles or hydrogen fuel cell electric vehicles (FCEV).

EV use is increasing. In May 2021, 3,100 EVs and 9,300 hybrid cars were registered in Dubai alone and the UAE wants 42,000 EVs on its roads by 2030 [34]. Dubai has had a commitment since 2016 that 10% of new vehicles bought by selected government bodies will be electric or hybrid cars, as part of its Green Mobility Initiative 2030.

Almost 3% of car sales in Saudi Arabia were for hybrid and EVs in 2020, and the government has stated that by 2030, 30% of cars in Riyadh will be electric [35]. Saudi Arabia, which is building an EV manufacturing plan with Lucid Motors (which it part owns through its sovereign wealth fund), expects to buy 50,000-100,000 cars from the company over 10 years [36]. This falls within its decarbonisation plans and its Vision 2030 strategy to diversify its economy.

However, EVs alone will not decarbonise the region's transport infrastructure. They take the same space as combustion engine cars, and must be able to cope with the region's high summer temperatures, when car users are reliant on battery-draining air conditioning to cool their vehicles. In addition, more charging infrastructure in buildings, public car parks and on-street needs to be put in place. To meaningfully decarbonise transport, charging points must be powered by renewable energy sources. This again, proves the critical link between energy and transportation.

Progress is also being made on how vehicle electrification will combine with automated technology and a shared use model. Dubai is leading the region by working with Cruise on deploying the Origin; an electric, autonomous taxi, to the roads of the emirate, with plans to have 4,000 transporting passengers without a driver by 2030 [37].

For fleet and heavy vehicles, FCEVs offer strong opportunities for decarbonisation. Again though, work will be required to ensure a strong infrastructure network is in place, and progress here will be longer term.

AVIATION

Around the Gulf, airports are being built, expanded or upgraded to attract more passengers or freight business. Dubai's airport remains the busiest in the world, having successfully built a world-leading aviation hub and air fleet in the past decade. In 2019, it had more than 85 million passengers through the airport and handled around 2.5 million tonnes of freight.

These major aviation hubs add pressure to government Net Zero strategies, as aviation levels return to pre-pandemic levels. For instance, Dubai's 2021 passenger numbers were 29 million, although freight was in line with previous years, at 2.3 million tonnes. For 2022, Dubai estimates it will have 55 million people travel through its airport [38].

Due to the complexity of the aviation sector, it will likely decarbonise later than other transport modes. Regulatory and policy frameworks at global and regional levels need to be established to drive the development of sustainable aviation fuels, and this will require collaboration across the whole sector. In the near-term, ground-based operations within aviation offer the best opportunities to accelerate the decarbonisation of the sector - terminals, airside vehicles and passenger taxis serving airports. There are examples that provide lessons, such as Denmark's Copenhagen Airport and in Sweden. Copenhagen Airport became carbon neutral in 2019, aims to run emissions-free operations by 2030 and to have all direct and indirect services be emissions-free by 2050. Sweden has 10 Net Zero carbon emissions airports, including Stockholm Arlanda.

Key to minimising the carbon footprint for airports is to focus firstly on greater energy efficiency within buildings, followed by usage of low carbon/Net Zero energy. Through smart building technologies, airport operators can manage demand and optimise technical infrastructure to drive savings in energy usage. Airports have large, flat spaces suitable for the use of solar PV for terminals. Implementing energy efficiency measures, such as for lighting and air handling units, as well as improvements around building management systems will all reduce carbon emissions.

Operational innovation and improving airport and airspace operating models through implementation of A-CDM (Airport Collaborative Decision Making) and better Air Traffic Management processes and procedures like performance-based navigation, have been seen to help improve sustainability and environmental performance in aviation. Beyond operational improvements in terms of better predictability and intelligent flight planning, also reduced fuel burn as reduced taxi times and flow management delays at a network level have been improved and this all contributes to more sustainable operations.

Airport vehicle fleets and site machinery can be electrified, and policies put in place that stimulate the use of zero-emission transport modes for passengers and commuters. For Dubai, extending operating times for the metro can also contribute to the decarbonisation of the aviation value chain, whilst Riyadh Airport will shortly be connected by metro services to the city centre.

Many airlines, including Etihad and Emirates in the UAE, are working with industry partners to adopt sustainable aviation fuels. Emirates received its first DAF powered A380 in 2020. Etihad is trialling mixed burn fuel and its effects on performance, engine clutter and fuel cleanliness. The focus on biofuels will grow as it becomes available through oil majors and hydrogen is an option being investigated, both for propulsion purposes and to manufacture synthetic fuels. This presents another sizeable opportunity for the region to become leaders in the production and export of such fuel.

