ECESR
المركز المصري للحقوق الاقتصادية والاجتماعية
Egyptian Center for Economic & Social Rights

HEINRICH BÖLL STIFTUNG
NORTH AFRICA TUNIS

80 GIGAWATTS OF CHANGE

EGYPT'S FUTURE ELECTRICITY PATHWAYS

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ECESR

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> *Greater inclusion, not just consultation in the latter stages, should be a prerequisite for civil society and private sector development of future energy scenarios in Egypt.*

1. EXECUTIVE SUMMARY

80 ***Gigawatts of Change ' is the first publicly accessible, modeled and civil society analyzed scenario for the Egyptian electrical sector ever produced.*** Through engaging with stakeholders and a participatory drafting process, this project details seven different options for how Egypt's electricity sector could develop between 2015-2035, all with different attributes and downsides. In summary they are:

BUSINESS AS USUAL WITH EFFICIENCY MEASURES (BAU)

Taking the status quo of current electrical generation and meeting the generation deficit, BAU with efficiency is cheaper to execute than BAU without efficiency measures, but it fails to tackle the current energy access issues across the country, or to address the level of carbon lock-in relying on natural gas as more than a transitional source of energy creates. The addition of energy efficiency saves money and 15.4 GW of energy and creates a thriving new industry with high job creation.

BUSINESS AS USUAL WITH COAL (BAU+COAL)

Workshop participants felt the more equitable and progressive the pathways would be, the more accurate they become, especially when compared to a baseline scenario that incorporates the government's move towards coal. Although we have not used BAU+COAL as our baseline in the other pathways, we found that the costs of including coal in the mix far outweigh the benefits of filling the energy deficit due to the air pollution issues; site locations potential for pollution of environments and communities surrounding areas coal will be transported too; the added cost to and pressure on the national health service; and that building, operating and maintaining coal fired power stations on a business as usual trajectory would cost 15.8 Billion U.S. Dollars more than BAU with energy efficiency measures. Finally BAU+COAL creates roughly 100,000 less annual jobs per Gigawatt hour than any other pathway.

TOWARDS ZERO CARBON (TZC)

TZC offers an insight into the costs, job creation and energy mix that transitioning to an electricity system with zero Green House Gas emissions after 2035 would look like over the next 20 years. Using natural gas as a transitional fuel and maintaining the centralized grid, large wind and solar farms are built to feed into the mains electricity generation. This core is complemented with existing and planned hydro capacity plus arrays of mini turbines along moving bodies of water, and the creation of a new fuel source from human sewage and agricultural waste biomass power stations situated locally. The pathway is State driven and doesn't offer many opportunities to aid small and medium enterprises and community owned energy generation. It does however, offer the beginnings of a blueprint for how to decarbonize an electricity system.

TOWARDS ZERO CARBON WITH NUCLEAR (TZC+NUCLEAR)

The most controversial of all the pathways, and rejected as unviable and unsafe in the Egyptian context by those in attendance of the drafting workshops, TZC+NUCLEAR was added to demonstrate that it provides very few jobs and although it reduces emissions, these emission reductions can be generated more cheaply and with more social and community co-benefits through proven renewable technologies, as demonstrated under the core TZC pathway.

TOWARDS ZERO CARBON WITH CONCENTRATED SOLAR POWER (TZC+CSP)

TZC+CSP replaces the nuclear part of the TZC+NUCLEAR with CSP in addition to large amounts of photovoltaic (PV) solar in the energy mix. CSP and biomass form the decentralized, community and governorate level energy generation in this mix, which is otherwise made of gas fired power stations, and large wind and solar farms distributed across Egypt. This is the most expensive pathway of all, due to the nascent form of CSP technology currently.

TOWARDS ENERGY INDEPENDENCE (TEI)

Aiming to build maximum resiliency to external shocks, price volatility and climate change, the TEI pathway also maximizes renewables, but on a centralized grid using natural gas for the transition to higher levels of renewables from 2030-2050. TEI requires the least oil product imports, has the third highest rate of job creation and emits the lowest amount of greenhouse gas emissions of all the pathways explored in **'80 Gigawatts of Change'.**

TOWARDS DECENTRALIZED ENERGY (TDE)

This final pathway offers the most radical departure from the status quo by decentralizing energy generation from the national grid, moving in the direction of devolving generation capacity using renewables to the governorate, community and domestic levels, where solar panels can directly feed the demand of an industry, a block of apartments or an Oasis. The economic cost of this pathway is high, but so are the benefits. With greater access to energy-related decision-making come more empowered and connected groups of Egyptians aware of their energy consumption and with more agency over their quality of access. TDE also offers the highest numbers of annual jobs created per Gigawatt hour due to its decentralized and high renewables model.

In summary, **'80 Gigawatts of Change'** is the first step on a much longer path towards generating increasingly accurate, detailed and sector-wide energy pathways for Egypt that are available to the public, involving stakeholders and civil society in their formation, and broadening the discussion on energy across the country. As such, **'80 Gigawatts of Change'** is a challenge to all those in academia, international organizations, research bodies, consultancies and non-governmental organizations, to collaborate and deepen what we have started in this study.

THE WAY FORWARD

In modeling, facilitating the workshops and writing these pathways, there are some key conclusions that we offer as the way forward to build on **'80 Gigawatts of Change'**.

Firstly, the timeline of these pathways must be extended to 2050. Long-term planning requires timelines relevant to the investment decisions made for different forms of energy generation, which are 40 years or more on average. To further build on the foundations laid in this report, a commitment to studying the possibilities for the entire energy sector – not just electricity – requires focus, academic and technical expertise and capacity building, and a convening body that can house the research and exploration of the huge body of work required for this task. Adding to this, we would like to see the nexus of energy, water and food addressed by future works, to ensure that increasingly accurate and holistic pathways are explored and synergies for positive and equitable development identified.

Finally, in the process of convening and authoring **'80 Gigawatts of Change',** huge amounts of varied skills-sets and vessels of knowledge and experience from civil society NGOs, human rights organizations, environmental impact assessors and others were drawn on; therefore, greater inclusion – not just consultation in the latter stages – should be a prerequisite for civil society and private sector development of future energy scenarios in Egypt.

> *The existence of fossil fuel subsidies has also meant Egypt's vast renewable energy resources have not had the opportunity to prove their worth, as falsely low fossil fuel prices ensure poor financial viability in comparison, restricting commercial availability to the consumer.*

2. INTRODUCTION

T***his study is the culmination of an 8-month project endeavoring to model how Egypt's electricity sector could look in 20 years' time*** if social and environmental constraints and community impacts are taken into account. It is the first report of its kind in Egypt, offering seven different pathways, each with different implications, costs, greenhouse gas emissions and benefits.

We have detailed the context, process, break down of results for each pathway and recommendations for next steps. Finally, this report is licensed under Creative Commons because it is important that its content penetrates all areas where people are working on Egyptian energy issues.

2. 1. EGYPT'S ENERGY SECTOR TODAY

The energy sector of today's Egypt has grown out of the bounty of the country's natural resources and the geographical spread of demand from its population and industry. As such, Egypt has a centralized national grid that follows the path of the Nile through the country, and until recently has been completely run by the State. Egypt is reliant on natural gas and oil for some 91% of its energy needs; the remaining 8% comes from the High Dam and 1% from wind and solar combined[1] . The energy sector in Egypt is constituted of fuel used for electricity, fuel used for transportation and other resources dedicated to producing power in industry. Sitting on vast reserves of natural gas have maintained the high rates of electricity access and consumption that has successfully helped Egypt to develop into the new millennium. However, between 2000 and 2013 the drop in native oil products production was not replaced with other energy sources[2] , along with a rise in consumption overtaking total production; Egypt went from being an oil exporter to an oil importer. The consequences of this switch fed into the plateauing of human, economic and industrial development which is still evident in 2015.

At its peak, energy demand in Egypt is currently around 30,000MW with a supply of a little over 26,000MW, leaving an energy deficit of around 4,000MW.[3] This deficit creates the frequent power cuts, which Egypt suffers from during peak demand, especially in the hot summer months. This deficit is not a mere hiccup but a substantial and deep-seated problem. The sustained increase in population that is predicted to continue at around 1.6% per year, is the most dominating factor that will fuel the continuation of the rising demand for energy.

Policies have naturally had a direct impact on consumption patterns. The Ministry of Petroleum and the Ministry of Electricity heavily subsidized conventional energy sources – particularly gasoline and diesel – which although they are targeted at the bottom wealthy quintiles, the subsidization policies have in fact benefited those with the most access to private vehicles, namely the middle and upper classes.[4] Until 2013/14, 70% of gasoline subsidies and 60% of natural gas subsidies went to the top 10% most wealthy in Egypt's population.[5] The other part of the electricity subsidization by the State prevents the full cost of production from being transferred to consumers. These unsustainable low prices have also been found to benefit the richest 20% of the population who consume the most, not the poorest that it is intended for. In total, fossil fuel subsidies in Egypt were taking up as much as 14.5% of the country's GDP by 2014 – more than the National Health Service budget.

Targeted subsidies can prove helpful in alleviating some impacts of poverty. The sweeping, non-means tested form of Egypt's subsidies finally prompted the government to enact a subsidy removal plan in July 2014, causing a sudden increase in both electricity and fossil fuel prices and an undocumented set of problems for low income business owners and families relying on their access to subsidized fuel for the bare essentials. The subsidy removal also impacted industry which no longer granted access to subsidized electricity and natural gas by the state, considerably increasing running costs. It could be argued that of all the sectors, industry is best placed to absorb the impact far better than families and small businesses with little or no margin within which to operate; also posing the moral question of whether industry should have been in receipt of subsidized fuel from a government with stretched resources in the first place.

The existence of fossil fuel subsidies has also meant Egypt's vast renewable energy resources have not had the opportunity to prove their worth, as falsely low fossil fuel prices ensure poor financial viability in comparison, restricting commercial availability to the consumer. Announced in late 2014, the government finally saw the opportunity to plug the energy gap in part with renewables. **A Feed-In-Tariff** [6] (FiT) program was introduced to encourage investors, businesses and landowners to install solar and wind power plants to sell electricity to the government in return for fixed rates. The announcements of the FiT and the subsidy removal programs, in late 2014 were perfectly synchronized to give birth to the long awaited renewable energy industry in Egypt. Individually the new electricity law introducing the FiTs, and the removal of the energy subsidies, are the two most major inflection points Egypt's energy sector has seen in many years. But these systems are still at the very early stages of implementation and will not come online before 2017.

FEED-IN TARIFF "FIT"

is a payment made to households or businesses generating their own electricity. Payments are made proportional to the amount of power generated and fed into the national grid.

The challenge of population growth, oil and gas price volatility, increasing desertification, changing weather patterns and more intense and frequent extreme weather events (such as heat waves, snow, dust storms, floods and droughts) will all be factors affecting Egypt's energy sector. The energy sector will consistently be at the very center of the government's fiscal and day-to-day policy-making, as without it, the country would come to a standstill. Egypt's energy sector also operates in the international sphere, affected by international agreements, trading, prices for fossil fuels, renewables and fossil fuel subsidies. With all these facets, it is clear that a functioning energy sector that can provide sustained access and affordability without compromising its surrounding environment and communities is a crucial but challenging set of requirements for us all to consider.

2. 2. THE ART OF VISIONING & THE MOTIVATION FOR THIS SCENARIO

"Visions are generally understood to have two main features: first, they are mental images of futures that are shaped by actors; second, they can, strongly or weakly, guide the actions of and the interactions between these actors."[7]

Smith, Stirling & Berkhout identify five potential functions of visions:

1. **Mapping a 'possibility space' to identify the realm of plausible alternatives and how to provide for them.**
2. **Identifying the technical, institutional and behavioral problems that need to be resolved.**
3. **Stabilizing technical target setting and other activities by creating a stable framework for actors to make decisions within.**
4. **Building a narrative that channels funding and resources into building its success.**
5. **Binding communities and networks of interests and actors** [8]

A core factor that has created this energy crisis and dictated how the policy decisions on solutions for averting it have been decided upon is the lack of recognition for how essential elements of visioning are to public policy planning. Some of history's most powerful forces are those that have mastered the art of storytelling and narrative, weaving together strands into a coherent narrative that engages people along the way, allowing them to envision a better/more stable/more prosperous/fairer future and their role in its creation and success.

Applying the five potential functions of visions outlined above to Egypt:

No mapping of possibility space has been done or publicly outlined, as the dominant narrative has been of ‘crisis’ and ‘power cuts’ that must be resolved as quickly as possible. Under these circumstances, seemingly quick fixes proposed by experienced actors will gain traction in the right circles, excluding the need or possibility for exploration of any other option.

Investigatory work has been done within the Egyptian Government and by private actors to identify the institutional and behavioral issues affecting the energy sector, for example, whether the regulator should be fully independent from the state as it is regulating state utilities. Technical barriers touch on multiple sectors which could be incorporated into a holistic energy vision, but when decision-makers are considering a narrow range of factors, can seem too insurmountable to tackle in the present (e.g. lack of relevant skills sets).

Stabilized target-setting was used before the political instability (e.g. 20% renewables by 2020 target), but when the target-setting is not combined with a plan on how to achieve the target in manageable time-budgets, it is impossible to mandate multiple government departments to work on achieving the end goal set in the future. Furthermore, this one renewable target did not sit within ‘a stable framework for actors to make decisions within, as the Government’s vision for the energy sector as a whole remained unwritten.

Where the overarching vision that creates the stable framework is lacking, it is very difficult to convince investors and actors of the political will to enact the shift, and therefore whether their money and time are in safe hands – narrative will carry a less detailed plan, but a detailed plan is stagnant without narrative.

Finally, where a sector has been state-run historically, the networks and communities of actors will be lacking. Already a fledgling renewables community has flourished around the announcement of the FiT – the target-setting in combination with the vision it encompasses has been the catalyst, in a way that a state-dominated, closed market with no vision beyond the status quo fails to engender.

In 2013, an EU fund and its consultants were dedicated to work closely with the Egyptian government on the Technical Assistance for the Reform of the Energy Sector (TARES) project to set a vision and action plan for the energy sector in Egypt for 2035. From the little that is publicly accessible of the TARES project, its biggest success so far has been to set the scene for the FiT program to come into effect as part of a more liberalized energy sector, opening it up to market forces more than previously. The new strategy also instills the energy efficiency mindset within the Egyptian culture to minimize high and inefficient consumption patterns. This has been operationalized through ministries finally approving a five-year subsidy removal plan in July 2014 where the price paid per KWh increases at a steady rate for higher consuming customers, while lower income consumers should not be gravely affected. In reality however, the incremental increases in cost to those in higher consuming tranches, were reduced at several points, and in 2015, the increases for consumption tranches 200 – 650 KW were canceled altogether, indicating a pro-rich policy of subsidy removal unfolding.

The introduction of FiTs and the subsidies removal program together have had a positive effect on encouraging consumers to be more efficient in their consumption and in seeking out alternatives to conventional energy, though given how recently the changes were brought in it is too early to determine trends in response to the measures.

> *"A new energy era is emerging, one which sees the confluence of three global policy drivers: energy security, climate politics and energy poverty. This energy trilemma now defines the global political economy of energy."*[9]

Egypt's energy sector is due to undergo big reforms. These uncoordinated stabs at solutions are based on a combination of firefighting crises, and a piecemeal set of policies which do not consider the nexus of 'the energy trilemma' that no country or person can escape.

In 2012, the UN Secretary General ***Ban Ki-moon*** described sustainable energy as

> *"the golden thread that weaves together economy, environment and equity."*[10]

Energy is deeply integrated in the daily lives of people. Consequently, decisions regarding which natural resources are used to supply the national grid with power have direct impacts on the livelihoods of people and the environment they live in. As civil society therefore, we do not see a governmental energy vision that encompasses the depth of energy's impact on society, communities, the surrounding environment, the economy or many more sectors besides. Moreover, what targets there are (e.g. 20% renewables by 2020) remain without a detailed pathway or plan for stakeholders to work to ensure the target is indeed met by 2020. In short, Egypt does not have a vision for how it will source its energy and is lurching from one crisis to another.

It is in this gap that the need for building an equitable energy scenario sits.

With this background in mind, ***Heinrich Böll Stiftung HBS*** North Africa and the ***Egyptian Center for Economic & Social Rights ECESR*** have collaborated to build a non-governmental energy scenario with various pathways to achieving it by engaging civil society, business and all industry hoping to build a cleaner future for Egypt.

2. 3. USING THIS REPORT

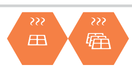
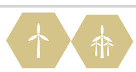
We want to make this scenario as useful and as readable as possible so we have written this report for those with technical knowledge about energy, and those without.

Each Pathway is presented using the same structure of analysis, if you would like to skip the graphs and tables, we suggest you read the 'breaking it down' section under each pathway for a description of the energy mix, the policies required, where the jobs will be created, the level of greenhouse gas emissions saved or emitted, and the overall vision that underlies the pathway.

We have wherever possible tried to unpack the technical terminology so that the average layperson can also read and understand the more technical parts of the scenario.

Finally, this report has a creative commons license, which means that any parts of the report can be quoted, used or reproduced without the authors permission, if referenced correctly. We encourage you to use this report wherever and whenever you can to spark further discussion.

2. 4. PAHTHWAYS ICONS KEY

CATEGORY		ICON	FEATURE
INFRASTRUCTURE	SOURCE		Thermal Power
			Solar (PV)
			Solar CSP
			Wind
			Hydro
			Biomass
			Nuclear
	SCALE		Thermal **Gas** Power plants
			Thermal **Coal** Power Plants
			Solar PV **(Small Scale/ Large Scale)**
			Solar CSP (**Small Scale/ Large Scale**)
			Wind (**Small Scale/ Large Scale)**
			Hydro Electric Power from the **High Dam in Aswan**
			Hydro Electric Power from **Pumped Storage**
			Hydro Electric Power from **Micro Turbines**
			Biomass Energy Plant from Agricultural and Sewage Waste (not solid waste)
	LOCATION		Power Plant Location – **Near to the Nile River / Within Proximity of National Grid**
			Wind Power Location – **Gulf of Suez / Desert: Western Desert and Southern Sinai**
			Hydro Electric Power Location – **River Nile / Streams**

CATEGORY	ICON	FEATURE
ENERGY ACESS		Pathway Promotes Centralized distribution of Energy via National Grid
		Energy Source Uses Micro Grid
		Pathway Promotes Decenteralization of Energy Distribution
COSTS – FINANCE	$	Total Cost of Implementing Pathway in USD
		Market Price of Fossil Fuels Used – No Subsidization Included
		Upgrade of the National Grid Required
	FiT	Feed-in Tariff Program for Renewables Required
	PPP	Public Private Partnership (PPP) Financing Model
	BOO	Build, Own, Operate (BOO) Financing Model
COSTS – IMPACTS	AIR / WATER / LAND	Energy Source Causes **Air, Water** or **Land Pollution**
		Energy Source Has **High/Medium/Low** Water Use
	CO_2 / CO_2 / CO_2	Energy Source Creates **High/Medium/Low** Level of Carbon Lock-in
IMPLEMENTERS		Central Government of Egypt Level
		Governorate Level
		Community and Domestic Level
		Private Sector
OIL SUPPLY	OIL / OIL / OIL	**High/Medium/Low** Total Primary Supply of Oil Equivalent in 2035 (includes production, imports and exports)
JOB CREATION		Total Number of Jobs Created per Annual GigaWatt Hour by 2035
CO_2E EMISSIONS	CO_2e	Pathway's Total Greenhouse Gas Emissions (expressed as Million Metric Tonnes of CO2 equivalent) Generated by 2035

> *“The timeline set for these pathways was designed to be comparable to the governmental scenario done by* TARES, *where short term is up to* 2020, *medium term is up to* 2025 *and long term ends at* 2035.*”*

3.

METHODOLOGY

With the goal of offering an energy scenario for Egypt that takes into consideration environmental and social aspects, three pathways with differing priorities were defined: firstly, a zero carbon pathway to understand the costs and extent of the challenge to fully decarbonize energy provision in Egypt; secondly, an energy independence pathway, intended to study the prospects of achieving energy sovereignty; and finally, a maximizing jobs pathway prioritizing job creation. However, as the discussions with the technical team and modelers commenced, the pathways had to be redefined due to technical constraints, as well as to account for the relatively short-term nature of the chosen timeline.

The timeline set for these pathways was designed to be comparable to the governmental scenario done by TARES, where short term is up to 2020, medium term is up to 2025 and long term ends at 2035. The revised pathways were defined as: 'Towards Zero Carbon', 'Towards Energy Independence' and 'Towards Decentralized Energy' – by 2035. As the first study of its kind, and given the limited modeling capacity, the team also decided that the focus of this scenario would be on the electricity sector, not the whole energy sector.

Setting out to execute this brief turned out to be more difficult than planned. One of the main initial challenges was in finding an Egyptian energy modeler both practiced in modeling and able to take on the vision of this project to consider issues wider than the conventional energy scenario. Furthermore, the team also found it hard to compile baseline data as the most accurate data is not made publicly available by the Government or just does not exist. Ideally the baseline should have been similar to the one used by TARES to allow for fair comparison and legitimacy, however this was not accessible.

The chosen time frame of 20 years until 2035, is of a relatively short-term nature when compared to the international arena, posing analytical issues after the model has been run. An example of how a 2035 end point is not the most accurate representation of how costs would be spread and recouped over time, is that investments in power stations are made on the basis of a minimum 40-year working lifetime. Thus investment in thermal power stations (which are required in all of the pathways) would not be made or viable without 2050 projections of energy use and mix. This is a shortcoming we suggest be built on in 'The Way Forward' section of this report.

The four pathways were then run using an integrated energy-modeling tool known as LEAP[11] **(Long-range Energy Alternative Planning system)**, which is a tool that is commonly used to plot consumption, production and resource extraction in all sectors of an economy and is then fed with a database of inputs, historical data and supported assumptions. The model is then run to produce results that aim at assessing the viability of each pathway, its advantages and its shortcomings.

The model inputs include energy demand projections based on consumer sectors, which are used consistently across all pathways. However, a different energy generation mix is specified for each pathway according to its defined focus (zero carbon, energy independence or decentralized energy). The results for all pathways are represented in carbon dioxide equivalent emissions, a balanced energy mix and a cost-benefit summary. A decision was made to draw the line between a full vision - outside the restrictions of current energy sector infrastructure - and a viable pathway based on current structures, given the short timeline of 2015-2035. It was decided that the latter was achievable within our constraints, therefore the energy mixes generated under each pathway are somewhat constrained by the load balancing principle required of a centralized grid maintained in the model.

After generating results, two workshops were conducted to collect feedback and input from relevant technical and social sciences professionals. The technical workshop was held for two days, the first day asked participants to carry out two brainstorming sessions.

In the first session the challenges from the technical, economic and governance aspects were listed while in the second session solutions to the challenges were proposed.

During the second day the results of the model-generated pathways were presented and constructive feedback from the professionals was discussed and taken note of. Between the two workshops, the modelers went away and incorporated some of the key recommendations made in the technical workshop. These updated model results were then presented to the social workshop and the participants were given a chance to give feedback and introduce new aspects to the model.

The facilitators prepared a set of policies that would be necessary for the implementation of each pathway, the workshop was then intended to go through each policy, traffic lighting each one according to its acceptability on grounds of social and environmental impact – suggesting improvements where the policy received an amber light, or a complete alternative proposal where it received a red light. However, the workshop did not reach this point, as participants felt strongly that they wanted to discuss the formation of the pathways themselves, the decisions behind the inputs and how they could be improved.

