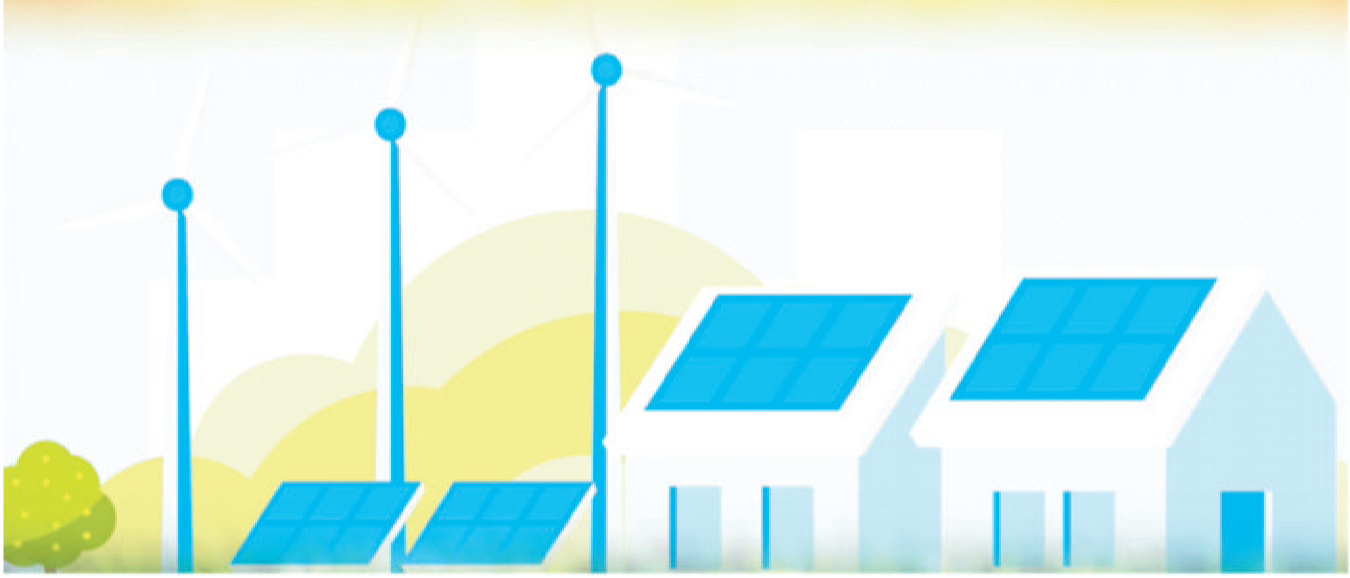
100% RENEWABLE ENERGY FOR BANGLADESH

Access to renewable energy for all within one generation

Summary for policy-makers



UTS Institute for Sustainable Futures

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VOICE OF FUTURE GENERATIONS

Brot für die Welt

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Promoting Peace & Progress

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ACRONYMS AND ABBREVIATIONS

ACOLA	Australian Council of Learned Academies
BftW	Bread for the World
BAU	Business As Usual
BBS	Bangladesh Bureau of Statistics
CDP	Coastal Development Partnership
CDP	Carbon Disclosure Project
CSP	Concentrated Solar Power
CHP	Concentrated Hydraulic Power
COP	Conference Of the Parties
DSM	Demand Side Management
DREA	Distributed Renewable Energy Association
DESCO	Dhaka Electric Supply Company Limited
DESA	Dhaka Electric Supply Authority
DNI	Direct Normal Insulation/Irradiation
EECMP	Energy Efficiency and Conservation Master Plan
EC	European Commission
ECN	Electronic Communications networks
FT	Financial Times
GWh	Giga Watts per hour
GDP	Gross Domestic Products
GIS	Geographic Information System
GOB	Government of Bangladesh
GSR	Global Status Report
ISF	Institute of Sustainable Future
IPCC	Intergovernmental Panel on Climate Change
IEA-RE	International Energy Association - Renewable Energy
IJHE	International Journal of Hydrogen Energy
IRENA	International Renewable Energy Agency
IOC	Intergovernmental Oceanographic Commission
IEA	International Energy Agency
ICAO	International Civil Aviation Association
JICA	Japan International Cooperation Agency
KWh	Kilo Watts per hour
LCD	Low Carbon Development
LPG	Liquid Pressure Gas
MWh	Mega Watts per hour

NOAA	U.S. National Oceanic and Atmospheric Administration
NDC	National Determined Contribution
NEEP	National Energy Efficiency Program
NREL	National Renewable Energy Laboratory
OECD	Organization for Economic Cooperation and Development
PPMC	Paris Process on Mobility and Climate
PPP	Public Private Partnership
PSMP	Power System Management Plan
PJ	Peta-Joule
RMG	Ready Made Garments
REB	Bangladesh Rural Electrification Board
REF	Reference Scenario
REN	Renewables
RE	Renewable Energy
Solar PV	Solar Photo-Voltaic
SHS	Solar Home Systems
SREDA	Sustainable and Renewable Development Authority
ToR	Terms of Reference
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNISDR	United Nations Office of Disaster Reduction
USAID	U.S. Agency for International Development
UTS	University of Technology Sydney, Australia
UNEP	United Nations Environment Program
USA-EPA	United States of America - Environmental Protection Agency
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
VRE	Variable Renewable Electricity
WCRP	World Climate Research Program
WFC	World Future Council
WEO	World Energy Outlook / World Energy Organization
WFP	World Food Program
WRI	World Resources Institute
WEB	World Electrification Board

Key Findings

- **100% Renewable Energy in Bangladesh by 2050 is technically feasible,** economically viable and socially beneficial.

- By 2050, around 200GW of renewable generation capacity needs to be installed to reach 100% RE in Bangladesh.

- **Solar PV:** Bangladesh has almost 6,250 km^2 of available land for PV where 156 GW of solar power can potentially be harvested through utility scale solar farms. 20% of these utility scale solar farms would be floating installations.

- **Wind:** Total wind power potential is 150 GW with offshore wind accounting for 134 GW and onshore wind for 16 GW.

- **Investment:** Additional investments (In addition to US$ 170 billion of the PSMP 2016) between US$ 80 billion (2.0°C scenario) and US$ 140 billion (1.5°C) until 2050 are required to transition towards a 100% RE system. Fuel cost savings in the RE scenarios (RE has no fuel costs) will reach up to US$ 140 billion (2.0°C) and US$ 200 billion (1.5°C). Higher investment needs are overcompensated by fuel cost savings.

- **Infrastructure needs:** Infrastructure expansion is necessary to meet the increasing energy demand, to accommodate new wind and solar power plants and to integrate decentralised systems.

- **Storage:** 100% renewable energy is possible without estensive storage capacities. Storage requirements are moderate and will only need to play an increasing role after 2030.

- **Transport:** By 2050 up to 40% of the transport sector can be electrified. Bio- and synthetic-fuels would complement the increasing renewable energy share in the transport sector.

- **Employment:** By 2050, renewable idustry can create up to 1 million more jobs than fossil fuels.

- **Heating and cooking:** By 2050, between 81% (2^0C) and 100% (1.5^0C) of Bangladesh's total heat demand can be satisfied by renewables.

- **Climate change:** An increased share of renewables will lead to CO_2 emissions of up to 123 million tons, as compared to 400 million tons under the reference projections. A full decarbonisation of all sectors is possible with increased import shares of renewable electricity and fuels.

Introduction

Access to energy is the perquisite for development and for a life in dignity: It is essential to overall human progress, social welfare, technological and social innovations and human rights. The United Nations Decade of Sustainable Energy for All (2014-2024) emphasises this necessity. The SDGs (Sustainable Development Goals) cannot be achieved by 2030 without a rapid progress on SDG7 – Ensure access to affordable, reliable, sustainable and modern energy for all.

The connection of energy, development and welfare is anchored in Bangladesh's Vision 2021: "Providing energy security and development and welfare"[1], in order to become a poverty-free, middle-income country. The sustained economic expansion in Bangladesh through an increasingly developed industrial sector thus has implications for the electricity sector, both in regard to overall energy demand – heating and electricity – as well as for higher electric loads which require infrastructural changes. At the same time, 15% of households in Bangladesh lack complete access to electricity, according to the most recent data published by Bangladesh Bureau of Statistics (BBS). This percentage varies significantly between urban households (94.1 per cent) and rural households (68.5 per cent)[2].