Airbus, whose planes are widely used by GCC airlines, has said that hydrogen could eventually halve CO2 emissions from aviation, and has launched its ZEROe strategy, aiming to have a zero-emission commercial plane in operation by 2035 [39]. For its part, Boeing is focusing on sustainable aviation fuel for commercial flights.

The aviation sector is less bullish on commercial electric planes though, due to battery weight (recognising they are as heavy when landing as on take-off) and the space required.. However, work is underway to develop electric vertical take-off and landing (eVTOL) aircraft that could carry passengers, offering zero emissions at the point of use and this is attracting attention in the GCC. A number of companies are working on eVTOL vehicles.

Built Environment

Sustainable urban master planning is a key aspect of future Net Zero strategies. Get this wrong and it negate other major efforts to decarbonise, such as reducing emissions from transport or energy.

There has been a tendency in the region to focus on high-quality, attractive gated communities for residents where a car is essential to get around, and there are few amenities available within a walkable distance. Local freight and logistics are managed by road and for many, a car or taxi is essential to travel to work. Still today, master plans are launched that are designed around road transport, although this is gradually changing.

Herein lies the strong link between the built environment and transportation.

Sustainable cities or communities need to consider liveability, work and access to shops, schools and essential services by a range of non-car and road-based modes. Good design and good planning that achieve Net Zero goals need to appreciate life-centric approaches to the built environment.

That means integrating land use and urban transport planning, and ensuring that high performance buildings and environmental solutions will reduce energy needs. Master planners and developers must consider how institutional investors and funds are making their investment decisions – do the plans meet their portfolios' sustainability requirements, and how those portfolios perform against ESG criteria. And big institutional investors are decarbonising their portfolios.

The three main strands of economics, integrated urban planning, and the application of smart technology will contribute to the planning, design and engineering Net Zero response. Delivering high performance-built environment solutions for new and existing urban environments is a critical activity and will be at the for front of decarbonising the towns and cities of the GCC.

To help reduce carbon emissions for existing buildings, SNC-Lavalin has developed DecarbonomicsTM, a data-driven solution to decarbonize the built environment in a cost-effective way to enable asset owners to contribute to demand reductions and Net Zero goals.

The three-step Decarbonomics approach develops a carbon baseline through benchmarking, creates a low-emissions road mapping by designing a cost-effective carbon reduction pathway and outlines how an organisation can implement the program.

The rapid growth in the UAE's built environment needs no introduction. It has made headlines globally and the SNC Lavalin Group has worked on some of the country's most iconic developments ranging from hotels such Bulgari and the Atkins-designed Burj Al Arab, through to world class smelters at EGA and Dubai Aluminium, Dubai's transport infrastructure through the Metro's Red and Green Lines and more recently Route2020.

Within Dubai, the 2040 Urban Master Plan integrates the individual master plans in the emirate. The plan will reduce energy demands by encouraging walking, cycling and sustainable mobility [40].

Saudi Arabia is undergoing a significant period of building new communities, towns and cities that will help diversify its economy and attract tourism, industry and long-term foreign investment as companies set up in new cities and create jobs for local communities, as part of its Vision 2030 strategy.

The plans include the development of several giga and mega projects and smart cities as part of its strategy to diversify its economy, including NEOM, Qiddiya, Red Sea Project and Amaala, Aseer Development Project, Diriyah Gate Development Al Ula, Jabal Omar, and Roshn.

NEOM's low-carbon ambitions include plans to reduce road traffic and attract organisations that fit within its ethos (see Energy section). The main city announced to date is The Line, a 170km-long linear, carbon-neutral smart city running from the Red Sea to the region's mountains. It is expected to cost $200bn to build and be home to one million people, and the city will include an advanced transport system that is highly autonomous, with no cars or streets [41].

The Red Sea Project and Amaala programmes will rely on low-carbon construction processes, such as offsite, modular construction and technologies such as digital twins, to minimise not just onsite construction waste but also any potential physical impacts the developments may have on the local environment.

DISTRICT COOLING

For district areas, District Cooling (DC) is proven sustainable and far more energy efficient alternative to conventional air conditioning that provides considerable energy savings and a reduced carbon footprint. Within master planned communities, where residential/office towers or public buildings are clustered, it reduces the power consumption required for cooling, creating better performance for Decarbonomics.

Where conventional air conditioning units consume about 1.5-2.0 kW per refrigeration tonne, for scaled district cooling it is closer to 0.75-0.85 kw per refrigeration tonne. For tall towers and public buildings, this can be a significant contribution to government decarbonisation plans. The UAE and Qatar has an oversupply of DC currently, but Saudi Arabia and Kuwait are both promising markets.

District cooling suits certain types of developments only. Where used, government mandates can ensure it is planned for and implemented.