This was a shortcoming that has impacted our ability to qualitatively measure the full range of social and environmental impacts of the pathways as originally intended. In future, it will be noted that the social scientists need a day's introduction to the process of modeling, inputs decision-making and certain principles regarding energy provision that those with technical knowledge take for granted.

Based on some of the suggestions of participants from both workshops, aspects of all pathways were revised and are presented in this report inclusive of the constructive feedback given.

For the first running of the model efficient demand was not assumed, but after feedback the 'efficient' scenario for each of the three pathways has been assumed in order to maximize the benefits energy efficiency offers. (It would not be sensible to maximize renewables on a centralized grid without also pursuing energy efficiency measures; otherwise energy would be being wasted.)

Demand figures used for this model are based on historical data and expected growth rates as collected and projected by CAPMAS (Egypt's Central Agency for Public Mobilization and Statistics). Energy Demand data is collected from the following sectors: industry, households, transportation, agriculture and other services.

The LEAP model presents the net value (the cost of implementation), the greenhouse gas (GHG) emissions and the total oil production, imports and exports for each pathway.

The cost of GHG emissions reductions is calculated by comparing the cost of BAU with that of the pathway with reduced emissions, attributing the gap in cost per unit of GHG saved.

Oil exports were assumed to remain at -7.6 million tonnes oil equivalent / year.

The Energy Sources are commonly referred to throughout all the pathways with the following definitions:

Thermal: except for the 'BAU+COAL' pathway which includes some coal in the mix, all other pathways use only natural gas for thermal energy.

Solar: here encompasses Solar Photo Voltaic (PV) only.

CSP: Concentrated Solar Power (CSP), used in only one pathway.

Wind: Onshore (on land) wind turbines in large groups known as 'wind farms'.

Hydro: 'hydro' refers to a combination of the existing High Dam capacity, implementation of already planned hydro projects (0.05GW pumped storage) and 1.15GW of micro turbines which can be installed in arrays down the side any moving body of water.

Biomass: biomass is used to refer to agricultural and domestic sewage waste only. It does not include food and solid waste collected from consumers.

Nuclear: refers to the use of one Nuclear power plant.

"Costs" as defined by the model's inputs only include the capital costs for the establishment, maintenance and operational costs of an energy source. It does not include decommissioning costs. The model was not built to include complex data that quantifies the cost of health, social and environmental related issues, and this is therefore, a major shortcoming of this first study. Recognizing this however, we built the workshops to include a qualitative analysis of costs, incorporating this analysis in the 'breaking it down' section of each pathway in this report.

Finally, all assumptions used in the model are detailed in the 'BAU – Baseline Pathway' section below, or where different, outlined at the beginning of each pathway.

> *Developed country scenarios have the difficulty but also the privilege of working out how to decarbonize and maintain a developed standard of living. Developing countries modeling has the challenge of incorporating many more factors as it must also support the development of the country to lift its people out of poverty ...*

4.

WHAT IS ALREADY OUT THERE?

We conducted a literature review in order to gain an insight into what work -academic or otherwise- is already out there, on both Egyptian energy sources and visions, and in the international sphere. We were looking for existing literature on building equitable scenarios, visions for future systems, how to conduct workshops to gain critical feedback and input and any other relevant studies or works.

4. 1. EXAMPLES OF ENERGY SCENARIOS FROM AROUND THE WORLD

When it comes to modeling, there are many varieties of techniques and models, combinations of inputs, and a prioritization of different issues, for example, GHG emissions is prioritized over dispersed energy generation. The 'Who's Getting Ready for Zero?' report[12] outlines case studies of energy and economy-wide modeling done in developed and developing countries, summarized in a couple of examples below.

Of those from developed countries, the example of 'Beyond Zero Emissions Australia' is among the most detailed. Carried out by a grassroots project engaging a variety of actors, including engineers, policy developers and academia in Australia, each sectoral report examines how to decarbonize Australia's economy, including moving to 100% renewable energy in only 10 years. They have calculated that spreading out the capital costs of decarbonization over a 29-year period (2011-2040) renders the plan at roughly the same cost as business as usual over the same timeline.

Developed country scenarios have the difficulty but also the privilege of working out how to decarbonize and maintain a developed standard of living. Developing countries modeling has the challenge of incorporating many more factors as it must also support the development of the country to lift its people out of poverty and participate in the country's pathway towards prosperity and a more sustainable energy mix, with the limitations of bad data collection, little institutional capacity and limited to access to complex and accurate models.

The Ethiopian report, 'Ethiopia's Climate-Resilient Green Economy Strategy'[13], carried out by the government of Ethiopia in 2011, is unique in its view that emissions reductions are a co-benefit of development and carbon neutral middle-income status. Ethiopia plans to achieve carbon neutrality by 2025. Their strategy of achieving this is done mostly through incorporating a larger share of renewables into the national energy mix, replacing older stoves with more energy efficient ones and improving production practices for farming and livestock. The plan comprises of decreasing the per capita consumption from its current 1.8 to 1.1 tonnes of Carbon Dioxide equivalent, and sustaining this level of consumption whilst developing into the middle-income country.

Setting the marker for low-carbon ambition and coverage of major emitting countries, the Deep Decarbonization Pathways Project (DDPP) by the Sustainable Development and International Relations (IDDRI) and the Sustainable Development Solutions Network (SDSN), have developed 16 decarbonization plans for 16 of the world's highest emitters: China, India, USA, Brazil, Indonesia, Mexico, South Africa, Russia, Japan, Germany, Australia, UK, Korea, France, Canada and Italy. Each of these pathways reflects the different dynamics, capabilities and resources of the country, offering decarbonization pathways in line with economic and developmental needs. For example Canada's pathway requires a 90% reduction in CO_2 emissions by 2050 while India's incorporates an increase in emissions, though still facilitating a shift to a decarbonized economy in the long term. DDPP have identified three pillars of reform that are common to all 16 scenarios however: energy efficiency, decarbonization of electricity provision and fuel switching to electricity.

DEEP DECARBONIZATION PATHWAYS PROJECT (DDPP)

The Deep Decarbonization Pathways Project (DDPP) is a global collaboration of energy research teams charting practical pathways to deeply reducing greenhouse gas emissions in their own countries. It is predicated on taking seriously what is needed to limit global warming to 2°C or less.

THE INSTITUTE FOR SUSTAINABLE DEVELOPMENT AND INTERNATIONAL RELATIONS (IDDRI)

A non-profit policy research institute based in Paris. Its objective is to determine and share the keys for analyzing and understanding strategic issues linked to sustainable development from a global perspective. IDDRI helps stakeholders in deliberating on global governance of the major issues of common interest: action to attenuate climate change, to protect biodiversity, to enhance food security and to manage urbanization. IDDRI also takes part in efforts to reframe development pathways.

SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK (SDSN)

In 2012, UN Secretary-General Ban Ki-moon launched the UN Sustainable Development Solutions Network (SDSN) to mobilize global scientific and technological expertise to promote practical problem solving for sustainable development, including the design and implementation of the Sustainable Development Goals (SDGs). Following their adoption, we are now committed to supporting the implementation of the SDGs at local, national, and global scales.

4. 2. RESEARCH ON EGYPT'S ENERGY SECTOR

In 2013, Siemens Egypt did some technical and economic modelling for future scenarios for Egypt, including the cost of varying mixes that included coal and nuclear. These scenarios are not publicly available.

The Egyptian Center for Economic Studies report, 'Energy Security in Egypt'[14] , has two focuses: assessing the various pricing approaches in a more liberalized sector, and the second looks at Egypt's energy policies for including new sources of energy (coal, nuclear, renewables) alongside some existing scenarios for energy mixes assessing their potential for reducing Egypt's energy 'insecurity'.

The Government's renewables Agency, the New and Renewable Energy Authority (NREA), published a document in 2015 on the "Future of Renewable Energy in Egypt.", which shows their role and near term planning for increasing renewables in Egypt.[15]

The League of Arab States, IRENA and RCREEE published a 'Pan-Arab Renewable Energy Strategy, 2030' in 2014[16] that aims to identify for the gaps for renewable energy deployment across the region of 22 countries. It also does a Strengths, Weaknesses, Opportunities & Threats (SWOT) analysis of the possibilities for maximizing renewable energies in the region.

Engineering and management consultancy Chemonics Egypt, produced a comprehensive review of the options for the government to fuel the cement industry in Egypt, covering the economics of a variety of options, including coal and nuclear.[17]

NEW & RENEWABLE ENERGY AUTHORITY (NREA)

It was established to act as the national focal point for expanding efforts to develop and introduce renewable energy technologies to Egypt on a commercial scale together with implementation of related energy conservation programs .

THE INTERNATIONAL RENEWABLE ENERGY AGENCY (IRENA)

is an intergovernmental organization that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a center of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy.

THE REGIONAL CENTER FOR RENEWABLE ENERGY AND ENERGY EFFICIENCY (RCREEE)

is an independent not-for-profit regional organization which aims to enable and increase the adoption of renewable energy and energy efficiency practices in the Arab region. RCREEE works inter governmentally with its member countries which include: Mauritania, Morocco, Algeria, Tunisia, Libya, Egypt, Sudan, Palestine, Syria, Iraq, Jordan, Lebanon, Yemen, Djibouti, Kuwait and Bahrain

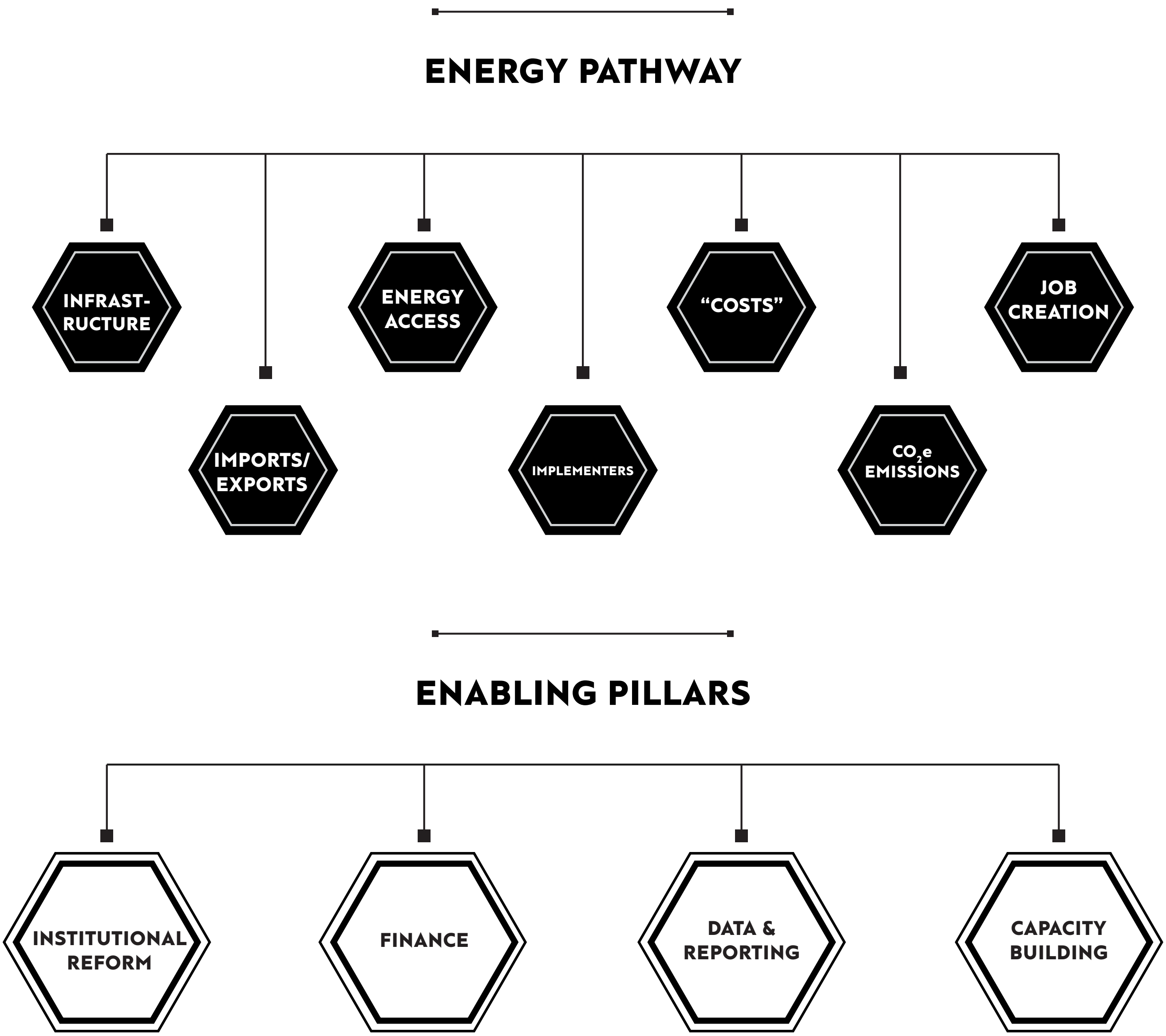
> *What we understand by energy access and how this interacts with the target population would also have a bearing on our understanding of 'energy equity' and 'energy poverty', since access, equity and poverty are closely linked concepts.*

5.

THE 7 PATHWAYS

Across all the proposed pathways the following structure is used to assess the attributes of each:

Figure 1: Pathways Assessment Structure and its Enabling Pillars



5. 1. INFRASTRUCTURE

Infrastructure refers literally to the structures that will have to be constructed, installed and maintained to support the specified form of energy generation. Infrastructure is generally constructed to last at least 10 years, and therefore requires consideration as to its geographical location, how it is done and with what materials.

Given the semi-permanence or permanence of new infrastructure, there are established templates for assessing the 'sustainability' of new and proposed infrastructure. The United Nations Commission for Sustainable Development 2001 framework for sustainability indicators[18] uses the following **guiding indicators:**

- **Social**
  Equity (poverty and gender); health (nutrition, mortality, sanitation, water, healthcare); education (education level, literacy); housing (living conditions); security (crime); population (population change).
- **Environmental**
  Atmosphere (climate change, ozone layer, air quality); land (agriculture, forests, desertification, urbanization); oceans, seas, and coasts (coastal zones, fisheries); freshwater (quantity and quality); biodiversity (ecosystems and species).
- **Economic**
  Economic structure (economic performance, trade, financial status); consumption and production (material consumption, energy use, waste generation and management, transportation).
- **Institutional**
  Frameworks (international cooperation; strategic implementation); capacities (information access, communication infrastructure science and technology, disaster preparedness and response).[19]

Moreover, according to the authors of the framework, infrastructure sustainability must use a long-term timeline; this allows for the assessment of whole project cycle, including the planning, design, construction, operation, maintenance and decommissioning processes.[20]

Another method of assessing infrastructure sustainability that is being increasingly recognized by investors concerned to avoid buying 'stranded assets'[21], is 'carbon lock-in'.

> *"**Carbon lock-in** is an example of the phenomenon of path dependence– 'the tendency for past decisions and events to self-reinforce, thereby diminishing and possibly excluding the prospects for alternatives to emerge'–recognized in economics and studies of technology innovation. Specifically, carbon lock-in refers to the dynamic whereby prior decisions relating to GHG-emitting technologies, infrastructure, practices, and their supporting networks constrain future paths, making it more challenging, even impossible, to subsequently pursue more optimal paths toward low-carbon objectives."*[22]

Common approaches to assessing carbon lock-in include:

- Equipment lifetime;
- Increase in CO_2 emissions over time;
- Financial barriers to subsequent replacement with low-carbon alternatives;
- Policy and institutional mechanisms that protect the dominance or economic viability of high-carbon options.

Combining both these approaches therefore, under this equitable energy scenario, carbon lock-in is considered a weakness to be avoided where possible, in combination with assessment of the broader sustainability concerns identified by the UN framework above.

5. 2. ENERGY ACCESS

Electricity allows for the better functioning of hospitals and schools;[23] in homes electricity allows families to refrigerate food to prevent waste, to improve their quality of life with heating or cooling systems, to have bathroom facilities, and to have light at night.

Irrigation pumps have revolutionized small-scale agriculture by doing away with the need for daily water collection, and irrigated land has been found to be twice as productive as non-irrigated land. Refrigeration facilities for a farm or grower reduce wastage, allow for export potential and can extend the life of their produce to maximize sales.[24]

These are just some examples of how energy access affects lives every day – access or lack of it is deeply ingrained in the 21st century way of living, there are many who could not survive without it, and many that still live and thrive without access, but could benefit from some of the opportunities electricity brings.

Broadly, there are three options for providing electricity in the home[25]:

- **National grid extension**
- **Mini-grids (localized electricity systems)**
- **Off-grid systems (from source to consumer directly)**

Energy access however is a wider concept than pure connection to the electricity grid or not. The International Energy Agency IEA combines 'connection', achievement of a 'minimum consumption level' and 'increasing electricity consumption over time' as an indicator of energy access - this starts to illuminate the dynamism and variability of achieving 'access' to energy.

THE INTERNATIONAL ENERGY AGENCY (IEA)

The IEA is an autonomous organization which works to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA has four main areas of focus: energy security, economic development, environmental awareness and engagement worldwide.

> *"What we understand by energy access and how this interacts with the target population would also have a bearing on our understanding of 'energy equity' and 'energy poverty', since access, equity and poverty are closely linked concepts."*[26]

Rehmana et al.[27] argue that access is related to freedom of choice, and therefore accessibility on the person's terms defines whether energy access has been achieved.

Combining several approaches, particularly those explored in the International Institute for Environment and Development's 2015 publication on energy access,[28] we offer a qualitative analysis of energy access for each pathway according to whether it offers reliability, connection to a source of electricity and the level of agency an Egyptian citizen might experience in trying to access a source of electricity (centralized or otherwise).

5. 3. "COSTS"

We use "Costs" in inverted commas as the limited nature of this study allows for only a conservative estimate of basic costs incurred in each pathway. The real costs on the ground and felt by people have been qualitatively analyzed and manifested throughout the report, and are therefore not fully represented under the figures for "costs" in this report.

"Costs", as defined by the model's inputs, only include the capital costs for building or installing the technology, and the maintenance and operational costs of it. It does not include decommissioning costs. Immediately, that does not give us the breadth of assessment required for a full sustainability measurement on the energy mix and individual technologies, as "costs" – often termed externalities - incurred from pollution abatement technology, environmental preservation measures, water treatment of effluent before going into the Nile, social security measures for workers, potential costs of negatively impacting local livelihoods etc. are not quantified in this study. "Costs" are however qualitatively assessed under each pathway.

No energy subsidies are included in any of the pathways offered. Therefore, the full "cost" of implementing reflects the market price for imported fossil fuels and the value of native production feeding domestic consumption of energy.

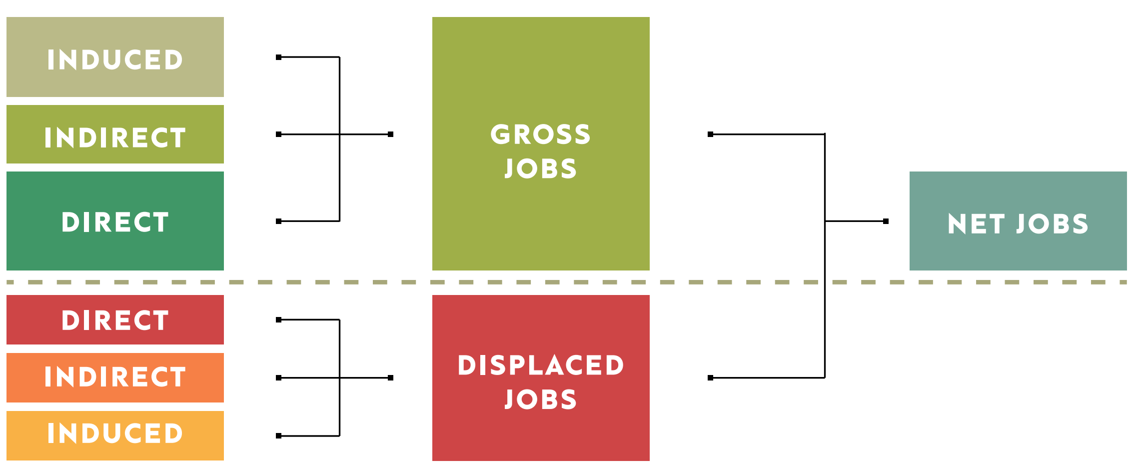
5. 4. JOB CREATION

The only quantifiable social metric used for all the pathways are the estimates of numbers of jobs created by each energy mix. The estimate of jobs created is calculated using the annual GWh of electricity generated (jobs/annual GWh), using the following upper limits of the European ranges per energy source, as calculated in the UK Energy Research Centre (UK ERC) report[29]:

- **Biomass** 1.1/annual GWh
- **Hydro** 0.6 /annual GWh
- **Solar (PV)** 0.57/annual GWh
- **Thermal** 0.2/annual GWh
- **Wind** 0.2/annual GWh
- **CSP** 0.1/annual GWh
- **Coal** 0.1/annual GWh
- **Energy Efficiency**[30] 0.2/annual GWh

The UK ERC report uses the "Net Jobs" method to calculate an average number of jobs created per annual gigawatt hour. Net jobs equals the sum of the gross positive jobs (jobs created directly and indirectly by the energy source) minus the displaced jobs (jobs lost in existing industries which are displaced by the new industries and jobs created). Figure 2 below illustrates this method.

Figure 2: Illustrating the "Net Jobs" method of calculation[31]



'Gross Jobs' includes the positive impact on employment associated with a particular investment including: manufacturing, installation, operation and maintenance of new equipment. With the caveat issued in the report that,

> *"...these indicators raise the contested question of whether high labor intensity is a good thing or not. A project or program with high jobs intensity may seem like an advantage from the point-of-view of a green stimulus programme, but they also indicate that labor productivity of the jobs are likely to be low, which could have negative consequences for the economy as a whole over the longer-term."*[32]

The UK ERC report does not include estimations of job creation for the nuclear industry, we have therefore taken a spectrum of 400-700 jobs created per nuclear power plant, according to a US nuclear industry report, which is likely to be generous in its estimations.[33]

5. 5. IMPORTS & EXPORTS

Despite the intention to move towards energy independence in general, and in particular in the 'Energy Independence' pathway, imports are included in varying amounts based on the technologies of the energy mix. All 7 pathways assume no exports of energy from Egypt. Though with a longer timeline considerations of exporting electricity from renewables could be considered and would offer more viability than on the 2035 timeline.