Renewables can tackle both the challenges of economic expansion and reliable energy access. Yet, the latest Power System Management Plan (PSMP 2016) largely ignores locally available energy resources. Further, a detailed analysis of Bangladesh's renewable energy potential is still lacking and the potential to tap into Bangladesh's solar PV resources and high off-shore wind potential are left untouched. The challenge is thus to expand local energy supply, to keep energy prices on a low level, to increase energy efficiency, to build necessary infrastructure and to decarbonise the energy sector to avoid catastrophic climate change. Times are changing however, the prices for renewables – in particular solar PV and wind – are decreasing annually and have become an economic alternative to building new gas power plants. In Bangladesh, electric rickshaws are on the rise and heating is increasingly electrified as well. It is therefore important, that any energy strategy takes an integrated approach across heat, mobility and electricity/stationary power.

Which kind of energy system can tackle all those challenges and utilise the strength of renewables? This study "100% Renewable energy for Bangladesh – Access to renewable energy for all within one generation" suggests that a shift towards 100% renewable energy is able to provide sufficient energy for all at lowest possible costs with no carbon emissions. The study, undertaken in 2018 by the University of Technology Sydney, the Coastal Development Partnership Bangladesh, Bread for the World and the World Future Council, addresses the gaps of the current energy framework in Bangladesh and complements efforts to map and analyse renewable energy potentials. It compares two renewable energy pathways with a business as usual pathway and is thus able to show several advantages of renewable energy over a fossil pathway. This document summarises this study's main findings and highlights action areas and policy recommendations to support Bangladesh to embark on a just transition towards 100% renewable energy. The full study is available at: https://www.worldfuturecouncil.org/wp-content/uploads/2019/08/100RE-in-Bangladesh_Final-Report.pdf.

[1] https://bangladesh.gov.bd/sites/default/files/files/bangladesh.gov.bd/page/6dca6a2a_9857_4656_bce6_139584b7f160/Perspective-Plan-of-Bangladesh.pdf

[2] http://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/a1d32f13_8553_44f1_92e6_8ff80a4ff82e/Bangladesh%20%20Statistics-2017.pdf

Scope of the Study and Methodology

The objective of the study is to showcase that a transition towards 100% renewable energy is feasible in Bangladesh, that it can supply sufficient energy at achievable cost levels for all and to understand implications for development ambitions of different pathways.

The study aims to support implementation of 100% renewable energy with a view on accelerating sustainable development. More specifically, it aims to establish pathways to:

- Provide universal access to renewable energy;
- Fully decarbonise Bangladesh's economy;
- Boost socio-economic development and reducing inequalities;
- Reach universal access to electricity and clean cooking solutions by 2030.

To embark on such a pathway, the Coastal Development Partnership, Bread for the World, the World Future Council and the University of Technology Sydney analysed

1) the technical RE potential of Bangladesh under space constrained conditions;
2) the country's future energy demand given universal energy access; and
3) optimal RE deployment pathways to achieve 100% renewables by 2030, 2040 and 2050.

The study focuses on final energy demand (a measure of the energy that is delivered to energy end users in the economy for day-to-day energy requirements) as well as primary energy consumption (direct energy use at the source, or supply to users without transformation) to develop future energy scenarios for Bangladesh. The study was careful that the scenario development should not harm food security or threaten food production in Bangladesh. This study specifically looks at possibilities to increase energy access for all citizens to 100 percent by 2030.

The study models two scenarios for RE uptake which would lead to a 2.0°C increase and one for 1.5°C. The 2.0°C scenario is designed to meet Bangladesh's energy-related targets to achieve 100% renewable electricity as soon as possible. This scenario includes significant efforts to fully exploit the extensive potential for energy efficiency available through current best-practice technology.

The RENEWABLES 1.5°C scenario takes a more ambitious approach. The scenario is designed to indicate the efforts and actions required to achieve the ambitious objective of a 100% renewable energy system and to illustrate the options available to change energy supply system into one that is truly sustainable. Both the Renewables 2.0°C and the Renewables 1.5°C scenarios are built on a framework of targets and assumptions that strongly influence the development of individual technological and structural pathways for each sector.

Energy scenarios can give answers to some of questions such as policy pathways, necessary investments, cost projections, economic benefits and required infrastructure. It is however, by no means a prognosis of what will happen, but an "if-then" analysis that provides decision-makers with an indication of how they can shape the future energy system. Scenarios cannot give definitive answers to how the future energy system could look like, because all scenarios are based on a set of assumptions for GDP growth, population increase, renewables industry growth, fossil fuel phase-out, industry sector development and technological advancements. Some of these assumptions, e.g. population increase, are taken from official reviews such as the World Population Review 61. GDP growth assumptions are based on Bangladesh's PSMP respectively.

The Institute for Sustainable Futures at the University of Technology Sydney has developed the [R]E24/7 energy access pathway methodology to develop future energy situation models for Bangladesh.The [R]E24/7 model is a bottom-up integrated energy balance model and particularly good at supporting policy makers and analysts to understand the relationships between different energy demand types in an economy, over a longer time period of 30-40 years. The long-term modelling approach used in this research is the development of target-orientated scenarios. A target is set, and technical scenarios are developed to meet this target and then compared to a reference case (BAU). The scenarios are based on detailed input data sets that consider renewable and fossil fuel energy potential via GIS analysis, energy demand, and specific parameters for power, heat and fuel generation in the energy systems. In addition, the scenarios calculate job growth, GHG emissions, and growth in various industrial sectors. The reference case (BAU) is based upon the PSMP and the Bangladesh Policy Road Map for Renewable Energy. Whereas the calculation for the renewables 1.5°C and 2.0°C scenarios are modelled according to input from stakeholders, government papers and international mapping tools.

The entire modelling uses four modules:

I. GIS analysis:

(a) for a regional analysis in regard to population, renewable energy resources and infrastructure

(b) to define the cluster break down

II. Long-term energy scenario:

(a) for a long-term energy development pathway

(b) to develop detailed national energy plans including cost- and carbon emissions analysis

III. Demand and load curve projection:

(a) for detailed demand development analysis

(b) to develop hourly load profiles for full years (8760 hours)

IV. Hourly cluster analysis for one year:

(a) for detailed supply analysis

(b) to develop detailed regional energy access and/or energy development plans

Study Findings

Bangladesh – Energy Pathway Until 2050

The study highlights that a decentralised energy system can achieve 100% energy access for all within one generation in Bangladesh. And increasing consumer electricity prices in Bangladesh could provide an opportunity for RE sources to compete with conventional energy sources. What's more, Bangladesh has the technical possibilities to implement new innovative technologies such as floating RE installations and to reduce its future dependence on energy imports significantly.

Electricity will become the major renewable 'primary' energy by 2050, not only for the direct use for various purposes, but also for the generation of synthetic fuels for fossil fuel substitution. Electricity demand in 2050 will increase up to 400 TWh/a for the 1.5°C pathway due to electrification of mainly the transport and heating sectors.[5] A 100% electricity supply from renewables in the 1.5°C scenario leads to around 200 GW installed capacity in 2050.