Although the district cooling industry brings several benefits to each country's infrastructure and their goals to achieve Net Zero Carbon emissions, there are a few factors which can be detrimental to the district cooling industry and the ENZ plan, such as:

A. Over estimation of cooling loads of the developments served by a DC plant

B. Inaccurate diversity factor used in deciding on the DC plant capacity

Such factors tend to mislead the DC service providers thus resulting in significantly higher plant capacities than actually needed.

Oversized plants would operate at low capacities for several years thus leading to inefficient operational trends, which consumes more specific power, thereby leading to a higher carbon footprint per refrigeration tonnage. Inefficient plant operation may offset the ROI model of the service providers, causing them to increase tariff rates, which ultimately could drive end users to switch back to conventional cooling, which ultimately will require more power from the grid and is counter-productive towards Net Zero.

It is therefore becoming crucial that new guidelines are developed for stakeholders to properly estimate DC plant capacities.

Solar PV can be used for a plant's auxiliary loads, reducing their dependency on grid power. Machine Learning and Artificial Intelligence platforms can be integrated and embedded into DC control systems to enhance plant performance and predictive maintenance, which leads to improved power consumption that reduces energy use per refrigerated tonne and cuts the carbon footprint yet further.

Further, Machine Learning platforms can be deployed to collect data from operational assets and use this to predict future equipment failures or anomalies. This will facilitate the move from reactive and preventive maintenance strategies to predictive and prescriptive strategies, allowing operations teams to take early decisions to avoid asset failures and increase equipment uptime, enhancing the facility management and optimising energy consumption.

By operating fully automated, unmanned plants, travel time and transportation requirements are cut, contributing positively to a lower-carbon transport network.

Emerging technologies such as digital twin will further contribute to improved running and predictive maintenance, further lowering the power consumption needed of these plants.

Having a fully integrated ERP digital twin in place from the planning and design stage plays a pivotal role in controlling and tracking the supply chains of construction materials and products to reduce embodied carbon. .

FACILITIES MANAGEMENT

Eighty percent of the cost of a building across its lifetime during its operational phase, so a well-structured facilities management (FM) plan is essential. A well maintained and managed building or facility will require less power and water, incur lower utility costs, and have a lower carbon footprint.

FM should be considered from the planning stage, with the operator involved in decision-making for major building assets. Their input can provide long-term benefits on how that asset functions and can extend its lifecycle and, to a large extent remove the need for costly and disruptive re-works after completion.

Opportunities to performance test an asset (building) and make recommendations for any re-works or retrofit would provide tangible cost reductions and performance improvements that would result in a positive return on investment.

The UAE and Saudi governments have introduced retrofit programmes for existing buildings to improve their efficiency and lower their carbon footprint, through energy services companies (Escos). These focus on government and public buildings and mosques. In future, programmes will need to also include non-government owned tall towers and privately-owned buildings.

There are simple steps that can be taken to reduce a building's energy footprint and therefore running costs, such as more focus on Life Cycle Cost (LCC) at the design and specification stage. Whole Life Cycle Costing (WLCC) is a concept that is relatively new to the construction industry, albeit based upon the foundations of analytical techniques that have existed for some time.

It is in essence an evolution of LCC techniques that are commonly used in many areas of procurement. Like LCC, the primary purpose of WLCC is to aid capital investment decision-making by providing forecasts of the long-term costs of construction and ownership of a building or structure. Unlike LCC, it is a dynamic approach, and can provide up-to-date forecasts on cost and performance throughout the life of the building.

Whole Life Cycle Costing (WLCC) explained

Some of the ideas behind the justification for WLCC are synonymous with key issues in today's construction industry.

MEETING CLIENTS' EXPECTATIONS

Clients (especially in the public sector) now require buildings that are efficient during and after construction. WLCC techniques can demonstrate real cost savings in design solutions.

SUSTAINABILITY

Achieving sustainable design solutions relies on the consideration of long-term operational costs and performance of building components.

MONITORING PERFORMANCE OF CONSTRUCTED ASSETS

By considering the whole life cycle costs, performance can this be assessed. Using WLCC also supports benchmarking and key performance indicators.

MONITORING COST EFFECTIVENESS OF CONSTRUCTED ASSETS

WLCC provides the means by which to constantly review this and base future capital investment on this information.