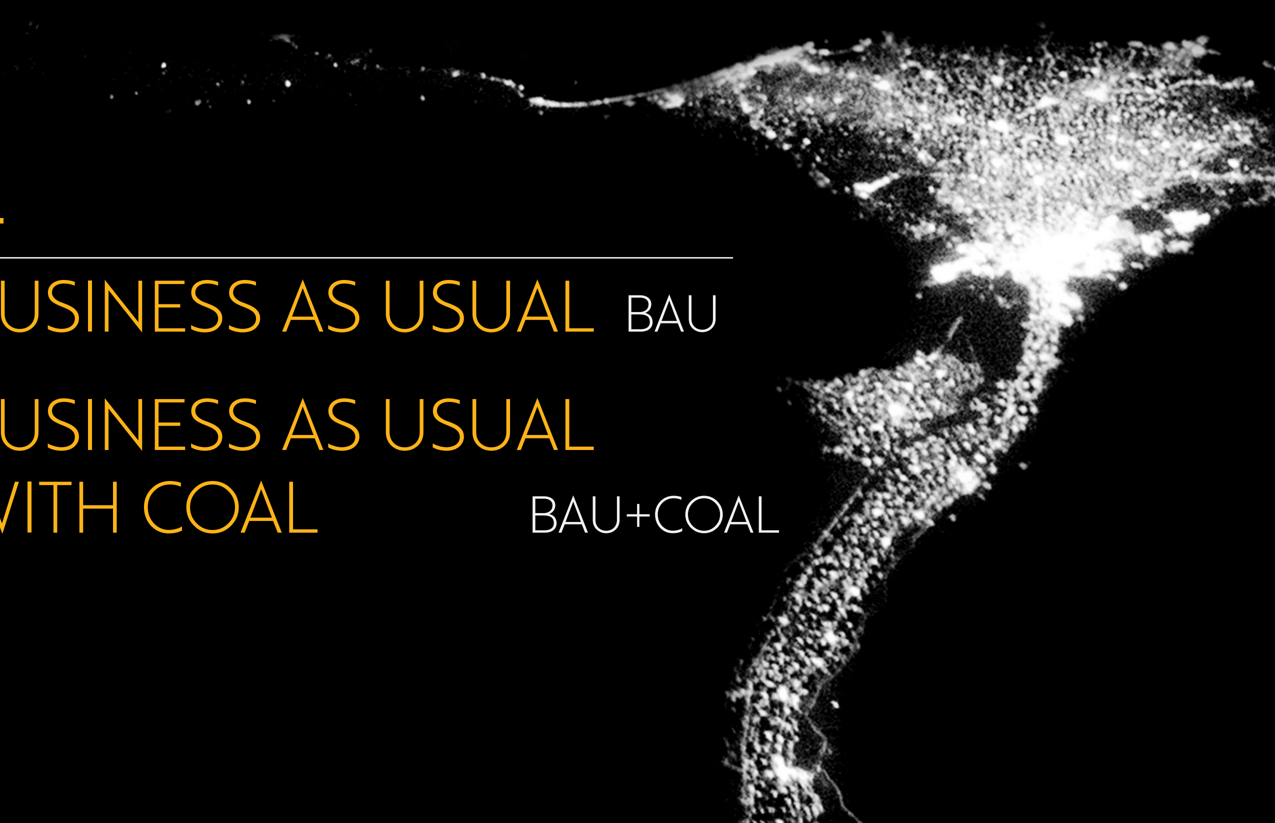
5. 6. IMPLEMENTERS

This section very simply looks at under each pathway who will be the main implementers in realizing the energy mix over the twenty-year period from the state, governorate, community & domestic or private sector levels.

5. 7. CO_2E EMISSIONS

In the final section of analysis the greenhouse gas emissions (expressed as CO_2 equivalent (CO_2e)) are presented in graph format and compared to BAU for the cost of achieving the CO_2e reductions in each pathway.

> *Two different energy demand rates are considered. The first demand profile is the normal demand rates as mentioned in the government's official reports. The second profile is the expected demand rates in case of a more efficient demand...*



6.

BUSINESS AS USUAL BAU

BUSINESS AS USUAL WITH COAL BAU+COAL

B***usiness As Usual (BAU) typically refers to the current status quo of the given sector, and then projects the outcome of applying the current rates of growth,*** consumption and availability of energy sources in a linear fashion – that is, consistently growing at the same rate year on year, without any major changes. We use BAU as a baseline pathway to be able to compare the financial, GHG emissions and technical impact of any given pathway, compared to the status quo.

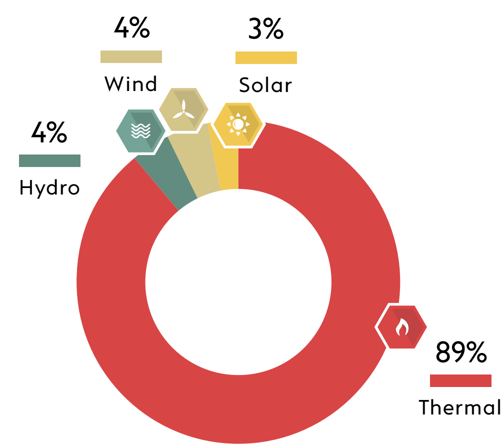
BAU

Business As Usual

ENERGY			LOCATION	COSTS		IMPLEMENTERS
SOURCE	SCALE	MIX		FINANCE	IMPACTS	
	GAS	89%	GRID	PPP	AIR, WATER, CO_2	
		3%	—	FiT, BOO, PPP	CO_2	
		4%	GULF, DESERT	FiT, BOO, PPP	CO_2	
		4%	—	—	CO_2	

JOB CREATION	ENERGY ACCESS	OIL SUPPLY	CO2E EMISSIONS (MILLION METRIC TONNES)
214,447.4		OIL	CO_2e 13,404.5

TOTAL COST = -4.6 BILLION USD

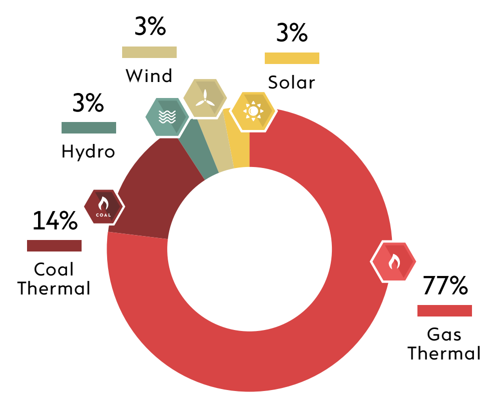


BAU+Coal

Business As Usual With Coal

ENERGY			LOCATION	COSTS		IMPLEMENTERS
SOURCE	SCALE	MIX		FINANCE	IMPACTS	
	GAS	77%	GRID	PPP	AIR, WATER, CO2	
	COAL	14%	GRID, NILE	PPP	AIR, WATER, LAND, CO2	
		3%	—	FiT, BOO, PPP	CO2	
		3%	GULF, DESERT	FiT, BOO, PPP	CO2	
		3%	—	—	CO2	

JOB CREATION	ENERGY ACCESS	OIL SUPPLY	CO2E EMISSIONS MILLION METRIC TONNES
114,120.6		OIL	14,687.3



TOTAL COST = 11.5 BILLION USD

6. 1. ASSUMPTIONS

In the model, there are certain assumptions that are made which are applied to all the pathways generated by the model.

6.1.1 DEMAND SIDE

Firstly, two different energy demand rates are considered. The first demand profile is the normal demand rates as mentioned in the government's official reports, assuming that the demand rates will keep increasing at predefined growth rates as set out in Figure 3. The second profile is the expected demand rates in case of a more efficient demand, assuming that consumption rates will decrease due to a combination of increased use of LED lamps, more efficient motors, savings in energy consumption due to pricing that reflects the costs of production, greater social awareness and other factors. The growth rates used are as follows:

Figure 3: Energy demand growth rates by fuel type[3 4]

Type	Normal demand rates % Growth rate	Efficient demand rates % Growth rate
Electricity	+6	+5
Natural Gas	+1	+1
Fuel oil and others	+5	+4
Diesel oil	+9.1	+6
LPG	+1	+1

Based on these assumptions, it was found that the demand capacity in 2035 should be around 96 GW with normal growth rates, and 80 GW for the energy efficient demand rates. Given that it would not make sense to run renewables without simultaneously increasing energy efficiency, all three pathways use an efficient demand rate.

6.1.2 ENERGY EFFICIENCY

Energy efficiency is included in all of the three main pathways. It is considered an industry of its own, creating jobs, contributing to GDP and to emissions reductions. Energy efficiency in this report includes:

- The complete removal of fossil fuel subsidies.
- The retrofitting of inefficient buildings with insulation.
- Consumer awareness campaigns to inform, monitor and feedback to energy consumers their levels of consumption building up their history over time.
- A labeling scheme and regulations to ensure all white goods are labeled with information on the products energy efficiency.
- The jobs created by energy efficiency are calculated to include jobs from energy efficiency measures in households, transport, buildings, the electricity grid and industry.

6.1.3 GENERATION SIDE

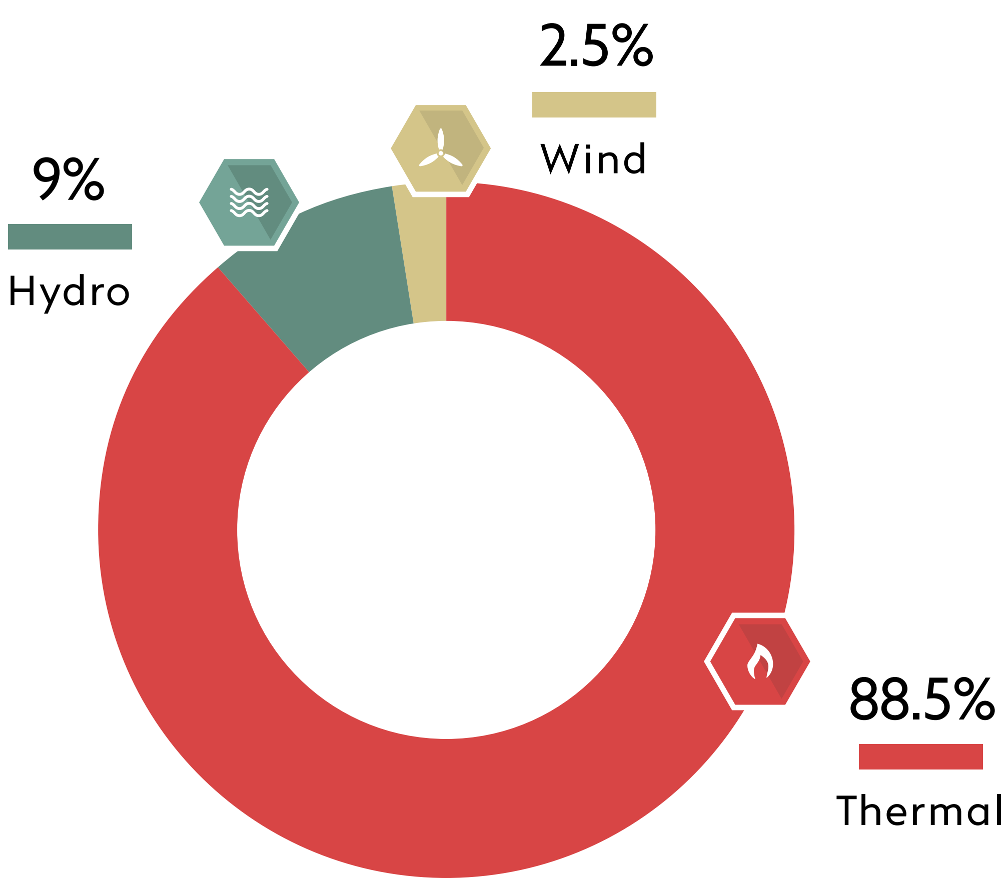
The BAU pathway builds on Egypt's current energy mix, which is elaborated on in Figure 4 below. This baseline pathway assumes that no major changes are introduced to Egypt's current energy mix where growth rates in energy generation increase to meet the growth in efficient demand. Growth rates are assumed as follows:

- An annual growth rate in generation capacity of 4.6% for thermal energy resources to meet any rise in demand that is not met by all other resources.
- It is assumed that hydropower has been utilized to the maximum and hence its generation capacity is expected to stay constant.
- Solar and wind energy resources are modeled using the government's announced renewable energy programs that target a 4GW reliance on renewables by 2020. It is assumed that the government will not introduce any other renewable energy incentive programs and hence a 2% annual increase is assumed for solar and wind energy. This 'bare minimum' is a worst-case scenario for renewable energy.
- No new energy sources are added to the energy mix.

Figure 4: Egypt's Current Energy Sources[35]

Type	Generation Capacity of 2014 (GW)
Thermal	27.0
Hydro	2.8
Wind	0.7
Solar	0
Nuclear	0
Biomass	0
Total	30.5

Figure 5: 2014 Energy Mix (Current)



6.1.4
ASSUMED COSTS

The models assume certain costs based on international market prices to set-up and operate the different energy sources. Figure 6 lists capital costs (costs in the initial building and installation of the energy source) as well as fixed and variable operation and maintenance costs. These costs are expected to increase over the course of the 20 years this study covers, hence the use of percentage growth rates, which are assumed as listed in Figure 7.

Figure 6: Assumed capital, operation and maintenance costs used[3][6]

Generation Type	Capital Cost (USD/kW)	Fixed OM Cost (USD/kW - year)	Variable OM Cost (USD/MWh)
Thermal	700	5	7
Hydro	2000	10	0
Wind	2000	25	0
Solar	2500	15	0
Nuclear	3500	65	1.5
Biomass	3000	80	3.5

Figure 7: Annual Growth Rate of Capital Cost

Generation Type	All Pathways			Towards Decentralized Energy		
	2015 - 2020	2020 - 2030	2030 - 2035	2015 - 2020	2020 - 2030	2030 - 2035
Thermal	-5%	-3%	0	-5%	-3%	0
Hydro	0	0	0	0	0	0
Wind	-5%	-3%	0	-5%	-3%	0
Solar PV	-10%	-5%	0	-5%	-2%	0
CSP Solar	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Biomass	0	0	0	0	0	0

Figure 8: Cost assumptions for coal fired power stations[37]

Capital cost ($/kW) *	2000
Fixed OM cost ($/kW-yr)**	40
Variable OM cost ($/Mwh)***	5
Capital cost growth rate****	-1%, till 2020 then 0%

* Using an average of the different station technologies, scaled to match the real cost of the Egyptian market. The scale factor used is based on the cost of PV in Egypt compared to its cost in the EIAs 2013 report.

** Using an average of the different technologies included in the EIA 2013 report.

*** Using an average of the different technologies included in the EIA 2013 report.

**** As used in the 2013 EIA report, -1% until 2020 is assumed, then a 0% growth rate from 2020 is used based on recommendations from participants in the technical energy workshop.

6. 2. BAU & BAU+COAL RESULTS
BREAKING IT DOWN

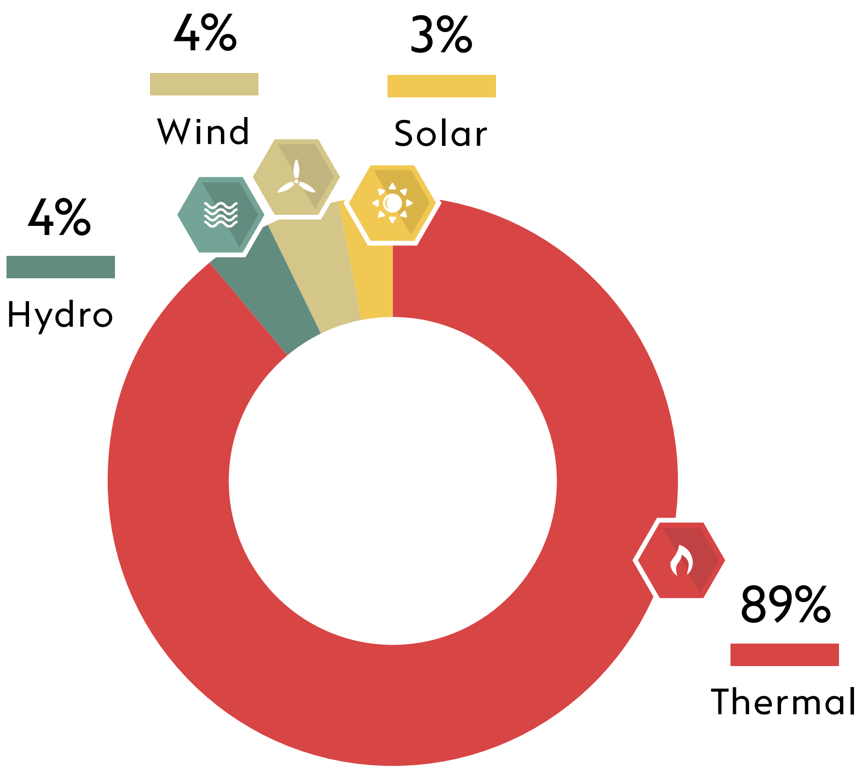
The reality of the current energy crisis is that there can be no 'business as usual' if the country is expected to simultaneously progress in developmental terms and also eliminate fossil fuel subsidies. As such, for clarity in spite of the volatile politics, our BAU pathway attempts to draw a line in the sand roughly where Egypt had come to before the energy crisis, extrapolating that energy mix and set of policies using a longer timeline. The BAU pathway assumes no new sources of energy are introduced to the energy mix but the volume of existing sources increases to match the growth in demand that continues through to 2035. However, it is assumed that efficiency techniques are adopted by consumers on the demand side, which allows for a more efficient BAU than a pure extrapolation of the current status quo, taking account of reasonable rates of behavioral change.

The 2035 energy mix is detailed in Figures 9 and 10 below, showing the linear projection of the 2015 energy mix into the year 2035.

Figure 9: BAU 2035 Energy Mix

Generation Type	Normal Demand		Efficient Demand	
	GW	%	GW	%
Thermal	84.8	89	69.4	89
Hydro	2.8	4	2.8	4
Wind	2.7	4	2.7	4
Solar	2.7	3	2.7	3
Nuclear	0	0	0	0
Biomass	0	0	0	0
Total	**93**	**100**	**77.6**	**100**

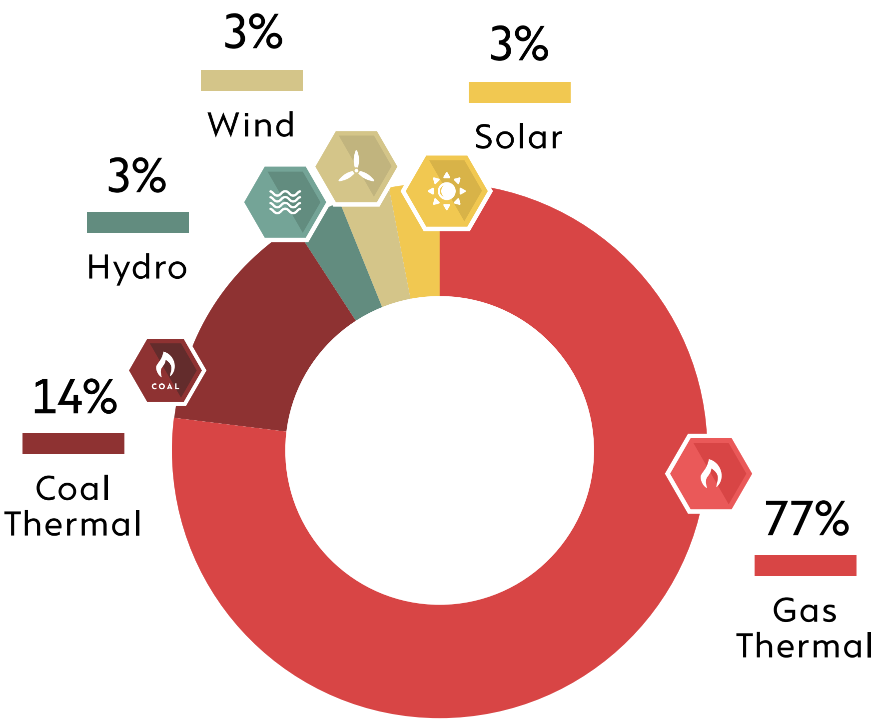
Figure 10: BAU 2035 Energy Mix



6.2.1
COAL

Due to an impending energy deficit, at the beginning of 2013 industry professionals and factory owners started to lobby for coal to be used as a thermal source of energy instead of natural gas.[38] The Government has allowed for the import of coal into Egypt, and has set out regulations to manage the use of coal in Egypt for both industry and to generate electricity. Feedback from the social workshops suggested that the study must include the introduction of coal to the energy mix. Whilst we have not included coal in the BAU pathway used to compare all three pathways against, Figure 11 shows the energy mix in 2035 with a 14% reliance on coal. Coal penetration was set at 14% based on an educated assumption. The unreliability of information on exact quantities of imports and projected capacities of new power stations does not allow for a more exact measure at this time. The inclusion of BAU+COAL as the baseline for all pathways was rejected as the amount of coal being used for power generation in Egypt is still unclear, and without clear and stable figures, it cannot be included accurately in the model.

Figure 11: BAU+COAL in 2035



6.2.2
INFRASTRUCTURE

Maintaining the centralized national grid structure and method of distribution, the energy-efficient BAU energy mix requires an increase in the current capacity of natural gas power plants by 200% to meet the curbed rise in demand. To support these extra power stations the grid must be upgraded by extending power transmission lines up and down the country and enhancing storage capacities by maintaining a larger number of reliable substations[39] which also help ensure a more uniform geographical reach of electricity provision. These substations are small in size, but numerous. They would require construction and basic electrical maintenance throughout the parts of Egypt connected to the national grid.

SUBSTATIONS are small 'stations' placed between the source of electricity being generated, and the main grid; the sub stations transform the high voltage electric currents from the source into a higher voltage that can be fed into the grid efficiently and without great loss of energy in the process; a further substation between the mainline grid and the plugs and sockets in our homes and offices then converts the current back down into a low voltage that is fit for domestic appliances and consumption. We calculate that 1 average sized substation is needed per 0.4GW of energy generated.

Gas fired power stations have no particular location requirements for construction, therefore a relatively even distribution of newly constructed gas power plants within proximity of the centralized grid that follows the Nile and the pattern of consumption (as the

Egyptian population also follows the Nile) is envisaged. This makes planning flexible with the potential for situating power plants away from human settlements and areas of environmental protection. Though current patterns of construction for thermal power stations follow the population, they are situated dangerously close to populations, including within the heavily populated city of Cairo.

Under BAU+COAL, coal fired power stations will have to be built within reach of the national grid and a reliable water source for cooling, placing them along the Nile. This will also require substations to be built between the power plants and the national grid, and between the grid and the settlements it serves. Investment in coal-fired power stations is considered using the premise that they run for 50-year lifecycle.[40] As such, coal fired capacity installed in 2015 would be functioning until roughly 2065, locking in the Egyptian government to operating and maintaining the coal fired power plants in order to fully realize the investment made in them. According to a study assessing carbon lock-in,

> *"...coal plants present one of the greatest lock-in risks globally"*[41]

In December 2015, an ambitious long-term goal was set out in the Paris Agreement[42] that emerged from the United Nations Framework Convention on Climate Change (UNFCCC) 21st Conference of the Parties (COP21). This long-term goal requires every country in the world to be part of the united effort in;

> *"holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels".*

To remain within the 'carbon budget' the Intergovernmental Panel on Climate Change (IPCC) has determined necessary to stay within 2ºC, the world would have to reach zero greenhouse gas (GHG) emissions between 2080 and 2100 at the latest. For a 50% likelihood of staying within 1.5ºC, the world must reach zero GHG emissions between 2060 – 2080, phasing out carbon dioxide (CO_2) emissions from fossil fuels by 2050[43]. This would require 82% of coal deposits, half of all known gas reserves and a third of the world's oil to stay underground; including 80% of potential shale gas reserves in U.S., Africa and the Middle East.[44]

In this scenario therefore, Egypt would be left stranded with a coal-reliant infrastructure for its energy needs, without the coal or the money to service energy demand. For a developing country that needs a sustainable source of energy with long term viability in order to develop, it is concluded that this is an unaffordable legacy to leave from decisions made today.

6.2.3 ENERGY ACCESS

By maintaining the centralized grid, remote areas and informal settlements that are already suffering power supply issues will not necessarily be able to access better supplies of electricity under BAU. Currently, communities suffering lack of energy access fall into two major categories: those not connected to the grid at all (e.g. Oases in Western desert), or ‘informal’ communities that are not formally given access to electricity by the State. By remaining within the dominant structure, which has successfully connected much of the country to the national grid but without updating it to ensure that developments in settlements and society are accommodated, the outdated infrastructure will perpetuate energy access issues across Egypt, with its effect felt most strongly in marginalized and rural communities. The State-centric model of energy generation and distribution ensures that those excluded from politics, decision-making or zones of investment, continue to be excluded; granting citizens no further agency over their energy related decisions.