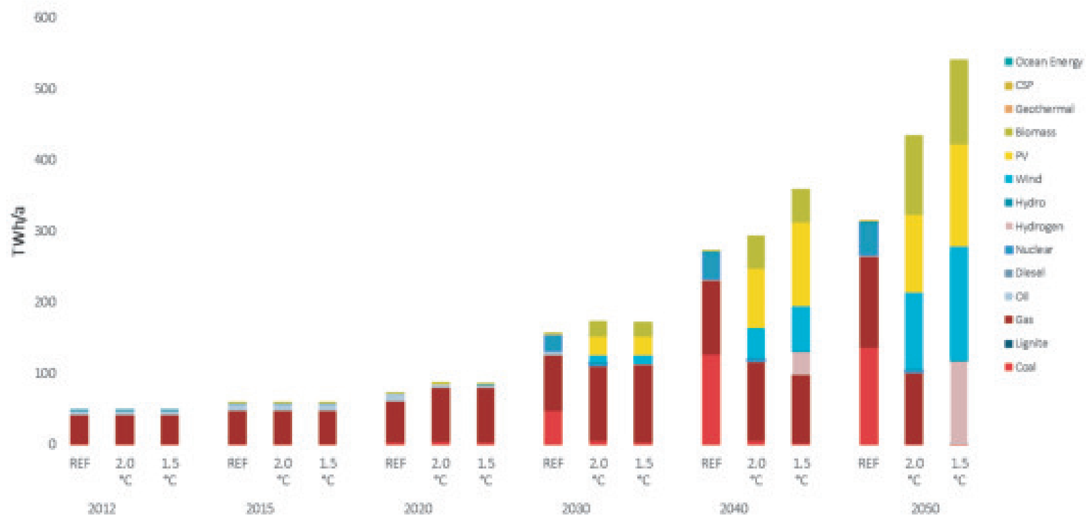
In the 2.0°C scenario, 76% of the electricity produced in Bangladesh would come from renewable energy sources by 2050. 'New' renewables – mainly wind and solar photovoltaic electricity – will contribute 56% to the total electricity generation in this scenario. While the renewable electricity generation in 2020, is as low as 2%, by 2030 the contribution of renewables will increase 33%. The installed capacity of renewables will reach about 30 GW in 2030 and 150 GW by 2050. The 1.5^{0}C scenario results in a complete substitution of the remaining gas consumption by hydrogen generated from renewable electricity. Wind power (on- and offshore) and solar photovoltaic would be to be the main pillars of future power supply in both renewables' scenarios, complemented by contributions from bioenergy and gas power plants (fuelled with synthetic-fuels/hydrogen after 2040. In both renewable scenarios, a massive growth of thermal solar collectors and a growing share of geothermal and environmental heat as well as heat from renewable hydrogen can further reduce the dependence on fossil fuels.

By 2050, electricity could provide 40% of the transport sector's total energy demand in the 1.5°C scenario. Bio- and other synthetic fuels generated using renewable electricity are complementary options to further increase the renewable share in the transport sector. However, due to the limited renewable electricity generation potential within the country, the use of hydrogen for transport is limited to imported fuels.

A full decarbonisation of all sectors seems possible with increased import shares of renewable electricity and fuels. The 1.5°C scenario results in a complete substitution of the remaining gas consumption by hydrogen generated from renewable electricity. Both RENEWABLE scenarios use Bangladesh's renewable energy resources to the maximum in order to reduce energy imports dependence and to utilize local resources. Since renewable synthetic fuels require (gas) pipeline infrastructure, this technology is not widely applied for Bangladesh's energy access plan due to relatively high costs in the early development stages. It is assumed that synthetic fuels and hydrogen will not enter Bangladesh's energy system before 2040. After 2045, the dispatchable conventional gas power plants will be converted to operate on hydrogen and / or synthetic fuels to avoid stranded investments and also to move the country towards decarbonized power system.

[5] Heating includes industrial process heat and cooking for the residential sector

Figure 1: Breakdown of electricity generation by technology



Renewable Energy Potentials

The study shows that by 2050, up to 100% of electricity produced in Bangladesh can come from renewable energy sources. This would be in compliance with the Paris Agreement's 1.5˚C limit. The installed capacity of renewables would then reach 200GW in 2050 (see Table 1), solar PV and wind sources would contribute the bulk share. The annual installation rates for solar PV installations must increase to around 5 GW between 2025 and 2035 and further increase to around 10 GW per year until 2050.

An increased share of renewables in the energy mix will require flexibility mechanisms. Smart grids, demand side management (DSM), energy storage capacities and other options need to be expanded to increase the flexibility of the power system for grid integration, load balancing and a secure supply of electricity.

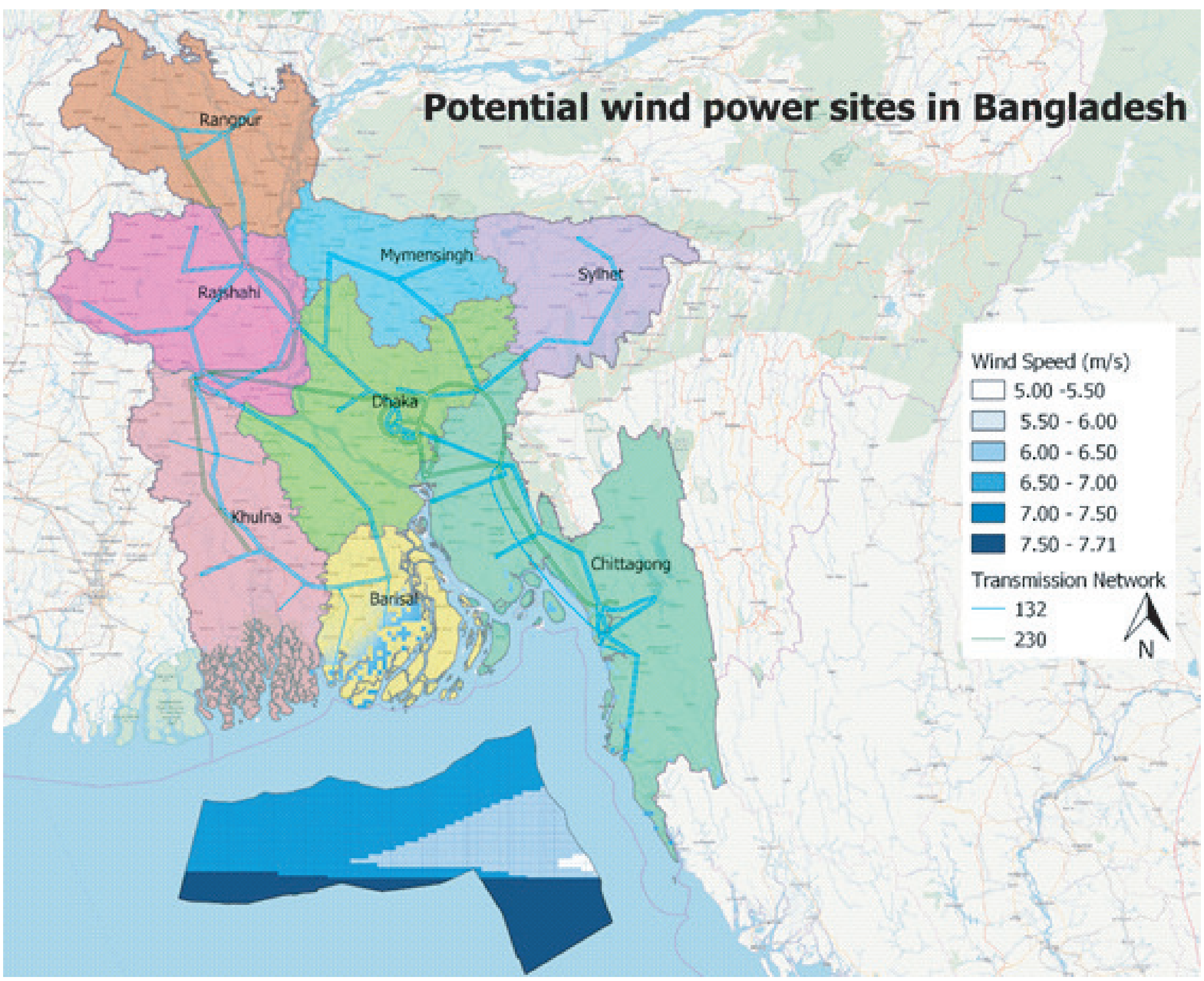
Table 1: Renewable energy potential – results from QGIS mapping

Resource	Maximum installable generation capacity [GW]	Maximum recoverable electricity [TWh/year]	1.5ºC in 2050: installed capacity [GW]	1.5ºC in 2050: generation [TWh/year]
Wind – onshore	16	55	10	27
Wind – offshore	134	525	36	133
Wind - total	150	580	46	160
Solar Photovoltaics – roof top	35	40	35	34
Solar Photovoltaics – utility scale	156	177	155	177
Of which is floating PV	31	35	30	35
Solar Photovoltaic - total	191	217	190	211
Total	341	797	236	371

Table 2: Bangladesh: Required areas for three types of renewable energy technologies under the most ambitious 1.5^{0}C scenario.