LEAN CONSTRUCTION

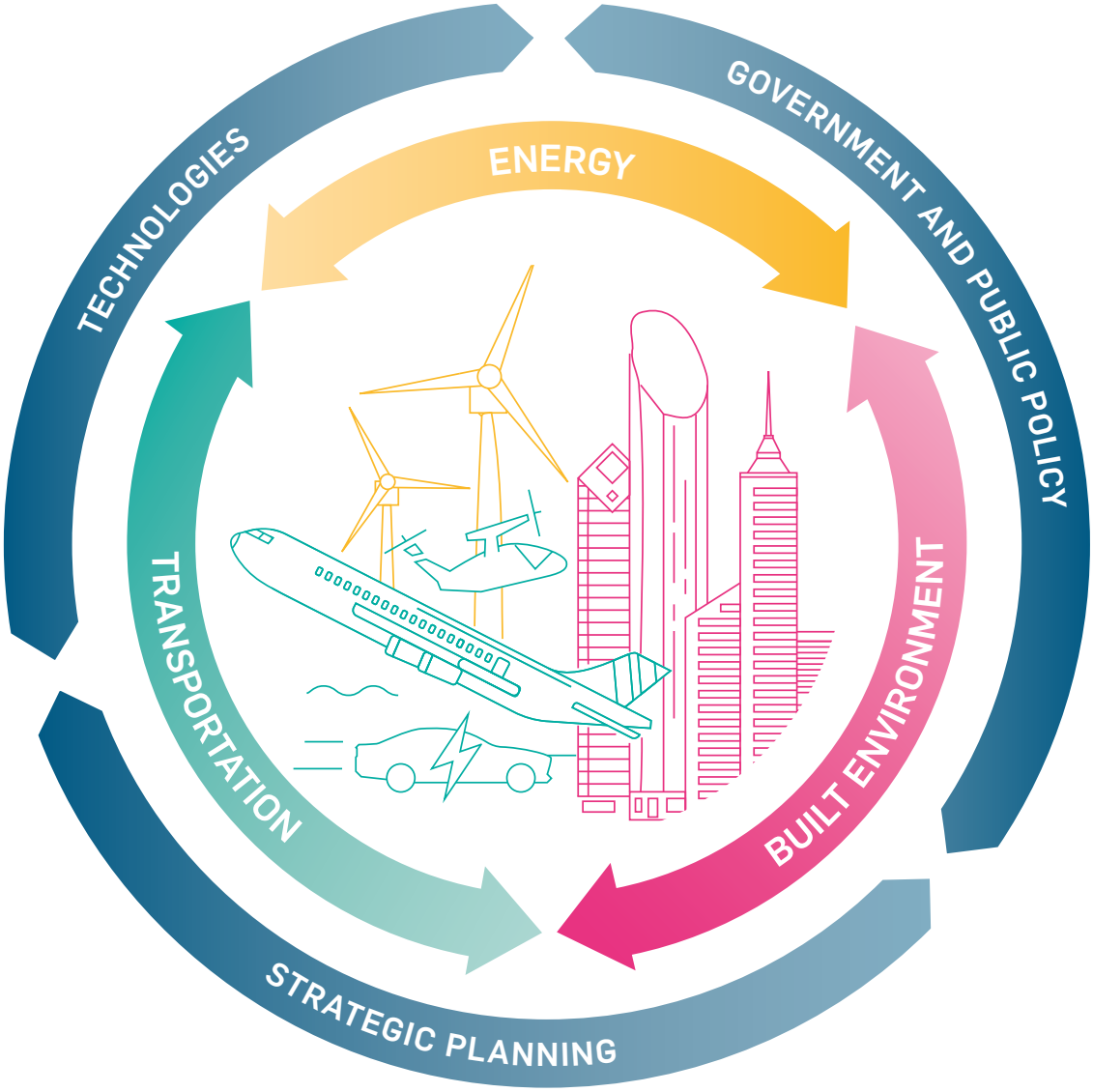
By considering long-term cost and physical performance, waste is minimised both during construction and through the life of the building.

STRATEGIES AND SOLUTIONS FOR A NET ZERO CARBON FUTURE

Key Recommendations

We are proposing a set of recommendations that are relatively broad given the span of countries in the GCC, and the varying baseline data available.

We have grouped the recommendations into a hierarchy, showing their relation to **energy**, **transportation** and/or the **built environment**, recognising that many are interrelated.



Government and public policy

ENERGY

Governments have set out clean energy strategies throughout the GCC. The UAE is yet to submit its long-term strategy to the UNFCCC but has made the most progress amongst the nations in its overall strategy.

Targets in the regions have been made, but remainder of countries are yet to commit, and could be mentioned in policy documents at the least. Putting targets into law would be the pinnacle of commitment, but recognise this may not be the approach this region wishes to take.

A shift away from the levelized cost of electricity as a driver for energy procurement is needed, recognising that this cost does not represent the overall national system cost that will be needed to ensure grid stability.

Governments may also want to consider incentives on technologies that decarbonise power, water and industry (such as carbon capture), if they wish to push home grown innovation and potential export.