For those people and communities with access to electricity but resident or operating in a poorer part of the town or city, there is currently an uneven distribution of power cuts which prioritizes government buildings, industry and the wealthier and middle class urban settlements.[45] The more rural and poorer the area, the longer the power cuts. During some of the worst shortages, ‘informal’ settlements within Cairo could go up to 12 hours a day without electricity whilst those in more affluent areas such as Heliopolis or Mohandiseen experienced only 3-4 hours of power cuts a day on average. Under our ideal BAU however, demand is matched, therefore power cuts should be eliminated, reducing this energy access inequity to a similar level as developed countries where power cuts occur only during faults with the grid or during extreme weather.

6.2.4
JOB CREATION

As detailed in Figure 12 below, the number of jobs created per annual gigawatt hour of energy generated depends on the source of energy. Jobs per annual GWh increase by more than three times by 2035 compared to 2015, with 121,731.7 jobs/annual GWh created cumulatively. The majority of the jobs are in the natural gas power plants as they make up the dominant part of the energy mix. The jobs for all energy sources are created in the installation process, and in the constant operation and maintenance required for energy generation. Reports that present these estimates show that renewables are by far the biggest job creators because they require more people to run. Generally, therefore, the higher the penetration of renewables in the energy mix, the greater the number of jobs created per annual GWh.

Introducing energy efficiency measures to BAU would also provide large numbers of jobs through greater regulation and enforcement, policy-making, energy efficiency small and medium enterprises, insulation manufacturing and fitting, and the sale of energy efficient white goods such was fridges. Furthermore, there will be a rise in the demand for energy efficiency experts to carryout audits, and to develop and enforce policies – with opportunities already starting to be explored by the Egyptian Electricity Regulatory Authority and the Information Decision Support Center for Egypt.

Figure 12: Job creation under a BAU pathway

Business As Usual

Period	2015	2020	2025	2030	2035
Thermal	31,910.4	43,005.5	58,558.4	79,019.6	106,139.9
Hydro	9,401.2	9,648.4	10,004.6	10,280.8	10,516.0
Wind	575.3	1,005.0	1,150.6	1,305.4	1,474.3
Solar	897.1	2,455.2	2,810.8	3,189.0	3,601.5
Energy Efficiency	1,146.1	9,579.7	24,559.1	50,140.8	92,715.7
Total jobs created/ annual GWh	**43,930.2**	**65,683.8**	**100,083.5**	**143,935.6**	**214,447.4**

Figure 13: Job creation under a BAU+COAL pathway in jobs per annual GWh

Business As Usual with Coal

Period	2015	2020	2025	2030	2035
Thermal	30,161.0	38,215.2	50,524.5	67,664.0	90,295.5
Hydro	8,945.1	8,900.4	9,287.3	9,791.9	10,287.2
Wind	547.4	850.6	1,068.1	1,243.4	1,442.2
Solar	853.6	1,981.7	2,609.2	3,037.3	3,523.1
Coal	927.3	2,586.3	4,374.4	8,123.8	8,572.6
Total jobs created/ annual GWh	**40,984.2**	**52,534.2**	**67,863.5**	**89,860.4**	**114,120.6**

6.2.5 "COSTS"

The "cost" of proceeding with an efficient BAU pathway totals: -4.6 billion US Dollars. The "cost" is expressed negatively as the energy efficiency measures save costs compared to BAU which consumes 16GW more electricity. This total includes the capital cost of increasing the gas power plant capacity by 200%, requiring the construction of the power plants and corresponding extension of the national grid with more power lines and substations.

There is a financial cost to implementing the levels of energy efficiency catered for in this pathway. Energy efficiency measures include running awareness campaigns to reduce the consumer's energy demand and to invest in abatement technologies like efficient lighting and efficient home appliances. Funds are also needed to invest in a nationwide labeling system for white goods (kettle, toaster, washing machine, AC, lighting, etc.). We envisage as a means of both curbing consumption and addressing the increased cost in energy provision, the implementation of a peak pricing system where prices are higher at peak hours has proven effective in many countries, this requires spreading advanced electric meters instead of the conventional old meters. The "costs" to the State are few and the benefits for low-income electricity users are high as they can manage their energy costs according to a predetermined and advertised pricing program determined by peak electricity use rather than income.

The LEAP model also does not include decommissioning costs[46] under the total 'net value' for each pathway. As such, the table below is extracted from figures the Organization for Economic Co-operation and Development (OECD) puts forward as the average efficiency and decommissioning costs of coal and gas fired power stations.

DECOMMISSIONING COSTS

The costs of shutting down a power station safely, within the regulation for safe disposal of waste, equipment, fuel and the space.

Figure 14: Average costs of coal and gas fired power plants for electricity[47]

Fuel type:	Average electrical conversion efficiency %	Decommissioning Costs USD/MWh
Coal*:	40%	1
Gas**:	53.40%	0.07

* Countries included in average: Belgium, Czech Republic, Germany, Japan, Korea, Mexico, Netherlands, Slovak Republic, USA, Brazil, China, Russia, South Africa and individual industry owned plants; with a sample of 48 plants.

** Countries included in average: Belgium, Czech Republic, Germany, Italy, Japan, Korea, Mexico, Netherlands, Switzerland, USA, Brazil, China, Russia and individual industry owned plants; with a sample of 27 plants.

As figure 14 indicates, the efficiency of gas power plants is greater than coal, and the decommissioning costs of gas power plants is 93% lower than coal fired power stations. Given that all the pathways except BAU aim to phase out use of natural gas across the sector to move towards a decarbonized sector, the decommissioning costs saved through using gas are very high.

Egypt's cement industry has already experienced the extent of potential costs for full compliance with Egyptian air pollution controls currently in place (not including the more stringent 2015 Coal regulations). Despite using natural gas, air pollution controls have been estimated to cost the industry 0.5 Billion USD[48]. Coal is an inherently denser fossil fuel, and the strengthened coal use regulations issued in 2015 will ensure that the cost of compliance for coal fired power stations will be significantly more than cement's 0.5 billion USD, adding to mounting 'external costs' that the model does not incorporate.

Finally, under BAU+COAL, concerns over both water pollution and water scarcity are high.

The required abatement technologies for coal fired power stations to comply with air pollution regulations creates two by-products: gas fixing effluent[49] and fly ash.[50] Without sufficient regulations and enforcement – as is currently the case[51] – BAU with Coal is likely to cause even greater levels of industrial wastewater (containing gas fixing effluent and run-off from fly ash) to pollute the Nile, to the detriment of freshwater species of fish and animals, river and lake biodiversity, and human health. Poor water treatment, poverty and lack of clean water options are already causing ill-health for the most vulnerable in the country that rely on the overburdened national health service. The introduction of coal is expected to exacerbate the existing problems.

GAS FIXING

Coal contains heavy metals such as Mercury, Lead, Cadmium and Chromium which are emitted in the combustion of coal. Pollution abatement technology 'fixes' the heavy metals in water as they are emitted. They are disposed of as polluted waste water to be treated.

FLY ASH

Burning coal results in "fly ash", which usually contains the following toxic substances: Arsenic, Lead, Mercury, Cadmium, Chromium, Selenium, Aluminum, Antimony, Barium, Beryllium, Boron, Chlorine, Cobalt, Manganese, Molybdenum, Nickel, Thallium, Vanadium and Zinc.

> *"Power plants require a reliable source of water in large quantities within a short distance from the plant itself. In coal using countries withdrawal and consumption is most often drawn from surface water (lakes, rivers etc.) but also frequently includes groundwater and seawater."*[52]

In Europe, its energy sector occupies a 44% share of total water consumption.[53] Within the energy sector, the primary consumers of water are nuclear and coal fired power stations because they use large quantities of water for cooling. Water shortages are already a reality in Egypt and the UN estimates that by 2025 Egypt will be in a state of "absolute water crisis"[54]. An equitable pathway for generating energy in Egypt cannot therefore rely on large amounts of water being accessible over the next 50 years. A vision for a sustainable pathway of energy development must incorporate a nexus of concerns, water quantity and quality being one of them.

> *"The average water consumption of coal power plants is 1.9m³/MWh [and] water consumption of gas plants is 0.7m³/MWh..."*[55]

Compared to the minimal water use of non-thermal energy sources such as wind and solar PV, we predict that the BAU+Coal pathway will incur huge water access issues in the near, medium and long-term. Access to water will inevitably hamper the capacity of the power stations to operate as water availability decreases and the following factors already observed in water-scarce countries using coal materialize[56]:

Lost revenue from blackouts as droughts and heatwaves reduce surface water availability and therefore capacity to generate energy, occurring more frequently over time due to climate change.

Increased operation costs as water shortages necessitate funding temporary water supplies, increasing production costs which increase the price paid by the consumer.

Increased infrastructure investment required to secure supplies of water in the medium and long term, through pipelines, dams & reservoirs and desalination facilities; as well as more advanced cooling technologies that reduce water consumption.

As stated by the Egyptian Ministry of Water Resources and Irrigation:

> *"The present rate of deterioration of quality will certainly increase the severity of the water scarcity problem or add to the cost of using water at the levels expected in 2020."*[58]

Finally, the extent of the 'carbon lock-in' [59] that a pathway with 89% natural gas fired power stations has created will be vast. The Carbon budget afforded by the world according to the Intergovernmental Panel on Climate Change (IPCC), requires that global decarbonization begin as soon as possible.[60] To achieve this they find that existing infrastructure that runs on natural gas can only be justified against the carbon budget as a transitional fuel in developing countries, but new investments in coal, oil or natural gas fired power stations are both bad investments and will contribute to exceeding the global carbon budget, with the potential to cause runaway climate change which will dramatically affect Egypt.

The loss of investment that enforcement of a global carbon budget would require through the shutting down of fossil fuel combustion capacity would be huge, and would catastrophically halt energy provision for the main part of the country reliant on the national grid. Reliance on natural gas as part of a phase-out plan would lead to only temporary lock-in; 89% natural gas infrastructure, with or without coal, would be the worst possible pathway for inducing detrimental long-term carbon lock-in for Egypt.

6.2.6 IMPORTS/EXPORTS

BAU with efficiency measures is the third highest import-consuming pathway after TZC+NUCLEAR and in first place, BAU+COAL.

Whilst production of oil based products (including natural gas) within Egypt would double over the twenty period between 2015 – 2035, the importing of oil based products would increase from 1.9 million tonnes oil equivalent to 31.2 million tonnes oil equivalent. This clearly indicates an increasing and unhealthy reliance on importing of non-native resources. This reliance renders the price of raw materials for energy production subject to the volatilities of the international liberalized pricing system and is now generally accepted to be part of a ‘carbon bubble’ that will burst in the near future, revealing that investment in, and reliance on, fossil fuels puts investors (or governments funding fossil fueled power stations) in receipt of ‘stranded assets’ – the value of which will cease to exist or become so expensive that they are unaffordable for a developing country to maintain.

CARBON BUBBLE

An economic 'bubble' is when market participants drive stock prices above their value due to cognitive biases that lead to group-think. A 'carbon bubble' is an economic bubble created by the overpricing of entities with investments in fossil fuels, because the true cost of fossil fuels is not taken into account in valuation. As such, investments made within this bubble may become 'stranded assets' when the carbon bubble bursts.

The construction of natural gas and coal power plants will require importing the technology and the fuel. Egypt has no native sources of coal. Under BAU+COAL, the country will be reliant on importing all of the necessary coal supplies through ports of the Red Sea and from the Mediterranean.

The PV solar plants, which make up 3% of electricity generation, will need to import up to 60% of the components, commonly from China.

Finally, the wind farms making up 3% of the energy mix require importing everything except the turbine blades from a variety of possible countries. The blades are made on site as near as possible to the wind farm itself. In doing so short-term jobs are created in their manufacture and transportation

6.2.7 IMPLEMENTERS

This scenario is entirely state driven and financed by the private sector and bilateral financial support from foreign governments to fund the thermal power stations. Depending on the serving government, there may be differing levels of access to public consultation with civil society and affected communities, especially as the main part of this energy mix will be implemented by central government, not at the local governorate level. There is a high likelihood of top-down, exclusive policy making that does not consider the impacts on local peoples and environment, without recourse to justice on energy access, pollution or land rights issues.

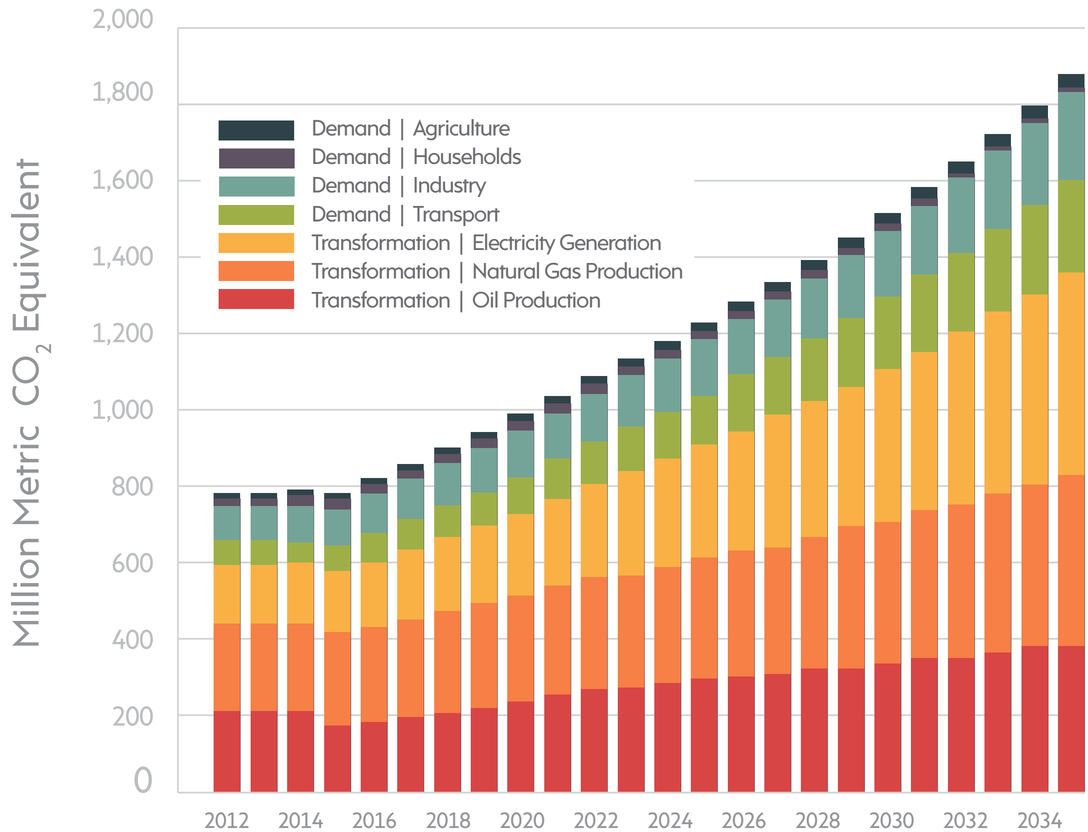
6.2.8 CO_2E EMISSIONS

If the Egyptian government continues managing its energy supply to meet its growing demand in the next 20 years by following the same philosophy it has so far, its greenhouse gas (expressed here as CO_2 equivalent (CO_2e) to allow for one unit of measurement) emissions will continue to grow as shown in Figure 15 below.

Emissions of greenhouse gases are a direct product of fuel consumption across all sectors and the dominance of the fossil fuel natural gas as a source of energy.

Under an efficient BAU scenario emissions increase linearly from less than 800 to over 1,800 Million Metric Tonnes CO_2e (MMmt CO_2e) by 2035. Emissions are mainly caused by thermal gas power plants, hydrocarbon refineries and the transport sector; with less contribution from emissions directly from the demand side as efficient demand is in place.

Figure 15: CO_2e Emissions of BAU 2012-2035



Overall, the efficient BAU scenario is a way of feeding the inevitable rising demand for electricity year on year. This reliability of energy provision comes at the price of access and participation in the policy making and infrastructure planning from the outset; redistribution of access to mains (central grid) electricity is unlikely; the reliance on natural gas as the main fuel source makes the country vulnerable to international energy prices, stranded assets, increasing costs of operation and carbon lock-in of energy infrastructure. Finally, as a result, Egypt's CO_2e emissions will increase in correlation with increases in demand ensuring that energy provision is not decoupled from CO_2e emissions.

The introduction of coal to the energy mix will result in an increase in emissions of around 50 Million Metric Tonnes of CO_2e due to the dense polluting nature of the fuel in comparison to natural gas.

> *Climate change will affect the poorest and most rural, changing their livelihoods and forcing them to migrate within the country to find work to feed their families. TZC aims to increase the resilience of Egypt's electricity sector...*

7.

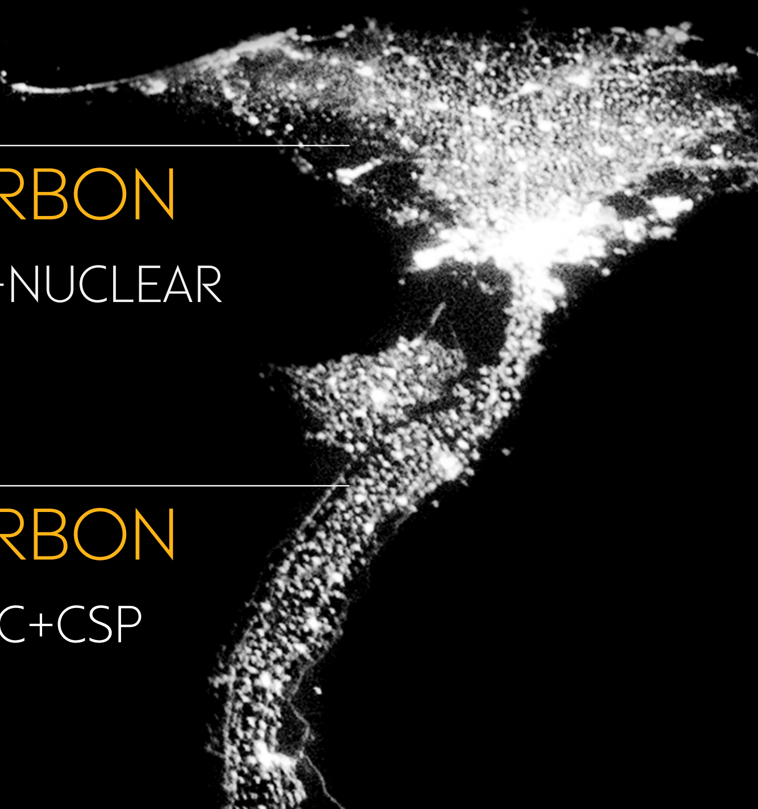
TOWARDS ZERO CARBON TZC

8.

TOWARDS ZERO CARBON WITH NUCLEAR TZC+NUCLEAR

9.

TOWARDS ZERO CARBON WITH CSP TZC+CSP

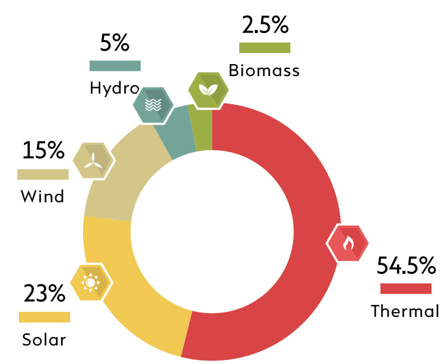


Towards Zero Carbon was originally intended as a 'Zero Carbon' pathway. As the research progressed., however, it became clear that the timeline of 2035 did not allow for rapid decarbonization of the energy sector without huge capital investment from abroad given Egypt's developing country status. As such, the 'towards' was added to ensure that if a longer timeline was applied the trajectory initiated the 2035 scenario would continue and contribute to a zero carbon pathway by 2050.

TZC
Towards Zero Carbon

ENERGY			LOCATION	COSTS		IMPLEMENTERS
SOURCE	SCALE	MIX		FINANCE	IMPACTS	
	GAS	54.5%	GRID	PPP	AIR, WATER, CO2	
		23%	—	FiT, BOO, PPP	CO2	
		15%	GULF, DESERT	FiT, BOO, PPP	CO2	
		3.5%	—	—	CO2	
		.75%	NILE, STREAMS	FiT, PPP	CO2	
		.75%	NILE, STREAMS	FiT, BOO	CO2	
	BIO	2.5%	—	FiT, BOO, PPP	CO2	

JOB CREATION	ENERGY ACCESS	OIL SUPPLY	CO2E EMISSIONS MILLION METRIC TONNES
216,776.5		OIL	CO_2e 12,708.4



TOTAL COST = 10.8 BILLION USD

7. 1. ASSUMPTIONS

This scenario prioritizes resources that ensure a reduction in GHG emissions where renewables are expected to constitute the highest possible percentage of the energy mix within the boundaries of technical feasibility. This pathway offers three different pathways using the GHG emissions reductions principle:

Towards Zero Carbon : TZC

Towards Zero Carbon with Nuclear Power : TZC+NUCLEAR

Towards Zero Carbon with Concentrated Solar Power' : TZC+CSP

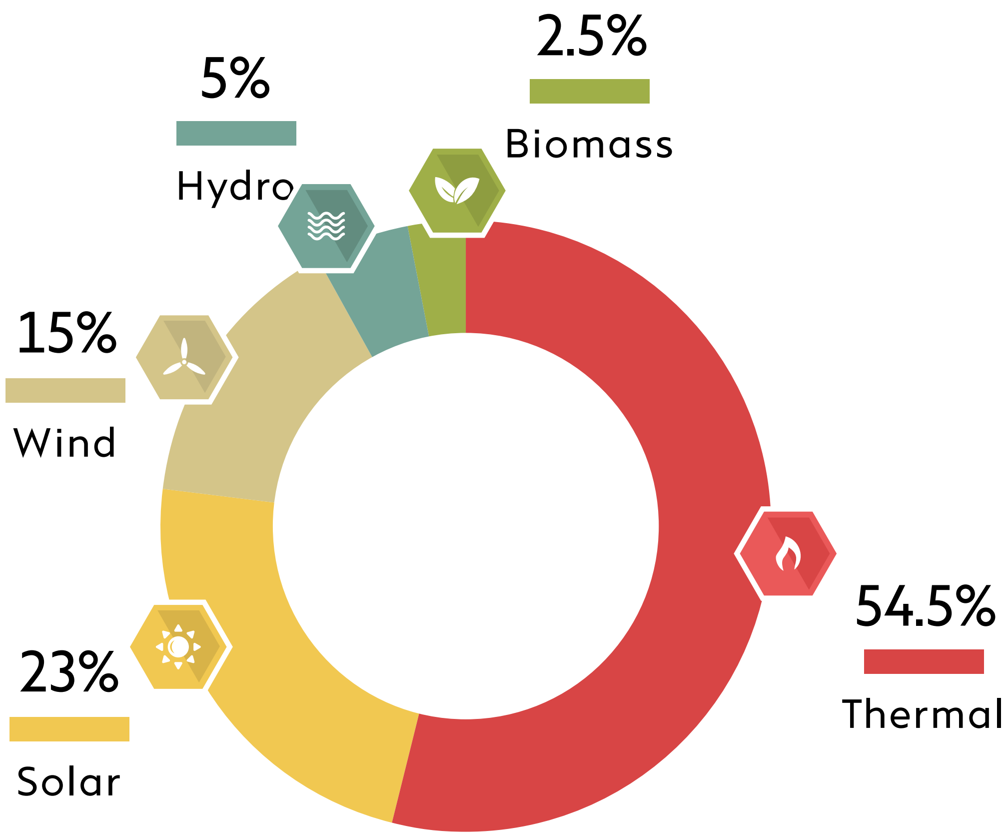
All TZC pathways assume efficient demand. Figures 16 and 17 depict the percentages of energy resources making up the TZC energy mix in 2035 where thermal is still a major player but is significantly reduced from the BAU case.