Technology		Unit	2020	2030	2040	2050	Percentage of landmass of Bangladesh (for 2050)
PV	Total installed capacity	GW	0.4	23.1	104.2	126.7	0.5%
	Specific nominal capacity	kW/m^2	0.15	0.16	0.17	0.17	
	Area	km^2	3	144	613	745	
Wind onshore	Total installed capacity	GW	0	0.9	3.7	9.6	1%
	Average capacity	MW	3.00	3.50	5.00	7.00	
	Number of plants	#	0	257	740	1,371	
	Specific nominal capacity	MW/km^2	4	5	5	7	
	Area	km^2	0	180	740	1,371	
Wind offshore	Total installed capacity	GW	0	2.5	14.4	36.3	2.5%
	Average capacity	MW	6.00	7.50	8.50	9.00	
	Number of plants	#	0	333	1,694	4,033	
	Specific nominal capacity	MW/km^2	7	8	9	10	
	Area	km^2	0	313	1,600	3,630	

Figure 2: Potential wind sites in Bangladesh

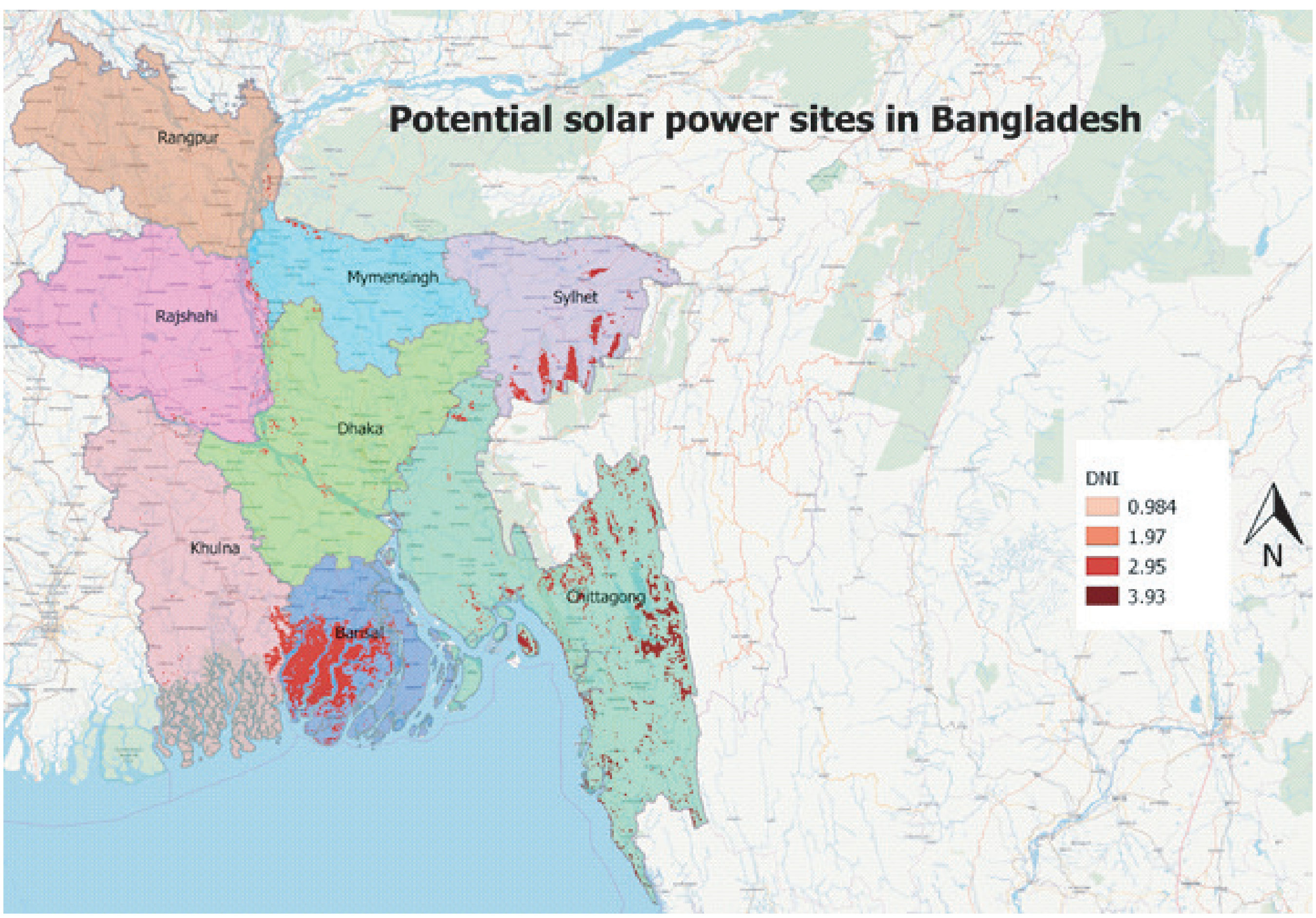


Wind

Bangladesh has 134GW off-shore wind potential within 50 to 120km off the coast. This is being complemented by around 16GW of on-shore wind potential, mostly located in the coastal areas of Khulna, Barisal and Chittagong. Wind resources can significantly reduce Bangladesh's reliance on energy imports and foster energy sovereignty. Further research is required to locate the exact offshore wind areas both in regard to the available wind resource as well as the offshore wind power grid capacities. Further research is also required to build up of off-shore wind industry so that the declining offshore gas sector can benefit from increased offshore wind deployment as workers and parts of the infrastructure can be re-used (e.g. ships, supply equipment).

Wind speed at a height of 80 meters was used to determine the electricity generation potential. Wind speeds are categorised and mapped within the range of 6 to 12 metres per second to gain an understanding of the potential of generation across the country. Wind speeds under 6 metres per second are ignored in order to plot optimal sites, as they are too inefficient for electricity generation. To date, Bangladesh has only 2.9MW onshore wind turbines installed with recent plans to develop additional 150MW in three locations.

Figure 3: Solar energy generation potential in Bangladesh



Solar

Bangladesh can install up to 156GW of utility scale solar photovoltaic power (see Table 1). By 2050, around 20% of these (31 GW) will come from the floating solar PV installations. Therefore, more R&D is required into floating solar, in particularly in regions prone to flooding and rivers with changing currents. In order to use Bangladesh's utility scale solar photovoltaic as efficient as possible, further research is required in regard to the breakdown the utility scale photovoltaic potential into ground mounted solar PV, agricultural solar PV and floating solar PV.

Currently, total capacity of all installed systems in Bangladesh adds up to 326 MW (PV-M 2019)[6], with around 5 million off grid solar home systems (SHS) in place. Although the potential for solar home systems is not considered in the 100% RE pathway, the study has identified that solar roof-tops have potential up to 35 GW power (Table 1).

Biomass

Bangladesh has a bio energy potential of 285 MW with an annual generation of 1,840 GWh/a which seems extremely conservative. The total bio energy potential for Bangladesh is estimated with 1,500 PJ/a (under 2.0^{O}C scenario) and 2,100 PJ/a (under 1.5^{O}C scenario).

Table 3: Bangladesh – Bio energy potential

Technology	Resource	Capacity [MW]	Annual Generat on [GWh/a]
Biomass	Rice husk	275	1800
Biogas	Animal waste	10	40

Hydropower

Until 2020 hydro will remain the main renewable power source and will be taken over by wind and solar afterwards in both Renewable scenarios. The only existing hydropower plants in Bangladesh are the 230 MW Kaptai Hydropower Plant and a 10 kW Micro-hydropower plant in Bamerchara. The capacity of large hydropower remains flat in Bangladesh over the entire scenario period, due to concerns about flooding and land use.

Hydrogen and synthetic-fuels

Hydrogen and synthetic-fuels are the main pillar for transport fuels after 2030 in both renewable scenarios, replacing natural gas. Renewable hydrogen and synthetic fuels will play an increasing role in the transport sector, where battery-supported electric vehicles reach their limitations and where limited biomass potential restricts the extension of biofuel use. However, future hydrogen applications may not be sufficient to replace all fossil fuel demand, especially in aviation, heavy duty vehicles and navigation.