TRANSPORTATION

Governments must change public perceptions around modes of transport used and where possible encourage the further digitalisation of work and services to avoid the need to travel. Ultimately the governments need to embrace the '**Avoid-Shift-Improve**' framework as discussed earlier in this report. Some aspects of transport decarbonisation can be tackled through policy decisions.

Governments in other countries have implemented favourable taxes and benefits for EVs, and people can be nudged to change their habits by either offering better options or making the current option far less attractive, such as closing or limiting access to roads, pedestrianising suitable areas and introducing increased parking or user fees.

Legislation and regulations around bicycles and e-scooters can encourage more last mile journeys whilst avoiding some of the poor press experienced elsewhere in the world around safety and public nuisance.

BUILT ENVIRONMENT

To really force and drive change in the way the built environment is designed and operated, legislation and design codes can be enhanced. These range from the use of sustainable materials and methods for construction, through to the clear codes or guidelines for the capacities of district cooling plants.

Emissions monitoring and reporting is an enabler to tracking how a country is progressing in decarbonisation, and is an area that can only be driven through a top down approach. The construction industry, as an example, must become better at monitoring the use of diesel-powered heavy equipment on site (including idling time). A longer-term ambition must be to decarbonise as much of this equipment as possible (through EV or hydrogen fuel cells), but until that happens such monitoring and reporting needs to become standard if countries are to meet their future Net Zero target dates. Environmental regulators have key role to play in this. An obvious route would be for all new builds to be required to report emissions from heavy equipment, and the introduction that all equipment undergoes an annual emissions check – much like a road vehicle.

Strategic Planning

ENERGY

The size and pace of clean energy targets in the UAE and Saudi Arabia – particularly when put into context of each country's Net Zero targets – leaves no room for slow decision-making. Build rates for generation and enhanced grid infrastructure will have to be carefully executed. What cannot be ignored in this region, is the demand for desalination (which is generally steady throughout the year) and the seasonal variances in power demand.

Given the complexity of government plans combined with the changing grid-connected energy mixes that will include firm and intermittent power along with storage, countries will need an energy system architect (ESA) to enable decision making. This is especially the case given the slightly siloed approaches across GCC countries.

Other countries need to fast-track their plans to increase the rates of tenders issued, projects awarded and plants completed. An Energy System Architect can play a key role in this and is a key recommendation for all governments transitioning their energy make up, recognising that one solution will certainly not fit all countries in this region

As that transition progresses, governments must ensure there is balance in the energy trilemma of security, cost and sustainability. Primary energy supplies must be reliable and well managed, and planning must consider how capacity needs will shift in coming years. Equally, as governments push their renewables and nuclear ambitions, we should not forget the continued importance of gas in the energy transition, which will continue into the foreseeable future.

Within each country, an ESA would oversee the master plans, ensuring that relevant parties align to avoid gaps, overlaps, mistakes and delays. An ESA will guide decisions, understand generation and demand nuances, and cast a critical eye on plans. They put structure around energy plans and understand how different technologies can be integrated and interoperated. With an overall picture around population growth, city and transport expansion and future demand – all aligned with government-endorsed targets – they can ensure well-engineered plans can meet the Net Zero energy challenge which involves optimising the use of natural resources while overseeing decarbonisation strategies at the same time.

This would enable each to develop a coherent national strategy that individual agencies, utilities and government departments could align to, and provide focus for sustainable investment decisions.

As electricity generation becomes more cross-border (evidenced by both the GCC Interconnected Grid and the electricity sharing agreements between Saudi Arabia and neighbours Egypt and Jordan), a GCC-wide ESA would be the next logical step, working with country-based ESAs to drive regional growth through long-term, sustainable energy planning. The challenge of this approach though would be navigating and balancing individual country interests and demands with wider GCC requirements. Aside from grid stability and interconnectivity, the energy sources to be considered should include:

TRANSPORTATION

Transport planning could enhance mass transit by providing new lines or extending daily operational times, particularly where it connects to major embarkation points or airports, giving people options beyond their car or a taxi. A simple recent example is the Route 2020 Red Line extension into the Expo 2020 site in Dubai, which made it far easier to travel to the venue by metro than by car.

The rising use of working from home, e-learning, online shopping and food orders will help reduce car journeys and therefore greenhouse gas emissions, although the wider mobility impacts, for example for motorcycle riders undertaking home and office deliveries, require more investigation.

Overall, transport experts need to be involved early on in urban and built environment master planning processes. Governments and planners must decide on what type of city they want, and the transport infrastructure that is derived from those early decisions. This part of the world is inclined to look for technology solutions to solve some of its challenges, but a broader perspective is required that ensures the long-term planning of a widespread, functional, integrated transport strategy, including balancing supply-based approaches with the management of demand, including user attitudes and behaviour.