7. 2. TZC RESULTS BREAKING IT DOWN

Figure 16: Energy Mix Of TZC In Gigawatts And As A Percentage Of Total Energy Mix

	TZC Efficient Demand	
Generation Type	**GW**	**%**
Thermal	43.5	54.5
Hydro	4	5
Wind	12	15
Solar	18.5	23
Biomass	2	2.5
Total	**80**	**100**

Figure 17: TZC Energy Mix in 2035



The premise for elaborating on a zero carbon pathway for electricity provision in Egypt is multifold.

Firstly, Egypt is a developing country that seeks middle-income status as well as to lift the large parts of its population in poverty and without access to basic healthcare and education into better standards of living. The global threat posed by climate change will impact Egypt very harshly at the national and local levels. Egypt will, and in some cases already is, suffering from extreme water stress, worse natural disasters and extreme weather events, salt water intrusion into the fresh water resources of the Nile Delta, sea level rise affecting coastal areas, a rising water table wiping out agricultural practices, loss of traditional livelihoods like fishing due to changing species migration patterns, ocean acidification and rising surface water temperatures.

As climate change has already done in Syria[61], where water scarcity forced many people (mainly farmers and herders) out of their homes, it will affect the poorest and most rural, changing their livelihoods and forcing them to migrate within the country to find work to feed their families. TZC aims to increase the resilience of Egypt's electricity sector to shocks, disasters and changing patterns of settlement. It also reduces the fossil fuel content of the energy mix as far as possible within the current infrastructure to prevent carbon lock-in.

Finally, under international treaties, especially the Paris Agreement approved at COP21 in 2015, Egypt is due to put forward emissions reduction contributions until a minimum of 2030. These pledges of ‘reductions’ (or most likely expressed as limited increases in GHG emissions for a developing country) will be binding under norms of international law.

In order to support the country in its achievement of reducing the emissions associated with developing, we have put forward TZC as a progressive stance that recognizes climate change as a threat and an opportunity, to increase the sustainability of energy investments with respect for Egypt’s natural resources and bountiful ‘free’ energy.

7.2.1 INFRASTRUCTURE

As we found under the BAU scenario, TZC still relies on a centralized national grid, maintaining the current inequities of distribution. The 54% thermal capacity is all natural gas, requiring a doubling of current thermal generation capacity. Without any particular constraints on location except proximity to the national grid lines, these plants can be placed outside of settlements and away from people, communities and environments that would be negatively affected by air pollution and industrial effluent. For TZC natural gas is seen as a transition gas, and the investment in the doubling of thermal capacity is an investment that will stand through to 2055. As such, it allows Egypt the time and space to convert to a fully zero carbon electricity system by 2055 at the latest, when the gas power plants would be retired. A recent study on carbon lock-in concluded that,

> *“Recent studies have shown that, though gas plants can in the near-term reduce CO_2 relative to coal, achieving ambitious climate targets may then require a swift transition away from these gas plants to renewable power. Rather than full retirement, for gas plants, unlocking [this carbon lock-in] may entail switching from base-load to less frequent, higher-value peaking or load balancing operation.”*[62]

The average lifetime of a gas power plant is 30 years. When comparing its CO_2e creation in a BAU scenario against a climate change compatible pathway of energy production (i.e. A maximum 2ºC temperature rise limit gives rise to a carbon budget), each gas fired power plant "over-commits" 20 gigatonnes of CO_2e in its lifetime.[63] Under TZC therefore, natural gas plants are seen as a transitional facility to be phased out or maintained as back up as soon as possible.

The 23% photovoltaic (PV) solar would be made up of mega-watt solar plants, where solar panels are collected in large groups in one place like a wind farm. These plants could be dotted around the country, with no particular location required for their successful running, though experts do not recommend the use of PV in the south of Egypt as extreme heat will reduce their efficiency and working lifetime.

It would be recommended the solar plants are placed in parts of the desert without sensitive ecosystems and communities but still within reach of the national grid. Unlike a power station however, there are no, or very limited, negative effects of generating solar energy foreseen, as they are static, without emissions and do not make a noise or produce effluent.

The 15% wind power is generated from large-scale wind farms such as Zafarana on the East coast of Egypt. Wind farms need to be constructed on coastal areas, which for maximum vantage point in Egypt, includes the Gulf of Suez, the coast of southern Sinai, and parts of the Western Desert north of Kharga.[64] Many of these areas are dominated by a successful tourism sector that contributes to the 18% of GDP generated annually by tourism in Egypt (pre 2011 uprising). Though wind farms are considered beautiful by many, and could be an attraction in themselves, Egypt is large enough to not situate wind farms in areas of touristic and historical value.

Governorates and the tourism sector in the vicinity of any proposed sites must be consulted publicly, with full access to the decision makers and planners for this aspect of the pathway.

The TZC pathway encourages the introduction of biomass plants, making use of Egypt's vast amount of agricultural waste and its human sewage. Municipal waste, such as that collected by the Garbage Collectors (Nazafa) and recycled will not be included and therefore does not pose a threat to their livelihood or their world leading recycling rates. Biomass plants will be located near or next-to sewage treatment plants in order to directly make the most of the energy source and reduce transportation needs.

This will mean that biomass plants are distributed all across the country in direct relation to the sewage plants current distribution. This will also reduce the burden on the sewage plants to treat the sewage to a sufficient standard that it can re-enter the water table, and so it is predicted that Nile water quality will improve as a result.

In future, sewage plants can be built at the same time as biomass plants. The agricultural waste will have to be collected locally, in a system to be determined. It could consist of dropping off points in each town and village, which the waste is then collected from and taken to be sorted and used at the biomass plant. At the plant itself, a space for sorting received waste must be constructed with standards that ensure workers are safe and operations are as clean as possible.

2.8 GW of the total of 4 GW of hydro used under TZC, comes from existing capacity generated annually by the High Dam. It is estimated that over 85% of the river Nile has already been exploited for hydro purposes, therefore the 1.2 GW increase in is attributable to 0.05 GW of already planned small pumped storage hydroelectric projects and the installation of micro turbines along the side of running water bodies such as the Nile, its tributaries and streams, generating the remaining 1.15 GW. The turbines are small and efficient, and can be installed in arrays at any point along a river or stream. These turbines average a 50 KW output per micro plant (an array of turbines), therefore to reach the 1.15 GW capacity, 2,300 micro turbine plants must be installed along moving bodies of water in Egypt.

Depending on location, new access roads will have to be created in conjunction with the 0.05GW of run-of-the-river hydro projects; these must be done sensitively so as not to disturb local ecosystems, livelihoods or local inhabitants homes.

Finally, more reliable and greater numbers of substations will be needed to connect the wind and solar farms to the national grid. We estimate the construction of 45 substations for solar and 30 substations for wind, located in between the national grid and the solar/wind farms, and the national grid and the end user.

7.2.2 JOB CREATION

Implementing this pathway will result in an increase in job opportunities as skilled labor will be needed for solar installations, including engineers, electrical technicians and construction workers and technicians and trained labor will be needed for plant operation. Furthermore, grid upgrading professionals from both private technical consultancies and public agencies (Ministry of Electricity and subsidiary technical teams) will be called on.

Job opportunities will arise from wind blade manufacturing, wind farm installations and operations and maintenance of wind farms, requiring management, unskilled labor, engineers and technicians. The transportation sector will receive a boost in demand for road and Nile transportation for the renewables industry. For the new biomass industry, jobs in collection and segregation needing unskilled and trained labor will be created, alongside demand for skilled professionals in the design, construction and operation of the biomass plants themselves.

The jobs created in the biomass industry specifically will be localized and sustained over the entire period 2015-2035. Conventional natural gas power plants will still be online, requiring the existing workforce to be increased over the twenty-year period from 30,325.6 to 58,956.6 jobs/Annual GWh.

Finally, the energy efficiency industry that is born out of a commitment to efficiency across the industry and by end-users, creates the most jobs of all the energy sources. These roles would include, with a relatively even dispersal across the country, energy efficiency policy-makers, regulators and enforcers, labeling scheme managers, public and private auditors and insulation manufacturers and installers.

The total number of jobs created by the TZC pathway are just under double the BAU scenario. This is owed to the energy efficiency component and an increase in renewables which create more jobs than fossil fuel based generation.

Figure 18: Job creation under a Towards Zero Carbon pathway, in jobs per annual GWh

Towards Zero Carbon

Period	2015	2020	2025	2030	2035
Thermal	30,325.6	36,200.9	43,622.4	51,449.7	58,965.6
Hydro	9,226.6	10,672.8	12,530.7	14,459.7	16,266.4
Wind	981.5	2,233.7	3,718.7	5,379.7	7,116.5
Solar	2,682.7	7,604.3	13,420.1	19,946.2	26,801.4
Biomass	1,492.5	4,230.6	7,466.2	11,097.0	14,910.8
Energy Efficiency	1,146.1	9,579.7	24,559.1	50,140.8	92,715.7
Total jobs created/ annual GWh	**45,855.0**	**70,522.0**	**105,317.1**	**152,473.2**	**216,776.5**

7.2.3 ENERGY ACCESS

As the dominance of a centralized grid with large developments in renewables implies, there is very little change in how energy generation and access is distributed around the country.

Similar to the energy access conclusions for the BAU scenario, maintaining centralized distribution via the national grid will likely maintain the areas of the country currently unconnected to the grid and therefore without ready or easy access to electricity. Attempting to develop without a constant supply of electricity will preserve the pockets of poverty and inequitable distribution of resources in the country currently.

For those connected to the grid and who do have access, their access is improved by the meeting of demand through increased generation capacity. This means no longer experiencing power cuts and a maintaining reliable source of electricity to live and work on.

Under this TZC scenario we do not see an increase in average citizens and small business and enterprises generating their own energy.

7.2.4 "COSTS"

Public and private investments will be needed to increase the number of natural gas power plants as well as introduce abatement technologies for gas-fired power plants. More importantly, massive investments are needed to give birth to solar and wind power industries from scratch in twenty years. Investments will also be needed for grid upgrades to increase its reach and efficiency to ensure it can accommodate the varying storage capacities, weather predictions and geographical reach that the renewables will bring.

Financing will be needed for a longer term implementation of the FiT program and other incentive programs to support solar and wind plants that would follow either BOO (Build Own Operate) or PPP systems to sell electricity to the grid or directly to the consumer for example to a resort or a cement factory.

The technology, construction and operation of biomass (biofuel or biogas) power production plants from sewage or agriculture must be financed to import technologies, tailor them and construct the plants. Introducing biomass also entails raw material collection and segregation systems investments.

Displacement of thermal capacity by wind and solar PV under TZC reduces costs incurred from water scarcity and worsening water quality for thermal power plants, as they have the lowest operational and total lifecycle consumption of water per unit of electricity generated. [65] The remaining 54% of electricity generated using natural gas still poses a major contribution to water insecurity in Egypt using 0.7m^3 of water per Mwh.[66] This challenge requires adherence to the principle of transitioning from natural gas to higher penetrations of renewables to ensure access to water issues are addressed and do not get worse.

7.2.5 IMPORTS/EXPORTS

For oil based products, Egypt would double its production of oil based products for domestic use, but also import more than 12 times the quantity of oil based products in 2035 compared to 2015.[67] Compared to the other pathways however, TZC is one of the lowest oil product importing pathways in 2035.

Similarly, to the BAU scenario but on a larger scale, progressing the TZC pathway would require that 60% of the components for the PV solar plants which make up 23% of electricity generation are imported - most likely from China.

The 15% wind energy also needs the importing of everything except the turbine blades from a variety of possible countries. The blades are made on site as near as possible to the wind farm itself. In doing so short-term jobs are created in their manufacture and transportation.

7.2.6 IMPLEMENTERS

Except for biomass, energy generation , and distribution for all aspects of this pathway will be state driven with support from private sector and bilateral financial support from foreign countries.

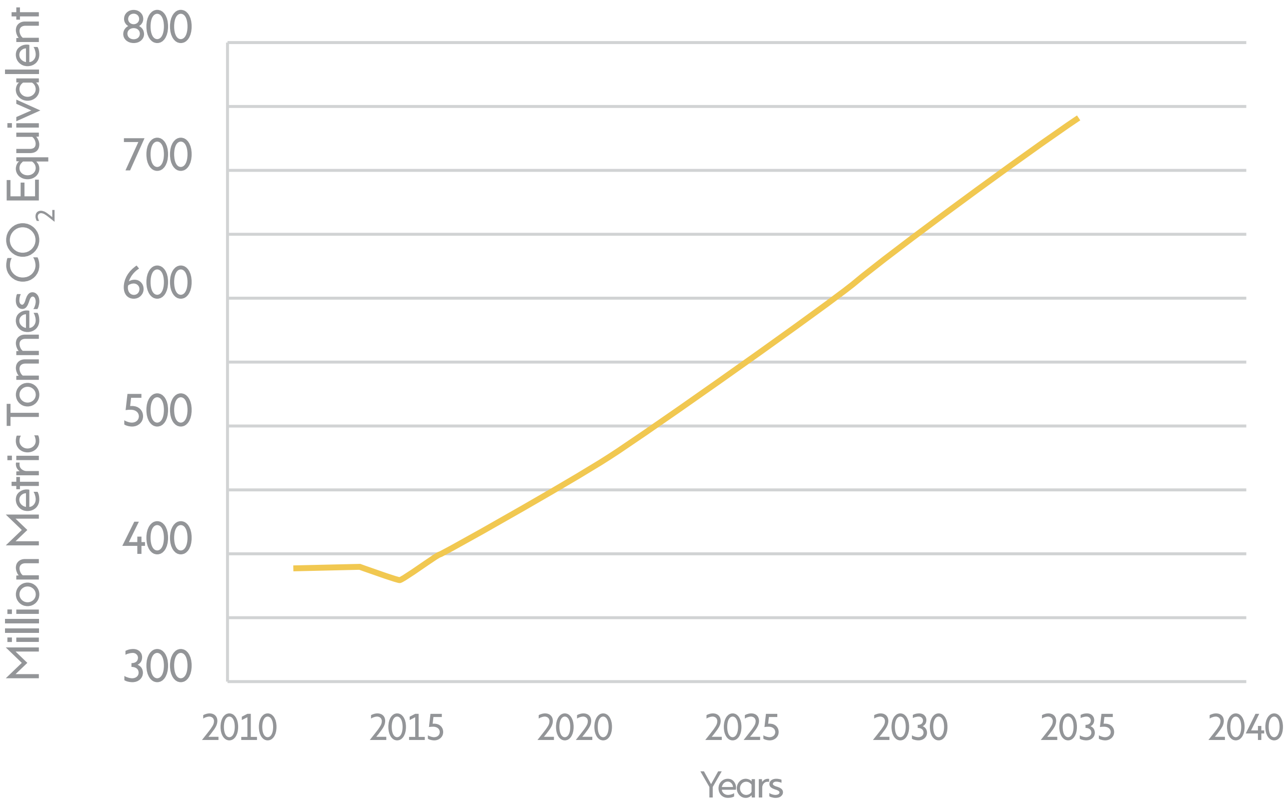
As a result, there is a high likelihood of top-down, exclusive policy making that does not consider the impacts on local peoples and environment and offers little space for public consultation.

The 3% biomass energy will be implemented at the Governorate level, in terms of planning and the infrastructure for collecting biomass from the locality.

7.2.7
CO_2E EMISSIONS

As envisaged originally, the TZC pathway would create a reduction in GHG emissions. This is quantified in the graph below as a reduction of 100 MMmt CO_2e compared to the efficient BAU scenario of 1,850 MMmt CO_2e, and 150 MMmt CO_2e less than the BAU with coal scenario.

Figure 19: CO_2e Emissions of the TZC pathway, 2012-2035



In the course of running the model, it was clear that the main premise of the TZC pathway was to reduce GHG emissions, inducing a much wider variety of co-benefits as a result of avoiding GHG emissions, but still being driven by this baseline. Following this line of inquiry, the modelers explored how a TZC pathway with nuclear would look like in Egypt.

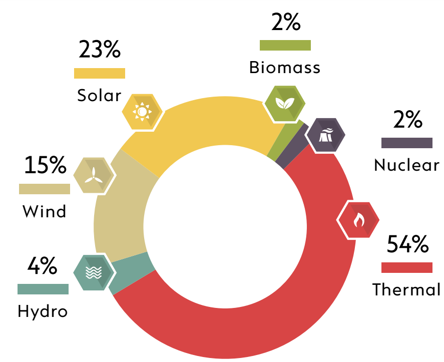
TZC+NUCLEAR

Towards Zero Carbon With Nuclear

ENERGY: SOURCE	ENERGY: SCALE	ENERGY: MIX	LOCATION	COSTS: FINANCE	COSTS: IMPACTS	IMPLEMENTERS
	GAS	54%	GRID	PPP	AIR, WATER, CO2	
		23%	—	FiT, BOO, PPP	CO2	
		15%	GULF, DESERT	FiT, BOO, PPP	CO2	
		3.5%	—	—	CO2	
		.25%	NILE, STREAMS	FiT, PPP	CO2	
		.25%	NILE, STREAMS	FiT, BOO	CO2	
	BIO	2%	—	FiT, BOO, PPP	CO2	
		2%	—	—	WATER, LAND	

JOB CREATION	ENERGY ACCESS	OIL SUPPLY	CO2E EMISSIONS (MILLION METRIC TONNES)
N/A		OIL	13,623.5

TOTAL COST = 23.7 BILLION USD



8. 1. ASSUMPTIONS

For cost assumptions, see the general assumptions above.

The main decision on assumptions was to build the TZC_WN pathway assuming the import of Uranium will be required, even though Egypt does have Uranium deposits. This was due to the lack of information surrounding the extent of the deposits and whether they were sufficient to reliably power a nuclear power station.

8. 2. TZC+NUCLEAR RESULTS
BREAKING IT DOWN

TZC+NUCLEAR is essentially the same energy mix as TZC but with 2% nuclear taking up half the generation capacity supplied by biomass under TZC, reflected in the lower CO_2e emissions but higher cost of achieving those reductions.

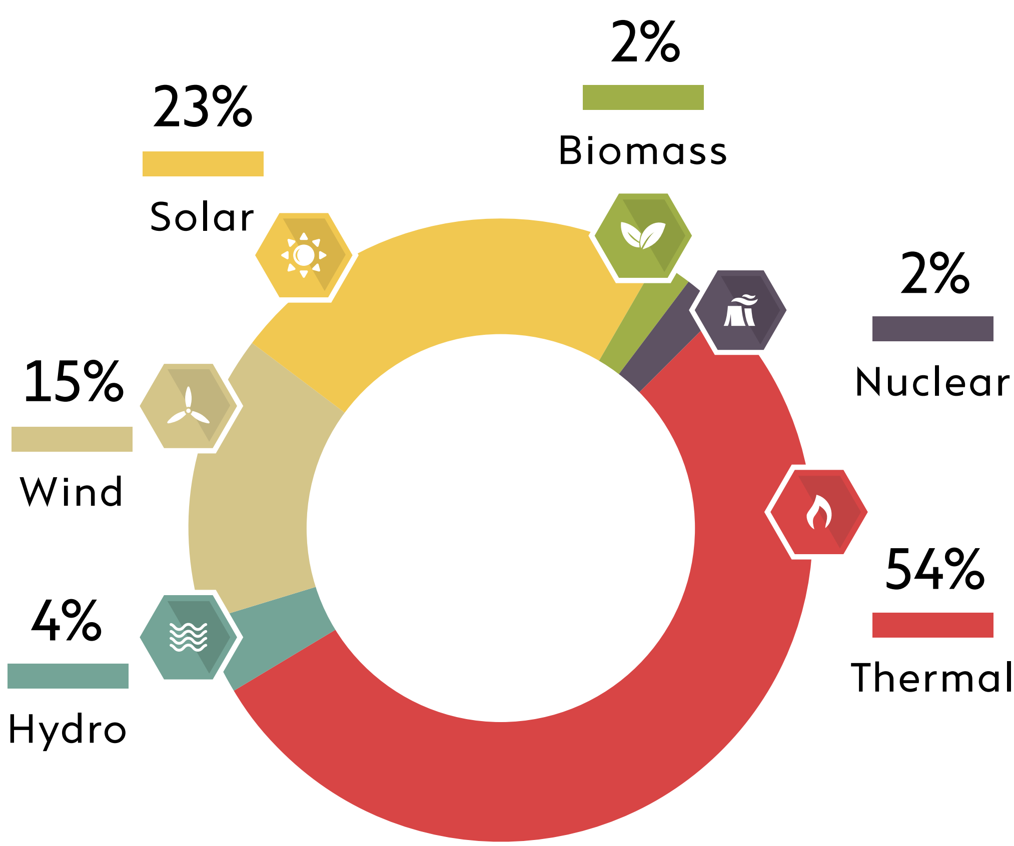
Given the qualitative nature of the social and environmental impact assessment that this project embraced, it is therefore essential to emphasize the opposition of both the social workshop, and the technical workshop attendees. On consideration of multiple factors, it was generally agreed that nuclear is not a well fitting solution for Egypt.

Figure 20: Energy mix of TZC+NUCLEAR in Giga Watts and as a percentage of total energy mix

Towards Zero Carbon With Nuclear
Efficient Demand

Generation type	GW	%
Thermal	43.2	54
Hydro	3.2	4
Wind	12	15
Solar	18.4	23
Nuclear	1.6	2
Biomass	1.6	2
Total	**80**	**100**

Figure 21: TZC 2035 Energy Mix with Nuclear



8.2.1 NUCLEAR INFRASTRUCTURE

Constructing a nuclear power station requires both manual laborers and highly technically trained staff to ensure that the plant meets internationally agreed standards of construction, operation and decommissioning. Currently, this skill set is not present in Egypt, and the institutions usually associated with such qualifications – namely universities – will also not have the requisite skills to train up a set of Egyptians in time for construction.

Nuclear power plants are sensitive to their location. In the US the prerequisites of building one are that it must be near a body of water that can be used as a source of cooling during plant operation and shutdown, for the ultimate heat sink and for fire protection.[68] In times of drought – to which Egypt will be increasingly liable – the power station will not be able to function. Characteristically, nuclear power plants must be placed away from human settlements in case of leakage, or in an area of least density of people. At the same time, sources of energy generation cannot be placed too far from the connection to the national grid, which follows the population through the Nile Valley throughout the country, posing a location issue.

8.2.2 NUCLEAR JOB CREATION

The UK ERC report used as the basis for the job creation estimates in the rest of this report does not include nuclear. In its place we have extracted results from a US nuclear industry report that quantifies one proposed nuclear power plant (as proposed by the Government currently and assumed under TZC+NUCLEAR) would create between 400-700 jobs in Egypt. Of all the technologies explored in these pathways, nuclear is the least job-creating energy source per GWh of all.

Furthermore, given the technical expertise and experience required, core operations roles requiring nuclear engineers, reactor operators, controls technicians, chemistry technicians and radiation protection experts will not go to Egyptians if these skills sets are not already present - they will go to experienced foreign workers, further reducing the jobs potential of nuclear power in Egypt. The rest of the small portion of jobs created require building maintenance, electricians, construction workers, administrative work, and vendor roles (arranging supplies of fuel and materials, and managing relationships with State entities and the national grid).