[6]PV-M 2019, PV-Magazine, Bangladesh to complete 7.4 MW of solar capacity in April, Syful Islam, 20th March 2019; https://www.pv-magazine.com/2019/03/20/bangladesh-to-complete-7-4-mw-of-solar-capacity-in-april/

Technical and financial requirements

Infrastructure

To facilitate the transition towards renewables as efficient as possible and harvest offshore wind and solar resources, power grids need to be able to transport large loads from the coast further north inland. Offshore wind will require transmission lines to the load centres of Bangladesh. Some parts of the gas infrastructure could be refitted to transport offshore energy into the load centres. In addition, decentralised distribution systems, to connect residential sectors will become important in the renewable scenarios.

The fast interconnection of micro and mini grids with regional distribution networks, storage and other load balancing capacities is also important. Other infrastructure requirements include the increasing role of on-site renewable process heat generation for industries and mining and the generation and distribution of synthetic fuels. Smart grids and efficient demand side management measures as well as storage would play an important role for flexible grid integration and load balancing, in order to assure secure supply of energy. Possible additional costs for grid expansion are not calculated as this was out of scope of this analysis.

Storage

Storage requirements stay within 10% of maximum curtailment targets, the study therefore highlights that 100% renewable energy is possible without extensive storage capacities. In fact, the study does not foresee any role for storage before 2030. After 2030, storage technologies would increasingly be used in combination with variable renewables as battery costs decline.

Table 4: Bangladesh: storage and dispatch service requirements

Storage and Dispatch		2.0^{0}C		15^{0}C	
Bangladesh		Required to avoid curtailment [GWh/a]	Ut lizat on Bat ery -through-put- [GWh/a]	Required to avoid curtailment [GWh/a]	Ut lizat on Bat ery -through-put- [GWh/a]
Rangpur	2020	0	0	0	0
	2030	0	0	0	0
	2050	982	6	3,079	793
Rajshahi	2020	0	0	0	0
	2030	24	11	16	0
	2050	2,679	1,017	6,225	1178
Mymensingh	2020	0	0	0	0
	2030	0	0	0	0
	2050	180	232	1,300	514
Dhaka	2020	0	0	0	0
	2030	1	1	0	0
	2050	1,499	1,486	7,534	2576
Khulna	2020	0	0	0	0
	2030	104	23	26	0
	2050	10,223	702	8,140	820
Barisal	2020	0	0	0	0
	2030	259	17	56	0
	2050	15,642	241	6,068	308
Chit agong	2020	0	0	0	0
	2030	12	0	4	0
	2050	6,511	1,446	10,770	1746
Sylhet	2020	0	0	0	0
	2030	3	2	1	0
	2050	941	463	2,531	562
Total	2020	0	0	0	0
	2030	403	55	104	1
	2050	38,657	5,593	45,647	8497

To reduce the storage demand though, further research to specify locations of utility scale floating solar PV is required, in order to optimise distribution and reduce storage demand. In addition, further research is required into floating storage devices to avoid battery damage in flooding situations.

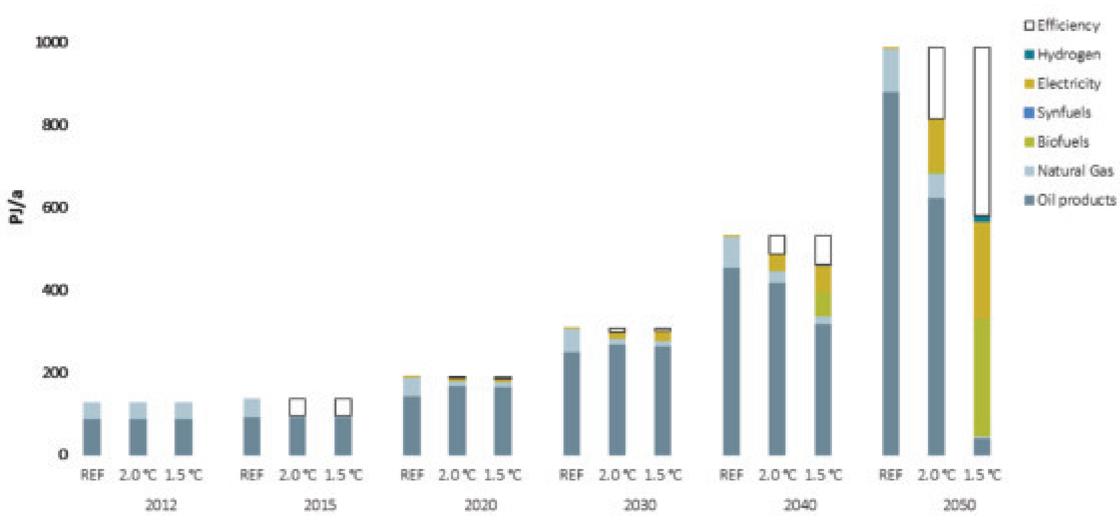
Transport

The study foresees that by 2050 up to 40% of the transport sector will be electrified. Bio- and syn-fuels will complement the increasing renewable energy share in the transport sector. Under the 1.5°C scenario, the use of electric rickshaws and try-cycles increases significantly, making them one of the backbones of the road transport systems. Bangladesh has among the highest densities of rickshaws in Asia – about 2 million. This is an immense opportunity to become a role model for countries relying on similar modes of transport. In addition, all urban regions will shift the transport system to a high degree towards efficient rail, light rail and buses. Given the limited supply of sustainable biofuels, their use for the transport sector is limited (see Table 3).

Table 5: Projection of transport energy demand by mode

in PJ/a		2015	2020	2030	2040	2050
Rail	REF	12	12	13	13	14
	2.0 °C	12	13	13	13	13
	1.5 °C	12	13	26	45	67
Road	REF	103	135	247	463	909
	2.0 °C	99	131	236	419	737
	1.5 °C	99	129	226	363	441
Domestic navigation	REF	17	17	20	24	30
	2.0 °C	16	17	20	24	30
	1.5 °C	16	17	20	24	30
Total	REF	132	165	280	501	952
	2.0 °C	127	161	270	456	780
	1.5 °C	127	159	272	432	538

Figure 4: Final energy consumption transport under the scenarios



Due to population increase and higher living standards, energy demand from the transport sector is expected to increase (see Figure 4). Yet, efficiency savings in the transport sector will curtail this trend to some extent. These efficiency measures, together with additional modal shifts and technology switches will lead to energy savings of up to 41% (410 P J/a) in 2050, compared to the BAU scenario.

Investments

Additional investments (In addition to the current government investment plan of US$ 170 billion by 2041,under the PSMP 2016) between US$ 80 billion (2.0°C scenario) and US$ 140 billion (1.5°C) until 2050 are required to transition towards a 100% RE system. Fuel cost savings in the RE scenarios (RE has no fuel costs) will reach up to US$ 140 billion (2.0°C) and US$ 200 billion (1.5°C). Higher investment needs are overcompensated by fuel cost savings. In short, while renewables produce energy for free after the first decades, fossil fuel plants incur continuous fuel costs and will thus continue to be a burden on the economy.

The electrification of the heating sector will require major revisions of the current investment strategies. Solar thermal, geothermal and heat pump technologies will need an enormous increase in installations, if their potential is to be tapped for the heating sector. Given the wide range of technologies available, the study can only roughly estimate that around US$ 7-8 billion needs to be invested annually up to 2050.