BUILT ENVIRONMENT

The basic building blocks for creating sustainable urban communities needs to be in place, driven by planning legislation and strategic land use planning. The Dubai 2040 Urban Master Plan strategy is a good example that introduces a clear limit to expansion into greenfield areas within the emirate.

The focus must be on existing sites within metropolitan areas, particularly those that lay fallow. This should include stricter rules around regeneration and retrofitting existing buildings to bring them up to the required standards in terms of energy efficiency and internal comfort and wellbeing.

The region's built infrastructure continues to be very concrete based, and for construction to decarbonise it needs to transform digitally, embrace modern methods of construction (MMC) and investigate novel materials use. Leading companies are taking these steps but government legislation is required in some cases to accelerate the process, particularly to push the use of MMC and to ensure safety is proven for greener materials.

Many owners or developers start with good intentions for their buildings or communities in terms of sustainability measures. But early grand visions often get watered down, especially once commercial pressures force cost reductions. There is also a lack of cohesiveness between communities, with no oversight or collaboration between adjacent developments. Design codes, masterplanning rules are areas which can help force change, in parallel with pressures from lenders and end-users.

Demand side management will also play a key role in energy planning, and governments can play an active role in shifting cultural thinking around electricity and water use in the region. This is happening but there is still significant opportunity to fast-track change in the GCC. Much of this will hinge on decisions made within the built environment and major industries, with a greater push required for the big energy users to improve building envelopes and implement energy efficient products.

Facility management (FM) planning needs to begin at the design stage for a major asset. There has been a tendency for contracts to be awarded to the lowest bid that will service the building as cheaply as possible. Poor maintenance does not fit with a building being well-functioning and low carbon long term. For owners, good FM will result in their investment performing far better, with controlled maintenance costs and the building being able to attract higher-value tenants.

Within the retrofit market, the biggest challenge is that the sector is not well-understood, particularly the energy services finance model. There is a clear need for education around the business model for building owners to understand the opportunities the Esco model offers and the benefits this will bring. If more buildings go through an energy audit at the very least, the result will be more energy efficient buildings that contribute positively to government Net Zero targets.

A second challenge is that of overcoming indifference. With so many organisations renting their space, and fewer owners occupying their buildings and therefore not paying the electricity and water bills, it can be hard to get them to improve its operations and install low-carbon options. Equally, there are no financial incentives for the tenant to make the changes themselves. This is a false economy for owners, as it will put off more discerning tenants, or those with internal Net Zero targets, and over time is likely to result in their built asset achieving lower returns.

However, a positive in the region is that large local organisations do have pride in their governments and tend to support their initiatives. A well communicated, clear strategy on the benefits of owning and running low carbon, highly efficient buildings would result in positive changes that benefit Net Zero strategies.

Technologies

Strategic planning, above, cannot sensibly achieved without a strong idea of the technologies and advancements that are underway across multiple sectors; some of which may not be commercially available for some time, but should be considered as part of the long-term plans.

NUCLEAR

Plans for new nuclear in the region need to be accelerated, especially within Saudi Arabia which needs to rapidly increase its clean energy options. The international market for nuclear is growing, and unless commitments are made soon, reactor suppliers and the global market will be focussed on their own domestic programmes. Whilst nuclear is, without a doubt, one of the most effective sources of low-carbon baseload power, it isn't necessarily the right answer for every country. The UAE could certainly capitalise on having invested in its nuclear infrastructure and capability, and Saudi Arabia has huge potential in addition to its first commercial plants that are being planned.

Special consideration should be given for:

The use of nuclear, not purely for power generation, but for process applications (particularly during winter periods where national power demands are lower) including desalination, smelting and hydrogen production;

Future nuclear technologies in addition to the traditional large Gigawatt scale plants as part of the long-term plans. Fusion technology (which is theoretically not nuclear, and doesn't come under the same regulation as nuclear) should be considered, as with the right funding in place, it could help the region become a global leader in this technology (and the associated supply chain). It has huge potential for safe, clean energy with minimal waste streams. Planning for this should recognise that the technology is perhaps at least 15 years from commercial availability

RENEWABLE ENERGY

The key forms of renewable energy for this region are solar, and in some areas wind and waste-to-energy, and these will continue to play a key role in low carbon energy production. It must be recognised that many of these technologies create intermittency problems for the national grid networks, and that a combination of energy storage, enhanced grid interconnectors, and gas plants with carbon capture (or nuclear plants) to provide that baseload will be critical to helping solve the energy trilemma. Coupling renewables to energy storage is key, and each country has its own natural features and constraints which influence this.

Energy storage such as pumped hydro would be a strong option for areas of the GCC with natural mountainous regions in the proximity of demand centres.