8.2.3 NUCLEAR ENERGY ACCESS

As another large-scale centralized solution, there is no likelihood of decentralizing or spreading out energy generation with the addition of nuclear. Nuclear power plants are highly regulated state driven entities that must be monitored and maintained meticulously. This responsibility would be carried out by the Government, with the likely assistance of an experienced private foreign energy company. Furthermore, nuclear power plants take an average of 7 years to construct, therefore it is possible that nuclear would not be contributing to the energy mix and meeting the supply deficit until 2022 or after, making it a mid-term solution for the energy mix only.

8.2.4 NUCLEAR “COSTS”

There are a huge variety of costs associated with nuclear.

Firstly, nuclear is an expensive option for low carbon generation in a developing country. Whilst it is highly efficient, it still requires importing uranium from abroad (given our assumption that not enough of Egypt’s native Uranium resources would be high grade enough to use for nuclear power generation), which is a constant cost that could also be subject to volatile pricing over time.

Given an equitable energy pathway’s requirements of placing nuclear power stations out of settlements and communities, the added cost of connecting the power plant to grid will be large. The total cost of the TZC+NUCLEAR is 22.7 billion USD, by far the most expensive of all pathways in terms of capital and operations and maintenance costs. The 22.7 billion USD does not include the decommissioning costs of nuclear, which are estimated by the OECD Nuclear Energy Agency in Figure 22 below.

Figure 22: Assumptions on Technology & Cost of Nuclear Power stations[69]

Technical Assumptions

	Nuclear	Gas
Capacity	1000 MW	1000 MW
Construction Years	7	2
Lifetime	60	30
Electrical Conversion Effi-ciency	N.A	.55
Gross Energy Content of Fuel Unit	N.A	1 MW
CO_2 Emissions per Mwh	0	.37 t Co_2/Mwh

Cost Assumptions

	Nuclear	Gas
Overnight Costs	4000 €/kwh	851 €/kwh
Operation & Maintenance	10.92 €/Mwh	3.54 €/Mwh
Fuel	6.31 €/Mwh	Daily
CO_2 Emissions per Mwh	0	14.44 €/Mwh
Decommissioning	**600 €/kwh**	**43 €/kwh**

Using these OECD figures to calculate the cost of decommissioning the 1.6GW of nuclear under TZC+NUCLEAR, we estimate decommissioning would cost Egypt 600 million Euros. Adding this to the already high cost total value of TZC+NUCLEAR, **the total costs for the lifecycle of the nuclear power plant within the TZC energy mix, is 23,660,000,000 USD.**

A wider "costs" analysis was delivered during the workshop. Concern over how the radioactive waste would be disposed of in a safe and regulated manner in a country where the quality of the Nile river water can't even be maintained to prevent illness and death to humans and species was expressed unanimously.[70] Further to this point, there will be significant waste water effluent from a nuclear plant, which would come under the industrial effluents regulations already in place, but already extensively proven to be unenforced, presenting one further contribution to an existing serious pollution problem.[71]

Under the TZC pathway and the next pathway of 'Energy Independence', the principle of using Egypt's vast wind and solar resources – some of the best in the world – because they are clean, proven technologies with less socially and environmentally negative impacts and more job creation is prioritized. This prioritization is threatened by the construction of a nuclear power plant, which renders other efficient and clean energy sources with many more co-benefits less affordable as they are not given the opportunity to penetrate the market. There is therefore an ethical "cost" to the desire to reduce emissions using nuclear without considering a wider set of social benefits offered by competing energy sources.

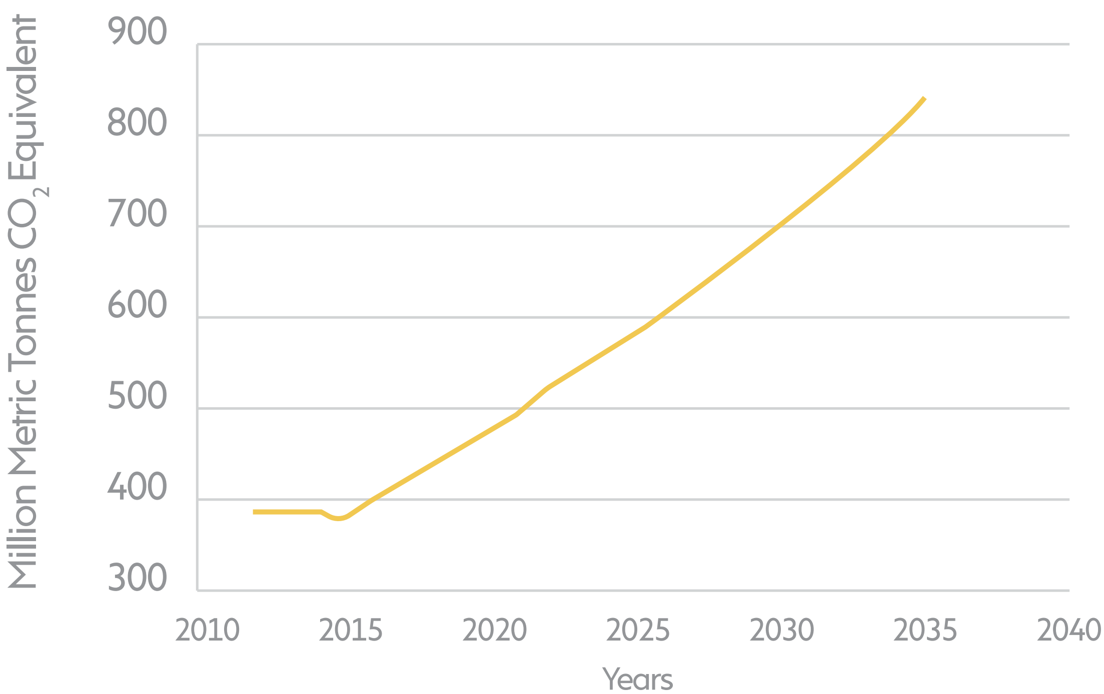
In assessing the water scarcity issue in relation to the inclusion of nuclear into the energy mix, the pathway becomes even less viable. Of all the energy generating technologies available, nuclear has the highest water-consuming footprint, at 2.7 m^3/MWh compared to 1.9 m^3/MWh for coal and 0.7 m^3/MWh for natural gas power plants.[72] In relation to the previous point about nuclear pushing out similarly low carbon options such as greater wind and solar penetration, this is doubly unacceptable when their water-consumption footprint is at the opposite end of the spectrum to nuclear.

"Non thermal technologies (such as wind or PV) have the lowest operational and life cycle water consumption of water per unit of electricity generated. Wind turbines, for instance, might only need water for cooling purposes (generator, transformer, inverter) and occasional blade washing (US DOE, 2006) – and even then, the blades are already washed by the rain."[73]

8.2.5 CO_2E EMISSIONS

As Figure 23 confirms, the inclusion of nuclear does create a reduction in total emissions. However, the difference in the cost of those CO_2e reductions is huge at 23.7 billion US dollars more than BAU, and 12.9 billion dollars more than the TZC scenario using biomass in the place of nuclear.

Figure 23: CO_2e Emissions Of TZC+NUCLEAR, 2012-2035



Another outcome from the workshops was that Concentrated Solar Power (CSP) technology was considered a viable enough option for Egypt to be included in this study. As a result, the TZC pathway was run to include CSP technology instead of nuclear, providing for 1.6GW of CSP installation by 2035.

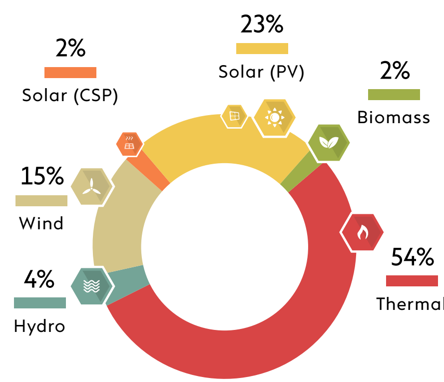
TZC+CSP

Towards Zero Carbon With Concentrated Solar Power

ENERGY: SOURCE	ENERGY: SCALE	ENERGY: MIX	LOCATION	COSTS: FINANCE	COSTS: IMPACTS	IMPLEMENTERS
	GAS	54%	GRID	PPP	AIR, WATER, CO2	
		23%	—	FiT, BOO, PPP	CO2	
		2%	—	FiT, BOO, PPP	CO2	
		15%	GULF, DESERT	FiT, BOO, PPP	CO2	
		3.5%	—	—	CO2	
		.25%	NILE, STREAMS	FiT, PPP	CO2	
		.25%	NILE, STREAMS	FiT, BOO	CO2	
	BIO	2%	—	FiT, BOO, PPP	CO2	

JOB CREATION	ENERGY ACCESS	OIL SUPPLY	CO2E EMISSIONS (MILLION METRIC TONNES)
230,667.9		OIL	CO_2e 13,603.6

TOTAL COST = 24 BILLION USD



9. 1. ASSUMPTIONS

The following cost assumptions for CSP were made, summarized in Figure 24 below.

Figure 24: Cost Assumptions For CSP Stations:

Capital cost ($/kW)	5000
Fixed O&M* cost ($/kW-yr)	67.2
Variable O&M* cost ($/Mwh)	0
Capital cost growth rate	4% until 2020 then 0%

*O&M : Operation and Maintenance

No estimates for annual cost reductions, as presented for solar PV and wind, were possible for building this pathway, as the technology is in its early stages, and therefore does not have a 'market' to indicate how the pricing of the technology will develop over time.

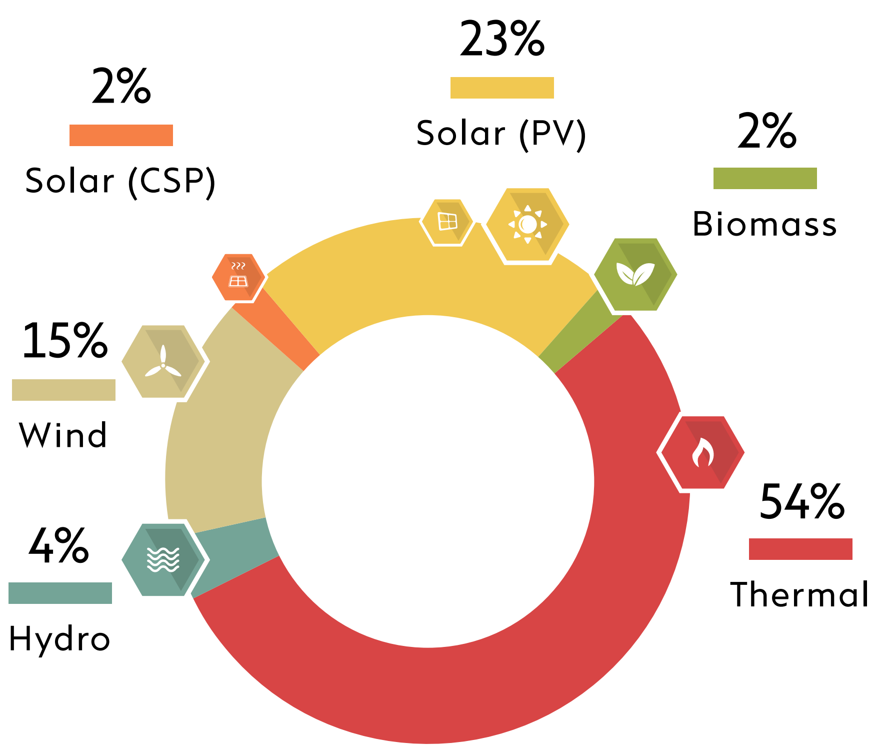
9. 2. TZC+CSP RESULTS
BREAKING IT DOWN

The resulting 2035 energy mix with CSP is shown in Figures 25 and 26 below.

Figure 25: Energy mix of TZC+ CSP in Gigawatts and as a percentage of total mix

Generation type	Efficient Demand With CSP	
	GW	%
Thermal	43.2	54
Hydro	3.2	4
Wind	12	15
Solar PV	18.4	23
CSP	1.6	2
Biomass	1.6	2
Total	**80**	**100**

Figure 26: TZC 2035 Energy Mix with CSP Technology

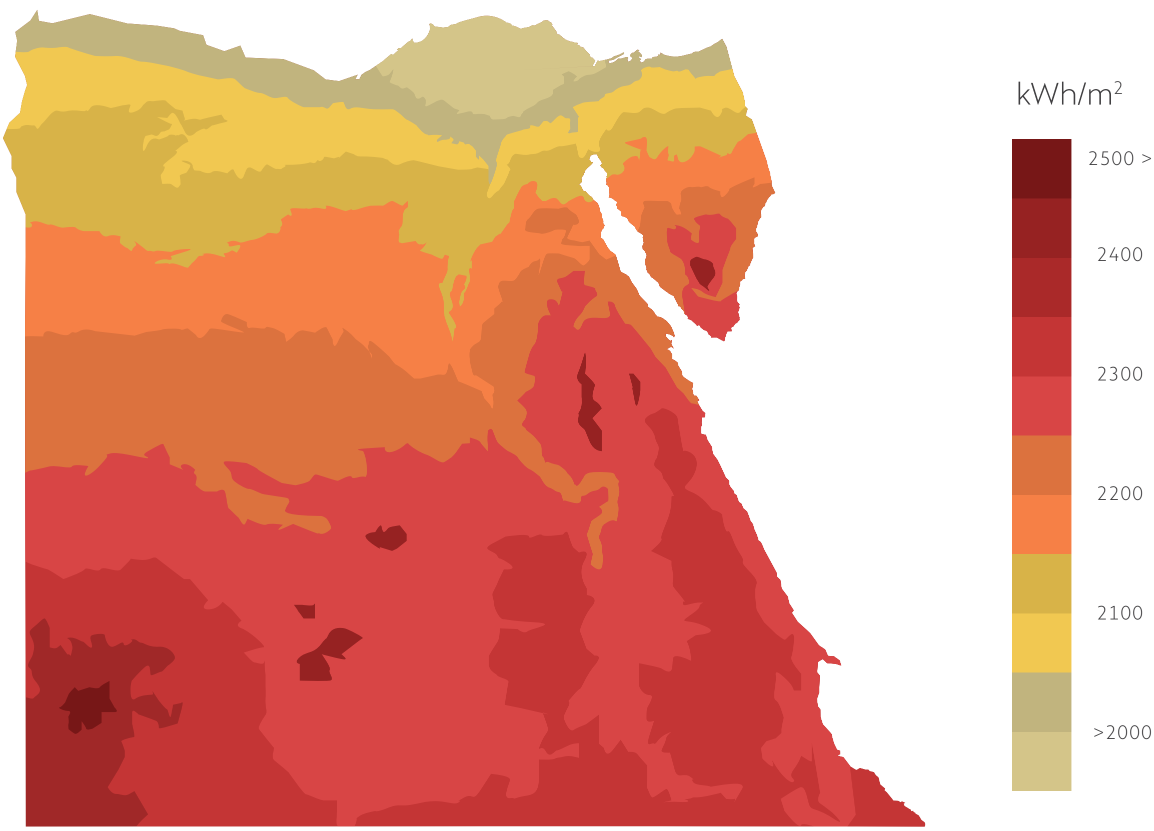


9.2.1
CSP INFRASTRUCTURE

Egypt has one of the world highest solar radiation potentials in the world, ideal for CSP. The major criticism of CSP plants is that they use large areas of land that could be used for agriculture, and that their water consumption is high. Land use is not a concern in Egypt's context as large deserts to the west of the Nile valley are not suitable for agriculture but could be used for CSP plants. As indicated by Figure 27 below, location is also not an issue in terms of harnessing the solar energy as it is more than adequate anywhere in Egypt.

Plants could be distributed to the west of the Nile valley through Upper Egypt and along the North Coast to allow for CSP-use on desalination plants to meet their heavy electricity demand and allowing for maximum efficiency.

Figure 27: Solar Atlas of Egypt[74]



9.2.2 JOB CREATION

Installing CSP infrastructure and operations and maintenance would require special training for Egyptian laborers with experts from outside Egypt to assist during the first few years to build their capacity through knowledge transfer — manufacturing, installation and maintenance — aiming at self-sufficiency in installing and running CSP plants around Egypt.

According to Figure 28, by 2035 CSP would have created roughly 1,290 jobs per annual GWh. However, a 2012 study has calculated that adding 1.6 GW would create 7,280 jobs in the construction phase and 1,500 permanent jobs in the operation and maintenance of the plants.[76] Further jobs would be created if adequate knowledge transfer were done, bringing more engineers and researchers into the sector.

Figure 28: Job Creation from TZC+CSP, in jobs created per annual GWh

Towards Zero Carbon with Concentrated Solar Power

Period	2015	2020	2025	2030	2035
Thermal	30,278.3	37,624.5	47,741.5	59,131.6	67,993.3
Hydro	8,893.8	10,223.6	12,195.8	14,365.3	15,966.7
Wind	1,089.1	2,542.6	4,341.9	6,440.7	8,197.9
PV Solar	3,075.2	8,662.4	15,532.5	23,565.0	30,320.0
CSP Solar	130.8	368.4	660.6	1,002.2	1,289.5
Biomass	1,438.7	4,052.6	7,266.7	11,024.5	14,184.8
Energy Efficiency	1,146.1	9,579.7	24,559.1	50,140.8	92,715.7
Total jobs created/ annual GWh	**46,052**	**73,053.8**	**112,298.1**	**165,670.1**	**230,667.9**

9.2.3 ENERGY ACCESS

To maximize energy access under TZC+CSP small CSP stations (20-50MW) should be constructed and distributed across the country. This would result in better knowledge transfer, higher job creation, distributed service along the grid to avoid technical shocks and lower connection costs. Within the constraints of maintaining the national grid, CSP – as with small scale solar PV – can provide direct access to electricity where independent power providers build plants for roof tops of businesses, resorts, compounds, industrial plants, schools, hospitals, government buildings and domestic buildings.

9.2.4 “COSTS”

TZC+CSP is the costliest pathway of all at 24 billion US Dollars; 14 billion US dollars more expensive than TZC, it implies that CSP is a costly contribution to the energy mix in this format.

Water usage in CSP stations would be similar to gas thermal stations ($0.7m^3$/MWh), which raises concerns over sustainability of a high water-consuming technology in an increasingly water scarce country. However, Egypt’s only existing CSP station enjoys 8% higher output than expected, this excess heat-generation can be used for air-cooling using water for minor quantities of cleaning only. Without this recycling process, the water consumption of CSP is of equal concern to that expressed for thermal power stations in other pathways. Though as this pathway uses only 1.6 GW of CSP generation, in a dispersed manner, as opposed to 43.5 GW of thermal natural gas power plants under TZC, it poses less of a threat to water security than gas. It must be emphasized however, the sustainability of this pathway relies on the recycling of the CSP plants excess thermal energy, or restrictions on the use of CSP plants in water-scarce areas of the country.

9.2.5 IMPORTS / EXPORTS

TZC+CSP has the lowest production of oil equivalent products of all the pathways, at 88.7 million tonnes per year in 2035; and only 1 million tonnes of imports a year, the lowest possible import-tonnage of all the pathways.

Construction materials for CSP plants, such as cement, concrete and steel are already produced in Egypt. Float glass is also produced locally, though a higher quality is needed for CSP construction sufficient demand would drive a higher quality native manufacturing process which would also create local skills and jobs. High quality float glass could also then be exported for other CSP stations in the MENA region. In total therefore, only the receiver and Heat Transfer Fluid would have to be imported.

9.2.6 IMPLEMENTERS

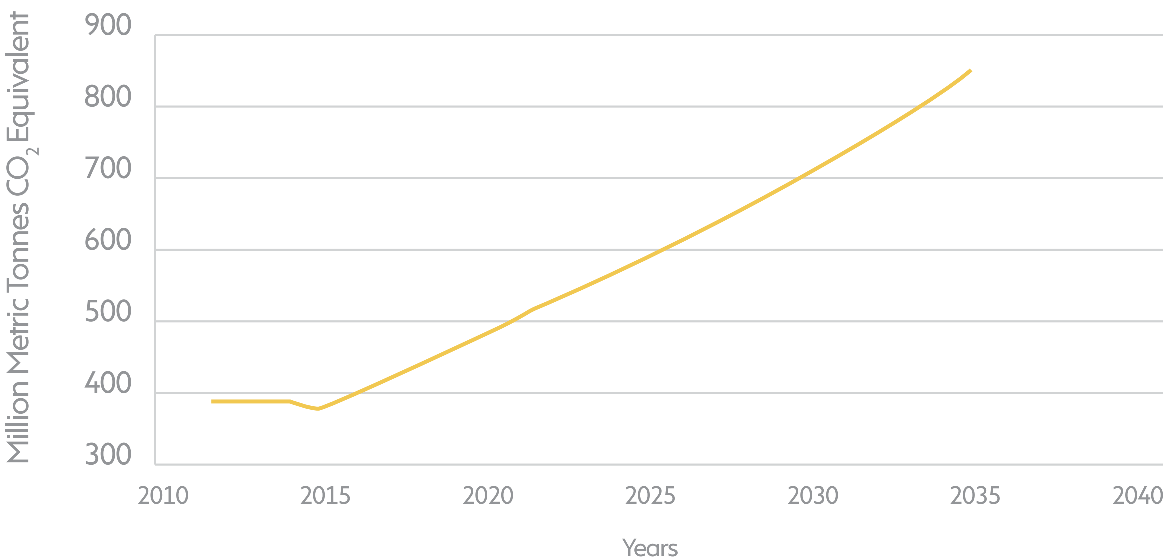
As with the core TZC pathway, a centralized grid is preserved and fed by large-scale wind and solar farms initiated through PPPs and State investment, as well as the thermal power stations run by the State.

The 4% Biomass and CSP combined are envisioned as devolved to the Governorate, local and private sector levels, as communities, industries, businesses, buildings etc. can invest in CSP plants. CSP plants can also be ‘Build Your Own’ or a ‘Public-Private Partnership’. Special support from the state may be needed to tackle the high initial cost (low interest loans, cheap rent, a suitable FiT etc.).

9.2.7 CO_2E EMISSIONS

CO_2e Emissions resulting from this scenario are considerably higher than those produced by the main TZC pathway, as indicated in Figure 29 below, and also higher than BAU with energy efficiency as Figure 41 indicates in the Summary.