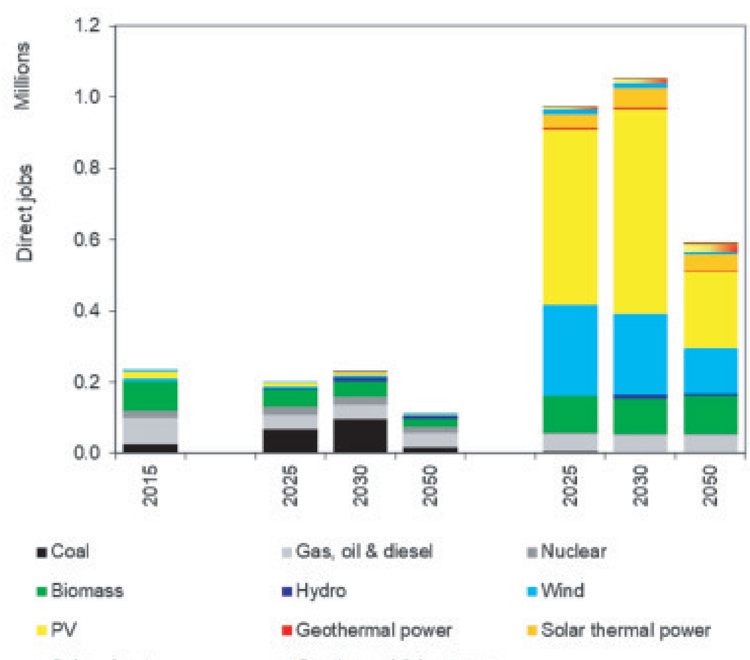
Implications for Agenda 2030/Sustainable development

Ensure access to affordable, reliable, sustainable and modern energy for all

Electricity will become the major renewable 'primary' energy by 2050. A 100% electricity supply from renewables in the 1.5°C scenario leads to around 200 GW installed capacity in 2050. The installed capacity of renewables will reach about 30 GW in 2030 which will ensure access to energy for all the remaining non-electrified households by 2030.

Poverty eradication through employment generation

Figure 5: Employment development under the RENEWABLES scenarios and REFERENCE scenario



The study shows that by 2050 the RE industry will create 1.1 million jobs while the BAU scenario will result in a mere 0.1 million jobs. Figure 5 shows that jobs in the BAU scenario will drop -7% below 2015 levels by 2020 and then remain at a low level. Strong growth in the RE sector on the other hand increases total energy sector jobs by 268% by 2020. The greatest share of jobs will be created in the solar sector.

Table 6: Bangladesh's total employment (thousand jobs) in the REFERENCE and 2.0°C scenarios

Bangladesh			5.0°C (Reference-PSMP 2016)				2.0°C		
Thousand jobs	2015		2025	2030	2050		2025	2030	2050
Coal	27		69	97	18		6	4	3
Gas, oil & diesel	73		37	39	38		49	47	49
Nuclear	20		23	24	16		2	2	1
Renewable	114		69	70	39		916	1,000	539
Total jobs	234		199	230	111		972	1,052	593
Construction and installation	53		55	77	5		167	230	89
Manufacturing	66		39	50	10		648	650	292
Operations and maintenance	14		23	25	32		45	69	137
Fuel supply (domestic)	101		82	77	64		112	104	46
Coal and gas export	-		-	-	-		-	-	-
Total jobs (thousands)	234		199	230	111		972	1,052	593

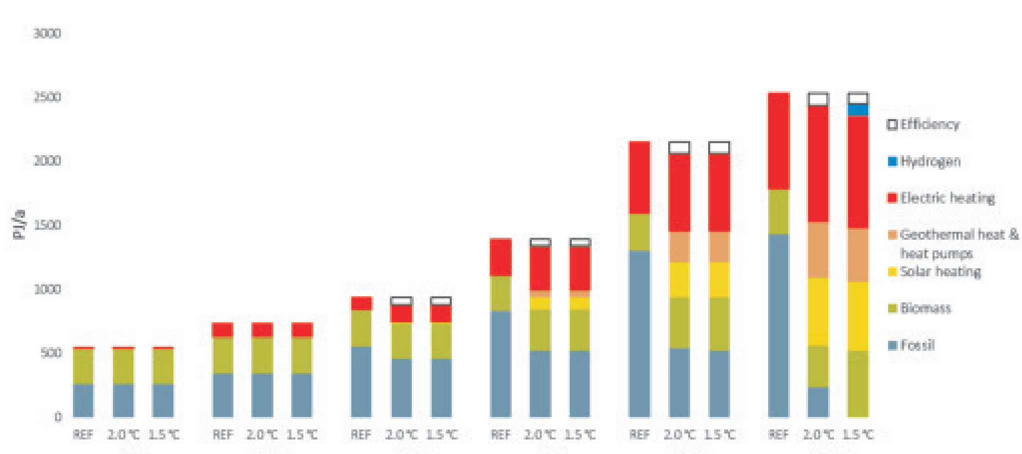
Zero Hunger

An increase in renewable energy would mean increasing its productive uses as well. Solar irrigation and solar pump projects are already being implemented in some areas of Bangladesh to maintain food security. In addition, renewables can shorten the drying periods for crops which allows storage for a longer time period.

Good health and well-being

The heating sector can be electrified almost solely with renewable power by 2050, according to the study. By 2040, the share of fossil fuels can drastically be reduced. To do so however, dedicated support instruments are required to ensure a dynamic development in particular for renewable technologies for building and renewable process heat production. Energy efficiency improvements will likewise play a crucial role and can help to reduce the currently growing energy demand for heating by 4% in 2050. By doing so, Bangladesh can significantly reduce the risks associated with indoor pollution.

Figure 6: Projection of heat supply by energy carrier (REF, 2.0⁰C and 1.5⁰C)

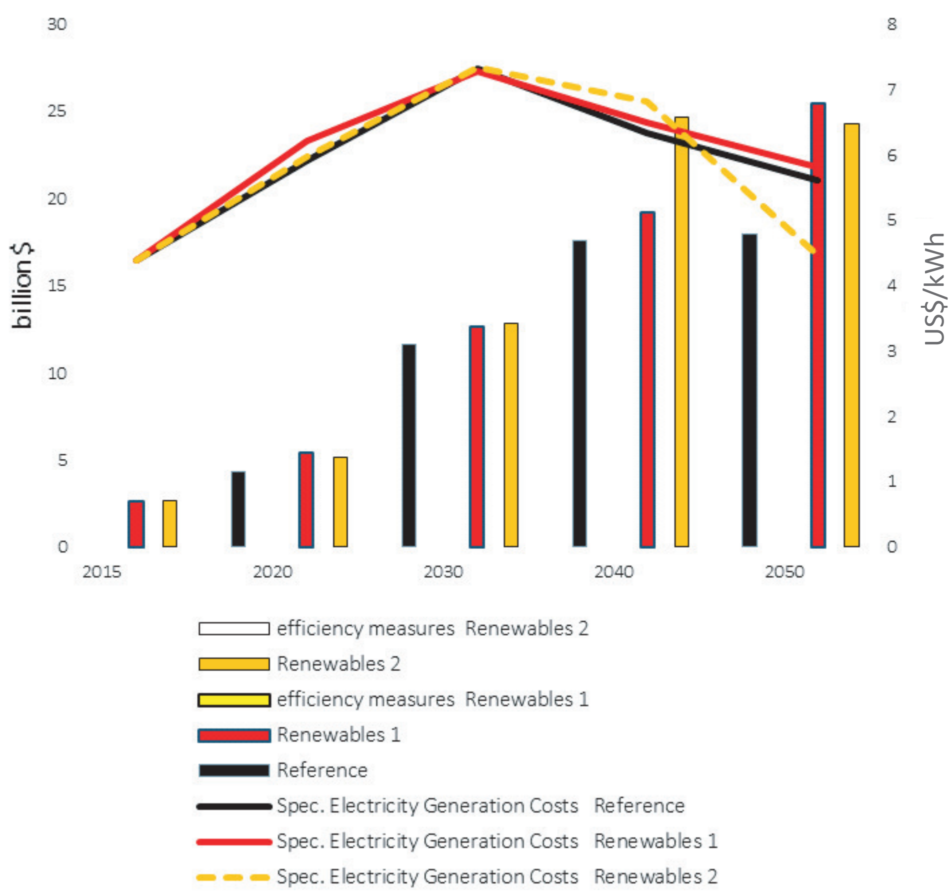


Gender equality

The successful installation of more than 4 million solar home systems have already benefitted 24 million people living in Bangladesh's rural regions. A decentralised RE system can foster gender equality by freeing free up time for women by giving them the means to spend their time – which is otherwise used to collect fuelwood – for income generation in different ways. This is especially important, as the participation of women in economic activities is limited in Bangladesh – only around 34% are part as the labour force.