THERMAL GENERATION

Let us not forget that modern and efficient gas fired power plants will continue to provide critical baseload power in this region during the transition to Net Zero. This region has successfully deployed carbon capture technology as part of the enhanced oil recovery processes, and this technology could be further exploited onto new thermal plants, without which, such plants, even those with the highest efficiency, will struggle to attract interest from developers or lenders who have put in place strict decarbonisation policies.

Unless incentives are brought in, there is little point trying to retrofit carbon capture to existing thermal plants, as their operating lives are typically 20 years, and the majority will be decommissioned in the next 10 to 15 years.

Carbon capture can be applied, with clever engineering (and of course the right economic incentives), to other industrial plants such as cement, to contribute to the decarbonising of major industrial processes.

HYDROGEN

Given that water forms a key input to production, the GCC should focus development and deployment of hydrogen techniques from seawater, as this could deliver huge savings in the energy cost associated with desalination.

Grid companies should be involved deeper in this projects to take advantage of the potential of the energy storage of the electrolysers to help them with temporary grid stability.

Overcoming the challenge of electrolyser manufacture through local production is a significant opportunity. It would remove regional bottlenecks, and create new jobs and skills, yet further diversify employment options. The region continues to attract new industries and electrolyser manufacturing is a key opportunity that goes hand-in-glove with its hydrogen plans.

Aside from export, regional countries can consider how to apply hydrogen domestically – whether it be for transport fuels (land or marine), blended with gas for power productions, or used to maximise 'green' industrial processes or use its derivatives such as ammonia for enhanced agricultural land to reduce reliance on overseas food imports even further.

TRANSPORTATION

PUBLIC TRANSPORT

More public transport is required to meet decarbonisation plans within the Net Zero 2050/60 strategies. Significant investment is required to extend current lines, routes and interconnections that allow for longer journeys. Residential communities need to be better served with public and shared transport if car journeys are to be reduced. Plans for national passenger and freight rail need to be extended, whether conventional, high-speed or new technologies such as Hyperloop or Maglev; as long as they are electrified (and that power comes from clean energy sources)

ELECTRIC AND HYDROGEN VEHICLES

Current plans to increase purchase and use of EVs must be accelerated, particularly for government-owned vehicles and public fleets such as buses and taxis. Immediate challenges around EV battery performance in hot climates and the environmental impacts of materials sourcing and recycling should not be underestimated, and there is much to be done (globally) on this. Where it does not make sense to use EVs, creating a hydrogen transport economy may be an opportunity, particularly to replace larger commercial and long-distance vehicles. However, for both EVs and FCEVs the associated infrastructure must also be built in tandem and the power used to recharge batteries or generate hydrogen must come from clean or renewable sources.

AVIATION

Aviation can actively electrify airport ground vehicles and install more solar power for use in terminals while longer-term research focuses on alternative or cleaner fuels for aircraft, including hydrogen. GCC airports must work with others globally to share and swap approaches that will decarbonise their operations. New airports being built (of which there are plenty in the pipeline) should plan from the design stage for their construction and operations to be low carbon.. For short-distance trips, Advanced Air Mobility offers the potential for eVTOL to transport people and goods with zero emissions and limited noise at the point of use.

MARITIME

The region has become a major maritime transport hub, and it is recommended that within ports, low carbon operations are developed. Research work also needs to be put into the use of clean fuels, such as hydrogen and other zero emission sources for shipping, which is a very energy intensive process.

BUILT ENVIRONMENT

DIGITALISATION

Digital transformation requires investment, but will introduce new approaches to the construction process and provide data that can be analysed, understood and acted upon. The construction sector has been slow to digitalise, but the pace is accelerating, especially as more case studies reach the market on the benefits of such transformations and as clients demand more digital clarity from planning to handover.

MODERN METHODS OF CONSTRUCTION

Modular construction introduces a factory approach to building, with increased automation, less waste and controlled conditions. It is increasingly finding favour for repetitive parts and processes, such as bathroom pods that can then be transported to site. It does introduce transport miles that must be monitored, but overall its greater use will contribute to a lower-carbon industry.

Likewise, 3D printing. Not as advanced in use as modular, but it introduces a factory approach to construction, should eliminate mistakes providing upfront programming is done correctly and significantly reduces waste. There are challenges with the technology around size of building and that it does not necessarily move the industry away from its reliance on concrete. Nevertheless, expanded use will decarbonise the sector. Dubai has a stated ambition that by 2025 25% of all buildings include a 3D printed element, and we recommend that more governments adopt similar targets. This is where the link to government policy and planning is important, as such a target would need to be reinforced through codes, permits or standards for it to be taken seriously and implemented.

GREEN MATERIALS

Some 11% of construction's greenhouse gas emissions are associated with materials manufacture for steel, cement and glass. Changing materials use will take longer to achieve and in some cases require the industry to work with government on legislation in each market.