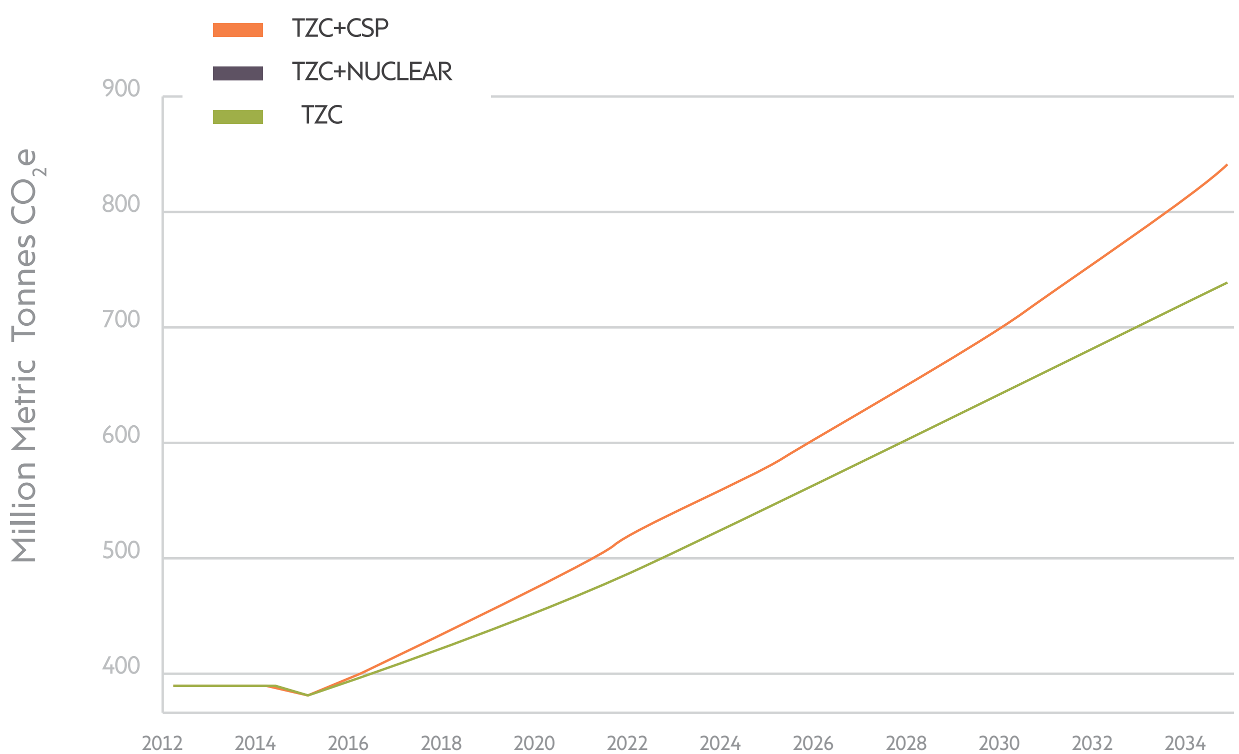
Figure 29: CO_2e Emissions in TZC pathway with CSP[77]



9. 3. COMPARING THE TZC PATHWAYS

Where CO_2e emissions are concerned, from the title of this scenario it is clear that the desired end-goal is for a completely decarbonized energy system – a zero carbon one. To decarbonize permanently, there must be a steady increase in the reliability and quality of the means for generating energy to accommodate the annual increase in demand, but without the CO_2e emissions associated with such growth. This requires a decoupling of energy generation from CO_2e emissions, which was achieved globally for the first time in 2014.[79] As such, with the 54% thermal capacity that dominates all of the TZC pathways coupled with an increase in generation output, emissions will rise as is indicated across the different pathways in Figure 30 below. However, on a longer timeline, the thermal capacity is intended to be phased out in order to achieve zero carbon energy meeting the increasing demand of the population – which would lead to a decoupling of energy from emissions if this was achieved.

Figure 30: Comparison of CO_2e Emissions of all Towards Zero Carbon Pathways



Note: TZC+CSP & TZC+NUCLEAR have almost identical CO_2e emissions profiles.

What this tells us is that to eventually phase out emissions and phase in enough electricity-generating capacity to meet demand year-on-year, renewables must be prioritized in order to decouple energy generation from CO_2e emissions. The original TZC pathway offers the most likely chance of achieving this vision out of the three, by facilitating the most hospitable pathway to increasing renewables penetration as close to 100% renewable energy as possible.

> Energy independence, rather than energy security, was preferred because it embodies a more aspirational goal and requires Egypt to be self-reliant in energy provision. Unlike 'energy security...

10.

TOWARDS ENERGY INDEPENDENCE

TEI

In these times of great upheaval, political quicksand's and multiple external pressures and world events that change discourses overnight, the ability to be self-sufficient in the very thing that keeps a country functioning and developing should be seen as a huge asset and advantage.

TEI

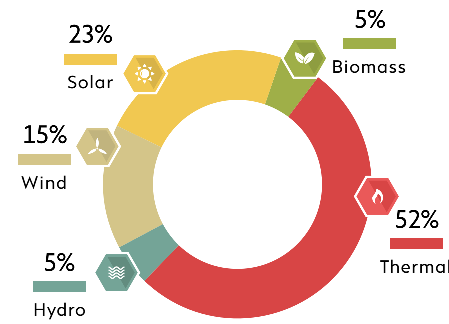
Towards Energy Independence

ENERGY			LOCATION	COSTS		IMPLEMENTERS
SOURCE	SCALE	MIX		FINANCE	IMPACTS	
	GAS	52%	GRID	PPP	AIR WATER CO2	
		23%	—	FiT BOO PPP	CO2	
		15%	GULF DESERT	FiT BOO PPP	CO2	
		3.5%	—	—	CO2	
		.75%	NILE STREAMS	FiT PPP	CO2	
		.75%	NILE STREAMS	FiT BOO	CO2	
	BIO	5%	—	FiT BOO PPP	CO2	

JOB CREATION	ENERGY ACCESS	OIL SUPPLY	CO2E EMISSIONS MILLION METRIC TONNES
228,976.2		OIL	CO_2e 12,047.7

$

TOTAL COST = 13.2 BILLION USD



‘Energy independence’ rather than ‘energy security’ was preferred because it embodies a more aspirational goal and requires Egypt to be self-reliant in energy provision. Energy security does not require that the energy source be native to Egypt and the definition of what security of energy requires will continuously shift as external and internal factors change in the world. Moreover, the use of ‘security’ implies an adherence to the current status quo for governance and energy provision, a status which we find profoundly flawed and therefore inadequate as an expression of future aspirations. This pathway was qualified as “Towards Energy Independence TEI” for the same reasons as TZC – the timeline of 2015-2035 is not long enough to ensure full energy independence and meet rising demand over that time period, it is working towards full energy independence however.

10. 1. ASSUMPTIONS

This pathway works on the premise that reliance on Egypt’s native resources is the priority. Moving in the direction of increased energy independence it uses maximum available generation of renewables, no coal or nuclear as they are both imported fuel sources, and the maximum possible generation of biomass/biogas considered feasible. The remaining energy demand is satisfied by natural gas thermal power stations as shown in Figures 31 and 32 below.

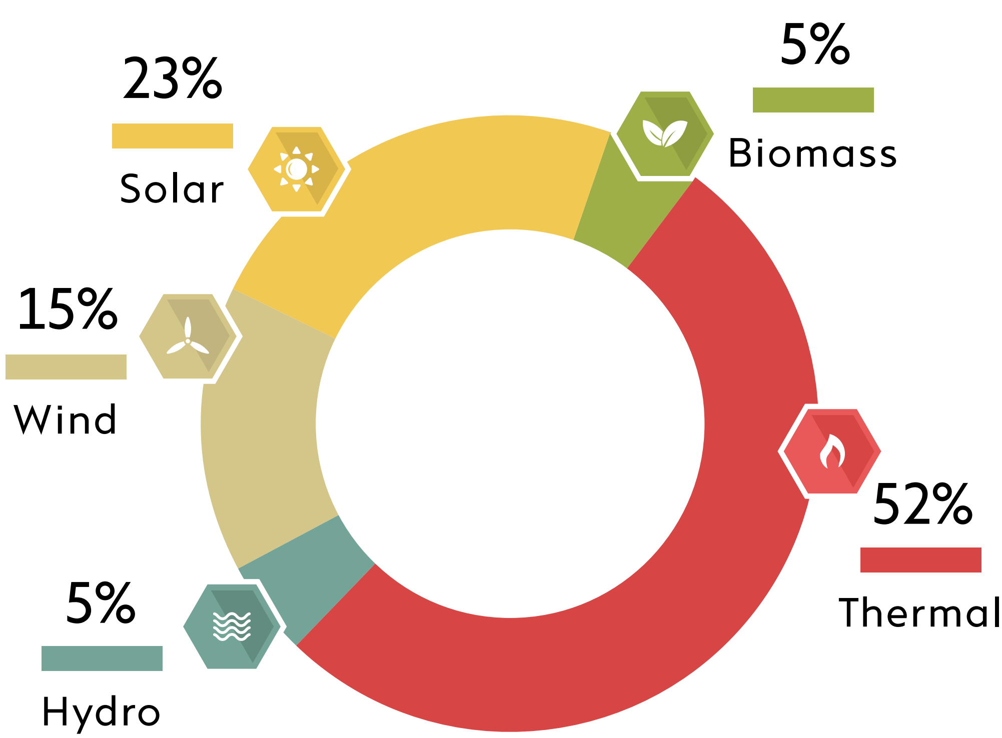
10. 2. TEI RESULTS BREAKING IT DOWN

The results for TEI are very similar to the TZC pathway except for a doubling of biomass generation capacity. As such the infrastructure and energy access issues are replicated under energy independence, as summarized below.

Figure 31: Energy mix of TEI in Gigawatts and as a percentage of total mix

Generation type	TEI Efficient Demand	
	GW	%
Thermal	41.6	52
Hydro	4	5
Wind	12	15
Solar	18.4	23
Biomass	4	5
Total	**80**	**100**

Figure 32: TEI Energy Mix in 2035



10.2.1 INFRASTRUCTURE

TEI still relies on a centralized national grid. The 52% thermal capacity is generated from natural gas, requiring a doubling of current capacity, and similarly without any particular constraints on location except proximity to the national grid lines. As such this allows there to be space for these plants to be placed outside of settlements and away from people, communities and environments that would be negatively affected. For TEI, as in TZC, natural gas is seen as a transition gas, and the investment in the doubling of thermal capacity is an investment that will stand through to 2055. As such, this allows Egypt the time and space to bring in more and more renewables with the backup capacity of natural gas to feed the transition. Although Egypt does have vast natural gas reserves, and is discovering more as time goes by, the certainty of supply is low compared to the certainty that the wind will always blow, and sun will always shine. The motivation for transitioning away from fossil fuels – even natural gas – is both climate change and the potential for carbon lock-in, as detailed under the TZC pathway.

The 23% photovoltaic (PV) solar would be mega-watt solar plants, where solar panels are collected in large groups in one place like a wind farm. These plants could be dotted around the country, with no particular location required for their successful running. It would be recommended that they be placed in parts of the desert without sensitive ecosystems and communities but still within reach of the national grid. Unlike a power station however, there are no, or very limited, negative effects of generating solar energy foreseen, as they are static, without emissions and do not make a noise or produce effluent.

The 15% wind power is generated from large-scale wind farms such as Zafarana on the East coast of Egypt. Wind farms need to be constructed on coastal areas, which for maximum vantage point in Egypt, includes the Gulf of Suez, the coast of southern Sinai, and parts of the Western Desert north of Kharga Many of these areas are dominated by a successful tourism sector that provides employment locally; therefore, the governorate and nearby tourism sector of any proposed sites must be consulted publicly, with full access to the decision makers and planners for this aspect of the pathway.

The TEI pathway encourages the introduction of biomass plants at 5% of the energy mix, making use of Egypt’s vast amount of agricultural waste and human sewage. Biomass plants will be located near or next to sewage treatment plants in order to directly make the most of the energy source and reduce transportation needs. This will mean that biomass plants are distributed all across the country in direct relation to the sewage plants current distribution. This will also reduce the burden on the sewage plants to treat the sewage to a sufficient standard that it can re-enter the water table, and so it is predicted that Nile water quality will improve as a result. In future, sewage plants can be built at the same time as biomass plants. The agricultural waste will be collected locally, in a system to be determined according to the tailored needs of each governorate. It could consist of drop-off points in each town and village, where the waste is then collected from and taken to be sorted and used at the biomass plant. At the plant itself a space for storing and sorting received waste must be constructed with standards that ensure workers are safe and operations are as clean as possible.

Of the 4GW of Hydro energy the TEI pathway incorporates, 2.8GW of capacity already exists and is being generated annually by the High Dam. It is estimated that over 85% of the river Nile has already been exploited for hydro purposes, therefore the 1.2GW increase is attributable to 0.05GW of already planned small pumped storage hydroelectric projects and the installation of 1.15GW worth of micro turbines along the side of running water bodies such as the Nile, its tributaries and streams. The turbines are small and efficient, and can be installed in ‘arrays at any point along a river or stream. These turbines average a 50KW output per micro plant (an array of turbines), therefore to reach the 1.15GW capacity, 2,300 micro turbine plants must be installed along moving bodies of water in Egypt.

Finally, more reliable and greater numbers of substations will be needed to connect the wind and solar farms to the national grid. We estimate the construction of 45 substations for solar and 30 substations for wind will be needed, located in between the national grid and the solar/wind farms, and the national grid and the end user.

10.2.2 ENERGY ACCESS

As the dominance of a centralized grid with large developments in renewables implies, there is very little change in how energy generation and access is distributed around the country. Similarly, to the energy access conclusions for the BAU scenario: maintaining centralized distribution via the national grid will likely maintain the areas of the country currently unconnected to the grid and therefore without ready or easy access to mains electricity. The difficulty in developing without a constant supply of electricity will therefore preserve the pockets of poverty and inequitable distribution of resources currently seen in the country.

For those connected to the grid and who do have access, their energy access will be improved by the meeting of demand through increased generation capacity. This means no power cuts and a reliable source of electricity to live and work on.

Under this TEI scenario the community and governorate level biomass collection and power generation feed into the national grid but overall we do not see an increase in the average citizen, small business or enterprise generating their own energy

10.2.3 "COSTS"

Public and private investments will be needed to increase the number of natural gas power plants as well as introduce abatement technologies to prevent particulate pollution from natural gas combustion. More importantly, massive investments are needed to give birth to solar and wind power industries from scratch over the course of twenty years, including continuation of Feed in Tariffs for small and medium scale renewables. Furthermore, investments will be needed for grid upgrades in terms of its reach and capacity to handle renewables' varying storage capacities, weather predictions and geographical reach.

Financing will be needed for a longer term implementation of the FiT program and other incentive programs to support long-term solar and wind plants that would follow either BOO or PPP systems to sell electricity to the grid or directly to the consumer for example to a resort or a cement factory. Biomass (biofuel or biogas) power production plants technology, construction and operation must be financed to import technologies, tailor them and construct the plants. Introducing biomass also entails raw material collection and segregation systems investments.

10.2.4 JOB CREATION

The TEI pathway creates a relatively high number of jobs per annual GWh, at 228,976.2 annual jobs created per GWh by 2035. By 2035, TEI creates roughly 12,000 more jobs per annual GWh than the TZC scenario. These extra jobs all come from the increase in biomass capacity; almost doubling the biogas generation capacity doubles the jobs created/annual GWh by 2035. The skills sets and distribution of these extra and permanent jobs are dispersed across the governorates, directly correlating to the amount of biomass collected, sorted and used in local biomass plants. The extra 12,000 jobs include waste technicians, waste sorters, unskilled workers and lorry drivers.

Similarly, to the TZC pathway, implementing TEI will create opportunities for skilled labor for solar installations, including engineers, electrical technicians, construction workers, plumbing technicians and trained labor will be needed for plant operation. Grid upgrading professionals from both private technical consultancies and public agencies will be called on. Job opportunities will arise from wind blade manufacturing, wind farm installations and operations and maintenance of wind farms. These all require managers, unskilled labor, engineers, and technicians. The transportation sector will receive a boost in demand for road and Nile transportation for the renewables industry.

Conventional natural gas power plants will still be online, requiring the existing workforce to be increased over the twenty-year period from 30,325.6 to 58,956.6 jobs/Annual GWh.

Finally, the energy efficiency industry that is born out of a commitment to efficiency across the industry and by the end-user, creates the most jobs of all the energy sources. These roles would include, with a relatively even dispersal across the country, energy efficiency policy-makers, regulators and enforcers, labeling scheme managers, public and private auditors and insulation installers.

Figure 33: Job Creation Under A Towards Energy Independence Pathway

Towards Energy Independence

Period	2015	2020	2025	2030	2035
Thermal	30,054.2	35,431.7	42,264.9	49,432.1	56,254.5
Hydro	9,226.6	10,672.8	12,530.7	14,459.7	16,266.4
Wind	981.5	2,233.7	3,718.7	5,379.7	7,116.5
Solar	2,682.7	7,604.3	13,420.1	19,946.2	26,801.4
Biomass	2,985.1	8,461.3	14,932.4	22,194.0	29,821.7
Energy Efficiency	1,146.1	9,579.7	24,559.1	50,140.8	92,715.7
Total jobs created/ annual GWh	**47,076.2**	**73,983.4**	**111,425.8**	**161,552.6**	**228,976.2**

10.2.5 IMPORTS/EXPORTS

In keeping with the title of the pathway, TEI, along with TZC, requires the least imports of oil-equivalent products of all the pathways. It does however require a bare minimum in order to transition to full energy independence over a longer period of time. As such, by 2035 under an TEI pathway Egypt would import 12.8 million tonnes of oil equivalent annually.

As with the other pathways, hardware imports for renewables, thermal power stations and the biomass plants would be expected.

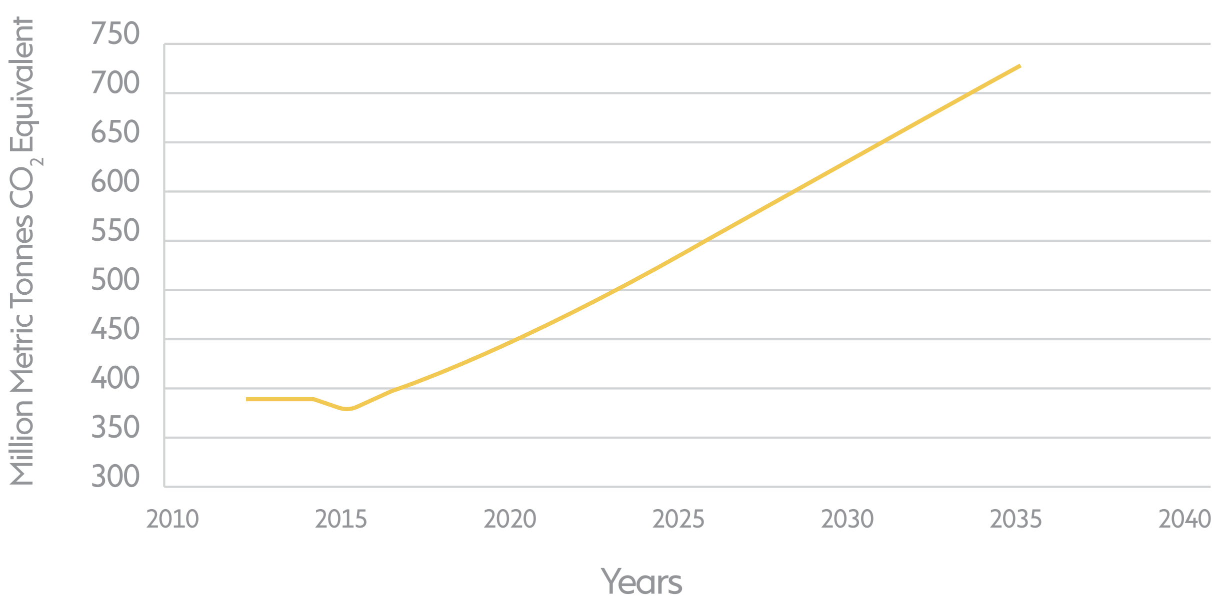
10.2.6
IMPLEMENTERS

This is a centralized implementation model, utilizing the national grid as the main electricity-providing infrastructure remaining in the control of the central government and all large-scale projects coming under their jurisdiction, except the biomass collection and biogas plants which are devolved to the governorate and community levels of decision-making and implementation.

10.2.7
CO_2E EMISSIONS

Since the energy mix for TEI is very similar to TZC, its emissions are almost the same, demonstrated by Figure 34 below. TEI also represents a reduction of 100 Million Metric Tonnes CO_2e compared to the efficient BAU scenario of 1,850 MMmt/CO_2e, and 150 MMmt/CO_2e less than the BAU+COAL scenario. Though its emissions trajectory increases annually through to 2035 because of the thermal capacity used to meet rising demand, 2035 is a mid-point on a trajectory that would see the phase-out of fossil fuels and phase in of renewable energy based on their qualities of providing free and native energy that allows Egypt to be energy-independent.

Figure 34: CO_2e emissions for TEI - 2015-2035



> *The ‘Towards Decentralized Energy’ pathway sets out to put Egypt on the pathway to self-sufficiency through decentralization of energy generation, devolving control to local communities and the governorate level, bringing citizens closer to energy decision-making and offering more agency over their lives.*

11.

TOWARDS DECENTRALIZED ENERGY

TDE

"From an African perspective, renewable technologies have two distinctive advantages: speed and decentralization. They can be deployed far more rapidly than coal-fired power plants and they can operate both on-grid and off-grid. In considering investment decisions today, Africa's governments should take every opportunity to lay the foundations for a low-carbon future, while recognizing that the transition away from existing high carbon infrastructure will take some time.[81]*"*

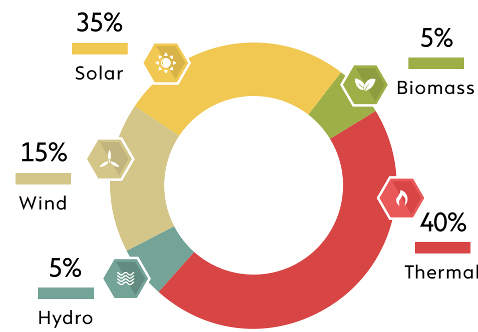
TDE

Towards Decentralized Energy

ENERGY: SOURCE	ENERGY: SCALE	ENERGY: MIX	LOCATION	COSTS: FINANCE	COSTS: IMPACTS	IMPLEMENTERS
	GAS	40%	GRID	PPP	AIR, WATER, CO2	
		35%	—	FiT, BOO	CO2	
		15%	GULF, DESERT	FiT, BOO, PPP	CO2	
		3.5%	—	—	CO2	
		.75%	NILE, STREAMS	FiT, PPP	CO2	
		.75%	NILE, STREAMS	FiT, BOO	CO2	
	BIO	5%	—	FiT, BOO	CO2	

JOB CREATION	ENERGY ACCESS	OIL SUPPLY	CO2E EMISSIONS MILLION METRIC TONNES
232,521.3		OIL	CO_2e 12,560.8

TOTAL COST = 19.5 BILLION USD



With the domination of the energy sector by the State – a controversial entity that has wielded deep and violent powers over Egyptians at the same time as affording many energy access through subsidization and a centralized grid – the decentralization of energy generation and distribution has not been on the political agenda, or envisioned by civil society on a large scale. Decentralized energy provision has been forced on the most rural areas of the country, with whole Oases being 'off-grid' though actually using comparably polluting methods to provide their electricity requirements, namely diesel generators.

These extremes of energy access – a lumbering, inefficient network with huge coverage versus an agile, vulnerable and small-scale solution of individual generators – are not the two poles that the country must continue to work towards. In this scenario we envision concrete steps to pull both extremities in the direction of decentralized energy, which cannot be achieved in full on a twenty-year timeline, but feeds into a longer-term aspiration for agency, change and human development that Egyptians are expressing the country over.

The secondary but equally important motive and concern behind a push for decentralizing energy provision in Egypt, is to avoid the corporate capture of the energy market that liberalization can bring, and has demonstrably had negative impacts in developed countries already using this model.

The UK has a dominant set of six energy companies 'the big 6' that are branded as delivering energy services across the country for the good of the people, although they are profit making corporations that transfer the costs of their operations to their consumers and have not done anything to change the UK's position as one of most fuel-poor nations in Europe.[82] More importantly however, this corporation-consumer relationship has divorced British people from more complex identification with being 'energy providers'[83], being self-sufficient, or often, having a basic understanding of personal and domestic energy use.