Low-cost energy for all

Figure 7: Development of total electricity supply costs and of specific electricity generation costs in the scenarios – with no carbon costs

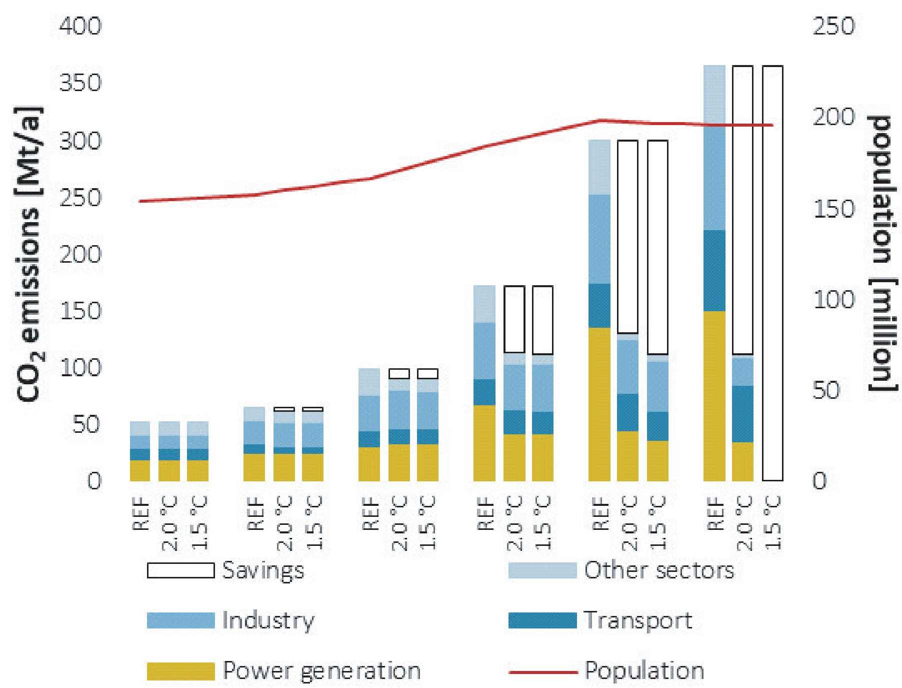


While the future costs of electricity generation from renewables will lead to a slight increase in prices over the next 10 years, it will lead to lower costs afterwards. Eventually, renewable energy sources would go on to produce electricity without any further fuel costs beyond 2050, while costs for coal and gas will continue to be a burden on the national economy. It is important to point out that the difference in full cost of generation will be less than 0.3 – 0.5 US$ cent/kWh. This estimation excludes costs for storage. Furthermore, renewable energy based scenarios contribute to the local economy as the money spend for electricity generation remains in the country and will not be spend on imported fuels.

Combat Climate Change and its Impacts

A full decarbonisation of all sectors seems possible with increased import shares of renewable electricity and fuels. Transitioning to 100% RE will drastically reduce the rate of CO_2 emissions. A transition with 2.0°C pathway would result in a moderate increase of about 123 million tons CO2/e, compared to 4000 million tons in the BAU scenario (see Figure 8). The 1.5°C pathway will go as far as to fully decarbonise the electricity sector. The largest share of emissions will in that case come from the transport and industry sector.

Figure 8: Development of CO_2 emissions by sector under the RENEWABLES scenarios ('Efficiency' = reduction compared to the REFERENCE scenario)



Policy recommendations

Set a Long-term 100%RE target and embed it across policy areas and SDG processes

A long-term 100%RE target with supporting RE policies needs to be set for the deployment of renewable power generation. To facilitate long-term investment certainty, instruments such as feed-in-tariffs or power purchase agreements are necessary.

The transition to 100%RE influences living standards, can boost rural economic development, increase participation of women in economic and social processes, generates jobs and supports agricultural productivity. Therefore, RE policies should be integrated in other areas such as social and economic welfare, industry development, employment, innovation and health. To do so, cross-sectoral approaches to policy-making need to be supported and RE policies streamlined in national development plans. A silo approach to policy-making can significantly reduce the potential co-benefits of RE development.

Accelerate development of wind and PV sources

Bangladesh has an estimated potential of 150 gigawatt of off- and on-shore wind. The potential for offshore wind is significantly higher (134 GW) than for onshore wind (16GW). In addition, Bangladesh has roughly 191 GW of solar photovoltaic generation capacity (including rooftop PV), of which 156 GW are utility scale solar farms, including 31GW floating PV installations. To reach 100% electricity supply from renewables, and be in line with the Paris Agreement and achieve the SDGs, around 200 GW of generation capacity will have to be added by 2050. Especially crucial is accelerated development of wind and PV sources between 2020 and 2030, in order to be in line with development targets stipulated by both Agenda 2030 and national development plans to achieve universal access to electricity and clean cooking.

Promote bottom-up electrification model using the existing Solar Home Systems (SHS)

Solar home systems (SHS) provide enough electricity to power bright efficient LED lights, radios, mobile phones, TVs, DC fridges and a variety of further household and consumer appliances. The potential capacity for further SHS installations is not counted for 100% RE scenario development. However, the study recommends to use the existing SHS to develop bottom-up electrification model. The bottom-up electrification model will take up the challenge of increased local generation and develop new business models that focus on energy services, rather than just on selling kilowatt-hours. In this model, community owned renewable power projects will play a significant role in the expansion of renewables. Currently SHS development is not coordinated with the national grid expansion plans of the Bangladesh government. It is important for Bangladesh to develop a technical and economic concept along with a real test case, to interconnect SHS to a micro grid in a first step and, in a second step, several micro grids to a distribution power grid, equal to those in industrialized countries. As a third and final step, distribution grids will be interconnected to a transmission grid.

Research and promote creative uses of innovative RE technologies

Bangladesh has the unique opportunity and technical possibilities to become a leader in the creative use of innovative Renewable Energy technologies and reduce its dependence on future energy imports significantly. Due to its particular geography and closeness to the sea, and its large offshore wind potential and solar potential in high-risk flood-prone areas, floating RE technologies and storage devices are especially well suited for use in Bangladesh. Up to 31GW of floating PV potential could be added to the country's energy mix. However, further research is required into floating solar in rivers with changing currents and tidal waters, and standardized floating devices as well as floating storage devices to avoid battery damage. The integrated floating solar homes could increase the housing area in flood-prone, coastal areas and would also be suitable for rivers.

Electrify the transport sector

Due to population increase, GDP growth and higher living standards, energy demand from the transport sector will increase. A key target for Bangladesh has to be to electrify the transport sector with local available and accepted technologies. The country has among the highest densities of rickshaws in Asia – about 2 million drive on the streets of Bangladesh. A majority of which is already in the process of electrification. Electric rickshaws and try-cycles, together with light rail and electric vehicles would become the backbone of the transport system in 2050. It is noteworthy that a faster electrification rate of the transport sector and stronger deployment of renewables would result in stronger energy demand reductions. Given that Bangladesh has only a limited supply of sustainable

biofuels and thus limited use, electrification of the transport system will be the best option to de-congest roads while utilising the electrification process which has started with rickshaws already

Prioritize Energy Efficiency measures across sectors

Without addressing energy efficiency simultaneously to renewable energy generation, Bangladesh will not be able to meet the 1.5°C limit. To achieve the stipulated reduction of CO_2 emissions, energy efficiency standards for electric applications, buildings and vehicles will need to be strengthened in order to maximize the cost-efficient use of renewable energy and double energy productivity by 2030. Establishing maximum standards for energy efficiency for electric appliances, electrification of transport, renovation of residential buildings, and implementation of "passive climatisation", Bangladesh can double energy productivity over the next 10 to 15 years. This equals a reduction in energy consumption by roughly 700PJ/a through efficiency gains. Efficiency improvements in the heating sector are even larger than in the electricity sector and can help to reduce the currently growing energy demand for heating by 4% in 2050 – a reduction of about 100PJ/a compared to the BAU scenario.

Prioritise infrastructure development for wind and solar energy

To achieve 100% renewable energy access, Bangladesh should prioritise development of the necessary RE infrastructure, also with a view of electrification of transport and heat. The use of smart grids and converting existing gas pipelines into renewable fuel pipelines would increase productivity and grid stability. Therefore, rapid implementation for infrastructure projects in all parts of Bangladesh as soon as possible, is recommended. Without long-term planning for infrastructure the power market of Bangladesh cannot function optimally.