But examples are on the horizon. Within the UAE, both EGA and ESI have or plan to introduce green products, using renewables or hydrogen to carbonise the manufacturing process. Elsewhere, greater use of biofuels or recycling will reduce carbon emissions associated with metal.

There is work underway to decarbonise cement production to an extent through the adoption of refuse derived fuel, which diverts waste from landfill. Carbon capture technology, as is used in the oil & gas sector in region, could be applied to the cement process creating a form of 'green' cement, but no incentives or drivers for this exist at present .Ultimately, more work is required to switch to alternatives to cement, be that green cement (an area in which 3D printing is likely to excel in future) or alternative materials, such as timber. Strict rules around the recycling of construction waste will drive construction practices and materials in this direction, and reduce emissions further.

Summary

	ENERGY	TRANSPORTATION	BUILT ENVIRONMENT
Government Policy	UNFCCC strategies to be put in place Removing Levelised cost of electricity (LCOE) as technology selection driver Incentives on low carbon tech	Develop **Avoid, Shift, Improve** Framework Change public travel attitudes and behaviour Policies and regulations to manage demand for different modes of personal mobility	Enhancing Planning, design regulatory and legislation frameworks cover engineering Net Zero, decarbonisation of cities, green materials, and low-carbon design and adaptation of existing buildings Emissions monitoring across construction
Strategic Planning	Consider role of Energy System Architect, or equivalent	Promote triple accessibility planning principles, including digital substitution of physical mobility Integrate sustainable transport infrastructure and services into all new master plans and developments	Planning and Design guidelines for the regeneration and adaption of existing built environments and building stock Demand side energy efficiency management considered upfront
Technology	Look at future nuclear and fusion technologies, not just for power, but for key process applications Hydrogen electrolyser development - R&D on higher efficiencies and taking advantage of energy storage capability into overall grid stability carbon capture on all new gas plants and industrial plants in the transition	Enable roll-out of electric and hydrogen road vehicles Extend and electrify urban and inter-urban rail systems Lead the world on new aviation power sources, green aviation fuels and advanced air mobility Move ports and shipping towards low emission concepts	Digitalisation to support planning, design, engineering and construction phases Digital tools make facility decarbonisation easy to track Green high performance building materials, including 3D printing, green cements, green steel using carbon capture

INFLUENCES

ACTION TODAY FOR A NET ZERO TOMORROW

Conclusions

GCC governments have shown that they are serious about embracing decarbonisation initiatives. Collectively, their per capita carbon emissions are among the highest in the world, but equally, they have recognised the economic benefits of decarbonisation initiatives.

These initiatives range from the introduction the right mix of clean energy for electricity generation, freeing up oil & gas for export, transport policies that will reduce today's reliance on polluting fuels and change the face of land, sea and air transport, and approaches to buildings, facilties and infrastructure that will not just result in lower embodied carbon but also reduce demand side usage.

There are also other benefits to the measures being taken. Cleaner air will introduce health benefits and the careful development of pristine coastal areas will encourage new forms of tourism. The list could go on.

Rapid development of a hydrogen economy will create new export streams, which will be a key factor in replacing the oil economy in a decarbonised world. Additional economic value can be gained from the leading the way in new product types for the region's heavy industries, such as green steel and aluminium, in turn building new skills and jobs, and further downstream, new manufacturing and export opportunities for higher values items.

The new hydrogen economy will be a globally competitive market. Products from the likes of Saudi Arabia, the UAE or Oman will have to be cost-competitive and the market will demand innovation. Again though, the region can take a leading position with careful planning, particularly if governments embrace research opportunities around technologies such as electrolysers and set up manufacturing facilities that can serve subsequent market demand.

Whilst this paper presents the most beneficial opportunities for the region, without more supporting data, it is difficult to suggest specific more targeted values and precise combinations of initiatives. The important point we are hoping to achieve with this paper, is that so much of the energy, transportation and built environment is interconnected, and Net Zero decisions and policies on one, can have a direct and indirect impact on another, and a holistic and joined up approach is really the only approach if a country wants to transition to Net Zero in the most effective way.

This is absolutely achievable. Countries in this region, with the right government push, have a track record of implementing world class complex projects at amazing timescales.

Individual governments appointing an energy system architect, or equivalent, will enable each country to have a systematic, well-planned approach to future energy needs that considers plans and policies in other sectors, such as the built environment and transport, that will affect future energy requirements. Taken to the next step, a GCC-wide energy system architect would allow the bloc as a whole to move forwards with a unified energy approach that would contribute directly to the decarbonisation of the region, introduce greater energy security and open up the opportunity to share power and transportation cross-borders.

LEADING INDUSTRY BY EXAMPLE

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