Egypt is not immune from this despite its state-centric energy system. Research found that natural gas contracts for export from Egypt to Jordan, Israel and Spain consistently undersold the resources of the country, losing Egypt $10 billion in revenues between 2005-2011.[84] Through bad negotiation with international corporations whose main priority is their bottom line, Egypt's energy sector and therefore the Egyptian people relying on the state budget for their healthcare, pensions and other services, has already lost out from international or large corporations being welcomed into the energy sector.[85]

> *"We need to shift power away from the entangled interests of finance and the big companies, and challenge the current monopolized energy system, so that these relationships can become intentional and active, so that energy consumers can become producers, distributors, owners, sharers and collective users of energy. We need to democratize energy. This means commoning resources, dispersing economic power and ending dependence on the multinationals that exploit public resources for private profit."*

The 'Towards Decentralized Energy' pathway sets out to put Egypt on the pathway to self-sufficiency through decentralization of energy generation, devolving control to local communities and the governorate level, bringing citizens closer to energy decision-making and offering more agency over their lives.

In the TDE pathway the centralized grid is superseded by more localized energy generation, cleaner and closer to the people. Solutions focus on solar, wind and biomass as the main vehicles for achieving an equitable spread of energy access across the country, with natural gas power stations forming the base load for the national grid that is maintained for populations with existing mains access.

> *"Expansion in centralized power generation serves industry, the services sector and already-connected households, before it serves the poor. Distributed, clean energy interventions are best suited to tackling energy poverty – and poverty more generally."*[86]

Tackling this central assumption – that centralized energy generation and distribution cannot lead to a fundamental redistribution of energy resources – the TDE pathway offers an insight into what powering up electricity generation at the levels of communities, buildings and individuals could look like by 2035, with a view to increasingly decentralized capacity thereafter.

11. 1. ASSUMPTIONS

Due to the use of small-scale PV generation, the average cost of PV will increase. In the model, it was assumed that the cost of a PV system is 15,000 EGP/KW, with a 10% annual decrease in cost up to 2020, decreasing to 5% between 2020-2030, then the cost remaining constant from 2030 through to 2035.[87]

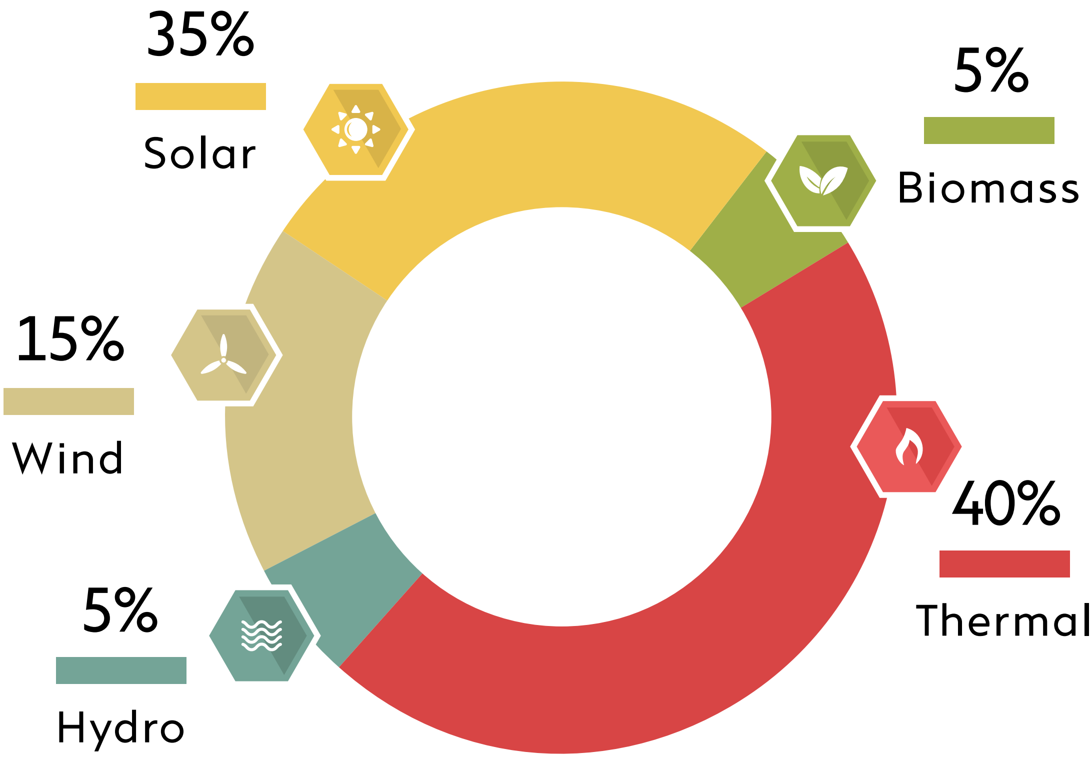
11. 2. TDE RESULTS BREAKING IT DOWN

The energy mix for TDE contains 40% thermal energy capacity from natural gas, 5% hydro from the High Dam and micro turbines, 15% wind, 35% solar PV and 5% biomass.

Figure 35: Energy mix of TDE in Gigawatts and as a percentage of total mix

Generation type	TDE With Efficient Demand	
	GW	%
Thermal	32	40
Hydro	4	5
Wind	12	15
Solar	28	35
Biomass	4	5
Total	**80**	**100**

Figure 36: TDE Energy Mix in 2035



11.2.1
INFRASTRUCTURE

This pathway will result in 40% increase in natural gas power plants, to be situated anywhere in Egypt that is within reasonable reach of the national grid. Substations situated between the power plant and the national grid will need to be installed. The new power plants will have to have the latest pollution abatement technology to ensure minimal pollution. The power plants form the core of the centralized national grid which is reduced in size but still the main source of electricity for high demand areas of the country.

Solar on the other hand is expected to be a decentralized source of energy where independent power providers build plants for roof tops of businesses, resorts, compounds, industrial plants, schools, hospitals, government buildings and domestic buildings. Micro-grid and individual generation from Solar PV panels will be location dependent as proximity to the power consumer is the main criteria for this decentralized infrastructure – this also eliminates the need for substations.

Micro-grids are adopted on a settlement level (based on population or usage) where consumers are self-sufficient using solar PV, community scale wind-farms, biomass plants and micro turbines in local streams and rivers. Biomass is collected from local farms and transported to the biomass power station situated alongside the local sewage treatment plant (if there is one) for sorting. This requires the extension of existing treatment plants or building in close proximity where possible. It also requires large areas of land for storing waste safely and without causing environmental or human health hazards.

11.2.2 ENERGY ACCESS

Prioritizing decentralized energy is the only pathway that tackles core energy access issues. Persistent access-to-energy problems tend to stem from poverty and oversight or discrimination by central authorities (particularly in rural areas and informal settlements) where reliance on a centralized grid precludes other options for accessing energy.

As such, devolving energy generation and distribution to the governorate, community and individual levels where possible, grants users decision-making power over their source, their usage and therefore the impact of power cuts when necessary. Where profit-making is not seen as a core purpose of energy generation, local communities can choose to share out access to electricity amongst its members using other currencies than just money, possibly benefiting poorer parts of communities.

11.2.3 “COSTS”

In the conventional sense of the word “cost”, TDE is the third most costly of all the scenarios after TZC+NUCLEAR and TZC+CSP, at 19.5 Billion USD. This is due to the increase in unit cost of solar energy as the smaller scale means that the solar used under TDE does not benefit from economies of scale seen in other pathways. This conventional costing of the pathway does not quantify the benefits of energy access to a much more diverse portion of the population; the community's increased co-operation and cohesion; and that “costs” would be distributed according to those using the decentralized energy options – the entire bill would not necessarily be paid for by the Government.

The "costs" to the State in feed-in tariffs, tighter regulation of energy generation and the creation and implementation of a quality guarantee program are not accounted for in the cost calculation of this pathway.

TDE, like all the pathways, has included the current cost of fossil fuels on the international market, therefore no energy subsidies have been included ensuring that the real economic cost of fossil fuel dependency is calculated – recognizing this does not account for the full breadth of other "costs" incurred from fossil fuel use, such as human health and environmental degradation from pollution.

11.2.4 JOB CREATION

The number of jobs generated by the TDE pathway is slightly higher than the TEI pathway as the replacement of thermal capacity with solar PV leads to an increase in jobs in installing, maintaining and operating the panels. Renewables have a higher job creation intensity than fossil fuels, therefore a TDE pathway that seeks to increase local and community owned and run energy sources and renewables, will see an increase in job creation for installation and operation and maintenance.

Of the skills-sets this increase in available jobs will require, we would expect to see demand for the regulatory aspect – including technical engineers, law enforcers, policy makers, environmental and health impact assessors; the design and construction of the energy sources – including iron workers, insulation engineers, electricians and plumbers, construction workers and insulation installers; the operation of energy sources – including engineers, technicians, waste technicians, waste sorters, unskilled workers and lorry drivers.

This program gives room for local Small & Medium Enterprises (SMEs) to install small-scale solar plants through employing local people and enhancing local know-how. There will be a demand for more professionals to manage, design, construct, operate and maintain micro-grids, and this demand will be as spread out across the country as the micro-grids themselves.

Figure 37: Job creation under a Towards Decentralized Energy pathway

Towards Decentralized Energy

Period	2015	2020	2025	2030	2035
Thermal	29,814.1	34,288.4	37,996.9	41,480.8	44,218.2
Hydro	9,563.0	11,515.9	13,293.4	15,052.1	16,581.8
Wind	554.3	1,044.0	2,972.5	5,087.9	7,254.6
Solar	4,208.4	12,418.5	21,547.7	31,425.7	41,351.0
Biomass	3,093.9	9,129.7	15,841.3	23,103.2	30,400.0
Energy Efficiency	1,146.1	9,579.7	24,559.1	50,140.8	92,715.7
Total jobs created/ annual GWh	**48,379.9**	**77,976.2**	**116,210.9**	**166,290.6**	**232,521.3**

11.2.5 IMPORTS/EXPORTS

Total oil equivalent production goes up from 87.8 million tonnes to 154.2 million tonnes. Exports remain constant at -7.6 and imports grow from 1million tonnes in 2015 to 15.6million tonnes in 2035. Of all of the pathways, TDE has the smallest oil product footprint, with total primary supply rising to only 162.2million tonnes by 2035.

Use of solar PV panels will require an increase in imported hardware and the importing of the wind turbine towers and the technologies required for the natural gas power stations and biomass power stations.

11.2.6 IMPLEMENTERS

TDE aims to become increasingly decentralized beyond 2035. On this pathway three layers or actors are responsible for various parts of implementation.

The State must play an active role in law-making and incentivizing the take-up of small-scale renewables in order to initiate this shift towards decentralization. One of the measures that is best implemented at the State level is the required quality guarantees to support the significant increase in domestic PV manufacturing and purchasing and to ensure purchasers are guaranteed a certain quality and warranty for the product. The State will also be coordinating the investment and installation of the large-scale wind farms, and the new gas-fired power stations required, though decision-making on the wind farms could be devolved to the Governorate level to increase accessibility of citizens to planning decisions made.

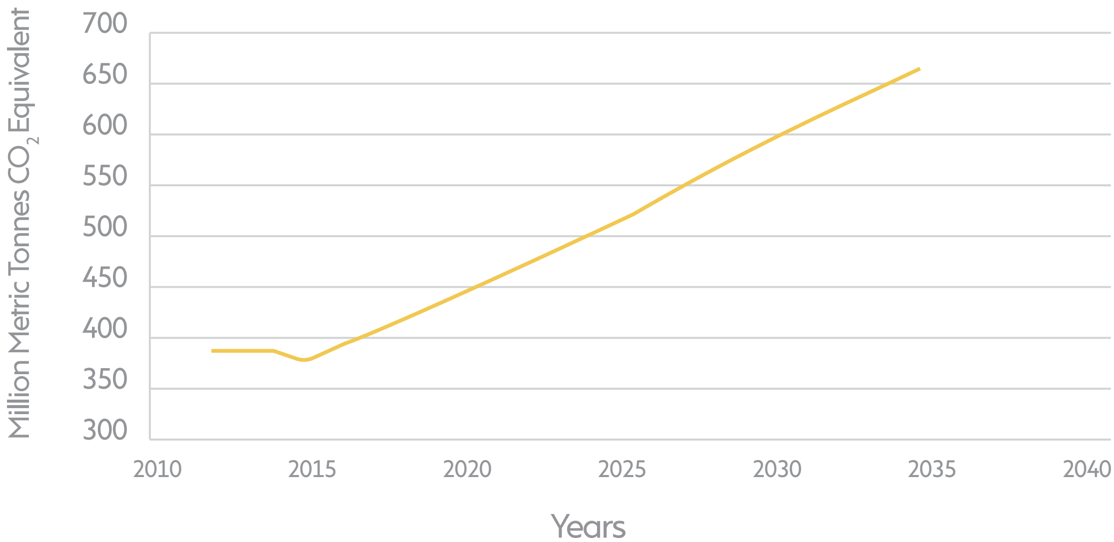
The second tier of implementation resides at the Governorate level. Responsibility for planning, installation and job creation for the micro-turbines, solar PV and biomass is held at the Governorate level with capacity to devolve each project's processes down to the community level.

Under TDE it is envisioned that the dominance of the centralized grid is diminished through use of micro-grids at the community and building levels; this forms the third level of decentralized implementation. Here, community groups, charities and organizations, co-operatives of workers, locals, small businesses, and whole building blocks and compounds could pool resources and efforts to install a micro grid that they collectively manage the supply and demand of for their mutual benefit.

11.2.7
CO_2E EMISSIONS

TDE produces the least CO_2e emissions of all the pathways due to the deployment of high levels of solar PV. This indicates that decentralization and greater community ownership is both positive for community cohesion, agency over their own development and creates the co-benefit of reduced CO_2e emissions.

Figure 38: CO_2e Emissions of the TDE pathway 2012-2035



> *Comparing all three scenarios to the BAU case, they all cause less harm to the environment through fewer emissions, all three scenarios are quite close since their mixes are almost equally reliant on renewables.*

12.

COMPARING THE PATHWAYS

T***his final section offers the numbers*** for total job creation, CO_2e emissions, cost, the cost of avoiding CO_2e emissions, oil supply and the implementers for each pathway, side-by-side.

12. 1. TOTAL JOB CREATION

Figure 39: Table comparing total jobs created per annual GWH for all pathways

Total jobs created per annual GWh

Pathway	2015	2035
BAU	42,784.1	214,447.4
BAU+COAL	40,984.2	114,120.6
TZC	45,855.0	216,776.5
TZC+NUCLEAR	N/A	N/A
TZC+CSP	46,052	230,667.9
TEI	47,076.2	228,976.2
TDE	48,379.9	232,521.3

In all the key renewables - wind, PV and CSP - the manufacturing of the equipment predominantly creates the jobs[88]. For CSP and wind only, there are at least many jobs created in operation and maintenance. However,[89] renewable and energy efficiency sectors are the most labor intensive of all energy sources, and therefore a high renewables penetration scenario will deliver more jobs.[90]

12. 2. "COSTS" AND CO_2E EMISSIONS

Comparing all three scenarios to the BAU case, they all cause less harm to the environment through fewer emissions as shown in Figure 40 below. All three scenarios are quite close since their mixes are almost equally reliant on renewables. The table in figure 40 provides a side-by-side comparison of each scenario's CO_2e emissions and Figure 41 outlines the total cost for achieving each pathway and the price for the CO_2e reductions as a result.

Figure 40: CO_2 Emissions Produced By All Pathways

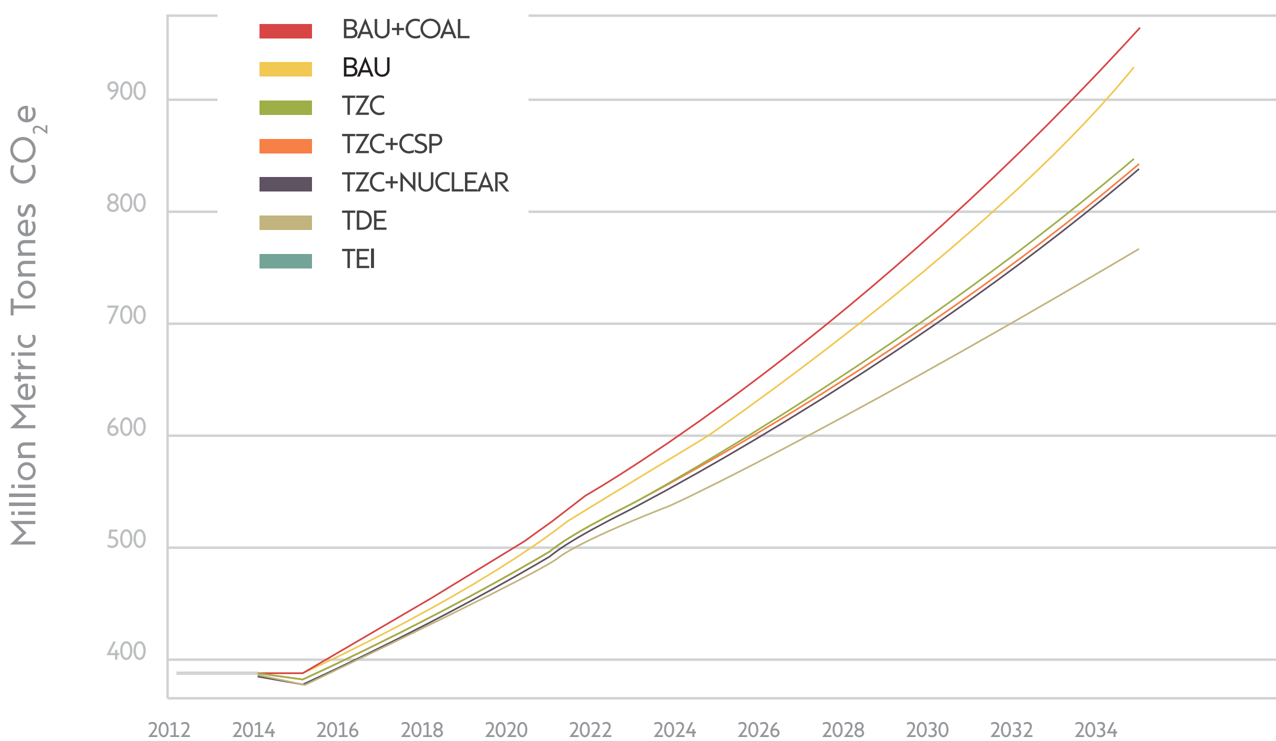


Figure 41: Costs and GHG Reductions For All Scenarios

Total Costs & Emissions Reductions: 2012-2035 (Relative to BAU)	Business As Usual (BAU)		Towards Zero Carbon (TZC)			Towards Energy Independence (TEI)	Towards Decentralized Energy (TDE)
	BAU + EFFICIENCY	BAU +COAL	TZC	TZC + NUCLEAR	TZC + CSP		
Net Value (cost in Billion U.S. Dollar)	-4.6	11.2	10.8	23.7	24	13.2	19.5
Total GHG emissions (Million Metric Tonnes CO_2e)	13,404.5	14,687.3	12,708.4	13,623.5	13,603.6	12,047.7	12,560.8
GHG emissions savings from BAU (Million Metric Tonnes CO_2e)	923.6	-359.2	1,619.8	704.7	724.6	1,767.3	2,280.4
Cost of Avoiding GHGs (in USD/TonneCO_2e)	-5	n/a	6.7	32.3	33.1	7.5	8.6

IMPORTS & EXPORTS

Figure 42: Total Oil equivalent (including natural gas) production, imports, exports for each scenario

	2015				2035			
Million tonnes oil equivalent/per year	Production	Imports	Exports	Total Primary Supply	Production	Imports	Exports	Total Primary Supply
BAU	88.1	1.9	-7.6	82.4	165.8	31.2	-7.6	189.4
BAU+COAL	87.7	3.1	-7.6	83.2	165.7	86.1	-7.6	244.2
TZC	88.2	1.0	-7.6	81.6	166.6	12.8	-7.6	171.7
TZC+NUCLEAR	88.6	1.3	-7.6	82.2	175.1	55.1	-7.6	222.6
TZC+CSP	176.3	51.4	-7.6	220.1	88.7	1.0	-7.6	82.0
TEI	88.0	1.0	-7.6	81.4	164.8	12.8	-7.6	170.0
TDE	87.8	1.0	-7.6	81.2	154.2	15.6	-7.6	162.2

12. 4. IMPLEMENTERS

Figure 43: Which levels are responsible for implementation under each pathway

Pathway	Level Responsible for Implementation			
	State	Governorate	Community & Domestic	Business
BAU				
BAU+COAL				
TZC				
TZC+NUCLEAR				
TZC+CSP				
TEI				
TDE				

> *This study has shed light on the nexus of technical, social and environmental aspects of energy strategies and visions that are interlinked but remain in the dark for many decision-makers. The conclusions offered in this study form a foundation from which further in-depth studies to create a stronger and more comprehensive energy strategy for Egypt should be built on.*

13. THE WAY FORWARD

> "*African nations do not have to lock into developing high-carbon old technologies; we can expand our power generation and achieve universal access to energy by leapfrogging into new technologies that are transforming energy systems across the world. Africa stands to gain from developing low-carbon energy, and the world stands to gain from Africa avoiding the high-carbon pathway followed by today's rich world and emerging markets.*"

– ***Kofi Annan,*** chairing the 2015 Africa Progress Panel:

This study has shed light on the nexus of technical, social and environmental aspects of energy strategies and visions that are interlinked but remain in the dark for many decision-makers. The conclusions offered in this study form a foundation from which further in-depth studies to create a stronger and more comprehensive energy strategy for Egypt should be built on.

Feedback from the workshops indicated certain aspects that could be added to this study, including a resounding call from all participants to extend the timeline to 2050 to allow for more representative conclusions on the cost of various pathways given the long-term nature of investments. This would also allow for comparison and integration with many international 2050 scenarios on the global and regional scale. This is useful for policy development as modelers and policy makers are increasingly given room to exchange knowledge and best practices

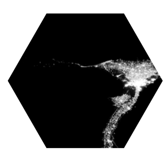
The second equally important aspect that must be taken forward from this study is to build 2050 scenarios that cover the entire energy sector in Egypt – not just electricity. The presence of energy in individual's lives is a web, a web that extends far beyond electricity to include transport, agriculture, industry and other sectors. If we are serious about offering ways and means of reducing inequalities, preventing environmental degradation, and promoting community building and development, the full panoply of energy-related issues should be included in future studies with greater capacity. For work of this depth and accuracy, academic and technical expertise and capacity building must be harnessed with a conveing body that can house the research and exploration of the huge body of work required for this task. This convening body does not currently exist.

We would extend this challenge to include the tight nexus of energy, water and food as well. Where shortages and surges in one directly affect the other two, we cannot pretend to have covered the variety of issues energy throws-up without including the relationships of reliance it resides within.

Finally, this study has demonstrated the benefits of wide stakeholder engagement, with Small and Medium Enterprises (SMEs), industry professionals, human and environmental rights organizations, social economists, human geographers, environmental consultants and policy-makers, all voicing their concerns, inputs and solutions to build a vision for a more equitable electricity sector in Egypt. These skills-sets and vessels of knowledge and experience are currently underutilized and therefore greater inclusion – not just consultation in the latter stages – should be a prerequisite for civil society and private sector development of future energy scenarios.

It is the hope of ***Heinrich Böll Stiftung HBS*** North Africa and the ***Egyptian Center for Economic & Social Rights ECESR*** that this project will spark discussion amongst the huge variety of people, institutions, businesses and sectors that have an interest and concern in engaging constructively to challenge assumptions and dominant discourses around energy in Egypt.

The future is for us to make; as citizens, workers, communities, business-people, academics and students, politicians and technocrats; therefore, we challenge everybody to open our minds and practices to innovation as we develop together, without leaving anyone behind.



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