To harvest Bangladesh's offshore wind and solar resources, the power grid needs to be able to transport large loads from the coast further north inland, while decentralized grids will have to shoulder a significant part of the residential sector. Offshore wind requires transmission lines to the load centres of Bangladesh. To do so, parts of the infrastructure of the declining offshore gas sector as well as workers could be re-utilised for wind infrastructure. In addition, interconnected district heating infrastructure within cities needs to be extended.

[7] https://www.worldfuturecouncil.org/wp-content/uploads/2019/05/Beyond-Fire_-How-to-achieve-electric-cooking.pdf

Enhance Renewable Energy in the Cooking Sector

The use of traditional and predominantly unsustainable biomass is still widely common for heat. The promotion of more efficient cook stoves remains an important interim solution, but is neither a truly-long-term nor sustainable solution to the challenge of cooking because much of the biomass used for cooking is harvested unsustainably and increases the rates of deforestation and soil loss. To achieve universal access to clean cooking solutions by 2030, phase out of unsustainable biomass for cooking and a direct leap from cook stoves to electrical cooking is necessary. A recent study[7] has shown that electric cooking can even be cheaper than what many households currently spend on firewood and charcoal, when high-efficiency appliances are used.

Enhance Renewable Energy in the industrial & residential heating system

Dedicated support instruments are required to ensure a dynamic development for renewable technologies for buildings and renewable process heat production. In the industry sector solar collectors, geothermal energy (incl. heat pumps) as well as electricity and hydrogen from renewable sources can increasingly substitute fossil fuel-fired systems. In the 2.0^{0}C scenario, renewables can provide 44% of Bangladesh's total heat demand in 2030 and 81% in 2050. The 1.5^{0}C scenario results in a complete substitution of the remaining gas consumption by hydrogen generated from renewable electricity. Nevertheless, solar thermal, geothermal and heat pump technologies need an enormous increase in installations if these potentials are to be tapped for the heating sector. Both renewable energy scenarios would require a major revision of current investment strategies in heating technologies.

Promote storage capacities

With the electrification of transport, storage capacities such as batteries will gain in importance. In addition, energy storage will increase the flexibility of the power system for grid integration, load balancing and a secure and stable supply of electricity. A long-term strategy to promote storage capacity should be developed.

Re-direct fossil fuel investments into innovative RE finance mechanisms

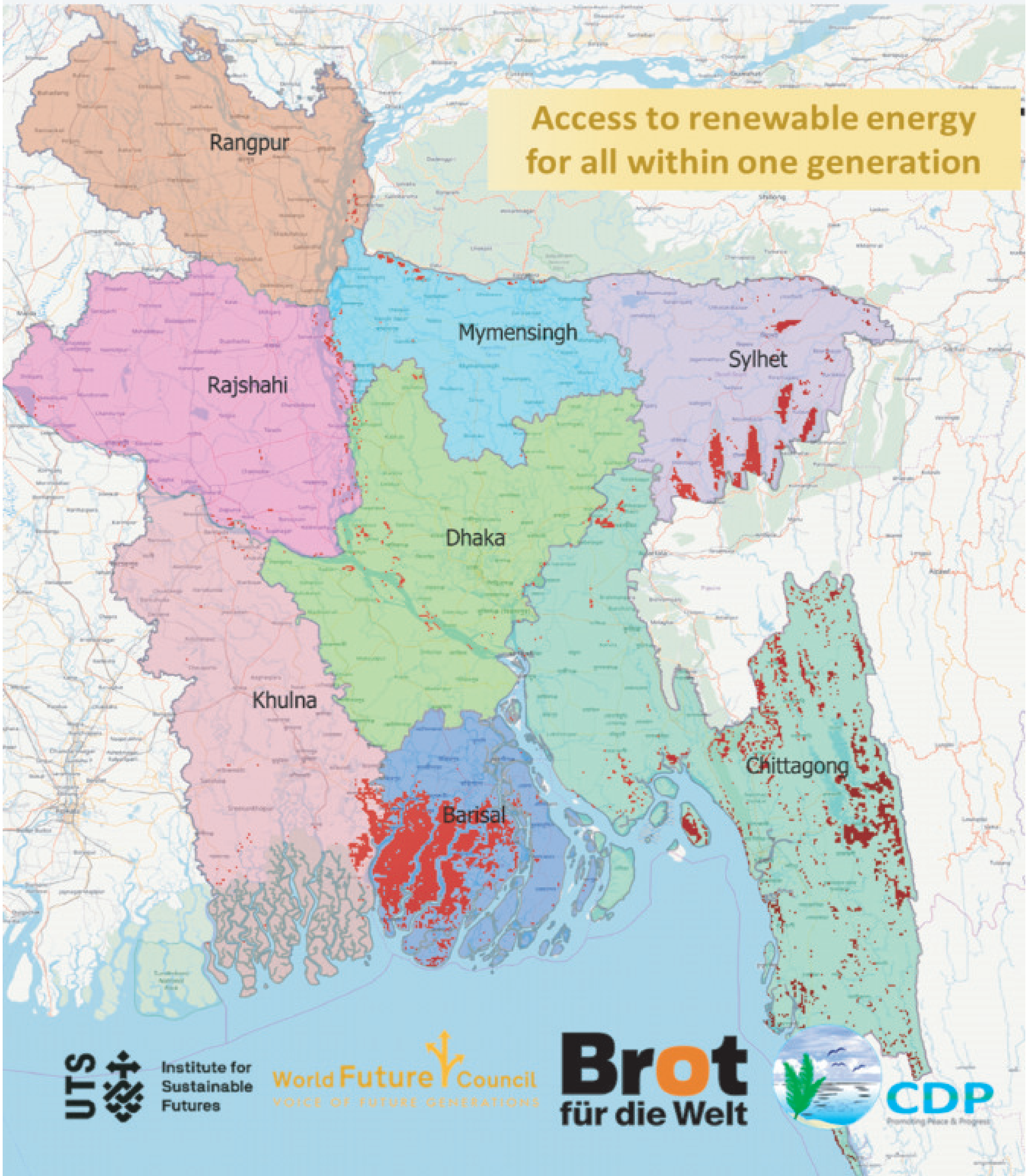
To meet the objectives of the Paris Agreement's 1.5°C limit, Bangladesh would need to invest up to US$310 billion until 2050, averaging US$ 8 billion per year. This would result in a slightly increased price for electricity generation over the next 10 years, but to lower costs afterwards, as renewables have no fuel costs. In fact, the additional investment of US$2.4 billion per year needed for renewables, compared to investments in the BAU case, could be covered 180% by fuel cost savings – adding up to US$3.7 – 5 billion/year in total. Coal and gas power plants on the other hand would continue to be a burden on Bangladesh's economy. And indeed, the cost balance is economically beneficial for increased RE deployment, compared to the BAU.

100% RE requires innovative finance mechanisms for distributed and stand-alone renewable energy systems, and research into state-of-the-art RE technologies (electric rickshaws and cars, light rail, floating solar homes etc.) and heating systems. The study recommends to involve the government-owned development financial institution IDCOL. IDCOL could make us of existing micro-credit models for SHS and adjust it towards to electric rickshaws and tri-cycles. Beyond that, IDCOL would be required to revise current investment strategies in heating technologies to shift away from traditional biomass. To harness the potential of solar thermal, geothermal and heat pump technologies roughly US$290 billion would be required up to 2050.

Set up capacity building programmes

To ensure a transition towards 100%RE, whilst maximising co-benefits, participation of the whole spectrum of stakeholders (civil society, government, communities, academia etc) is indispensable. The decentralised structure of RE based on SHS in Bangladesh requires a distributed and participatory system of operation made up of many small-scale initiatives. Therefore, civil society engagement is essential to ensure communities are actively involved in this transformational process – be it awareness raising, or technology maintenance training. Engagement of local actors and capacity building are thus crucial elements of a fair and effective transition to 100% RE in Bangladesh.

100% RENEWABLE ENERGY FOR BANGLADESH



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