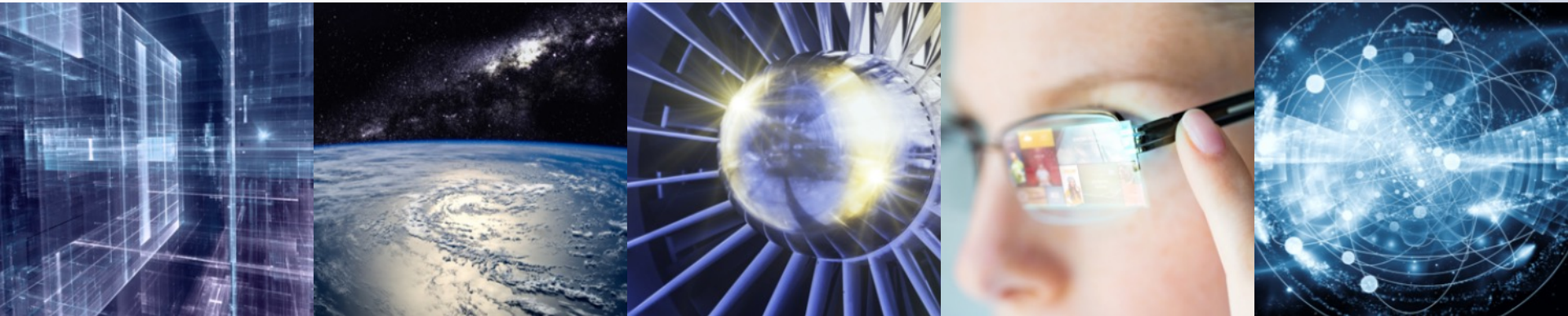




Technology's Role in Decarbonization in the Electric Power Sector

Keynote Speech, SENZE'25, Hail University, Saudi Arabia

Professor Saifur Rahman, IEEE Life Fellow

2023 IEEE President

Director, Virginia Tech Advanced Research Inst.

28 October 2025





PPT slides are available at
www.srahman.org

Date

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Saudi Arabia

Technology's Role in Decarbonization in the Electric Power Sector

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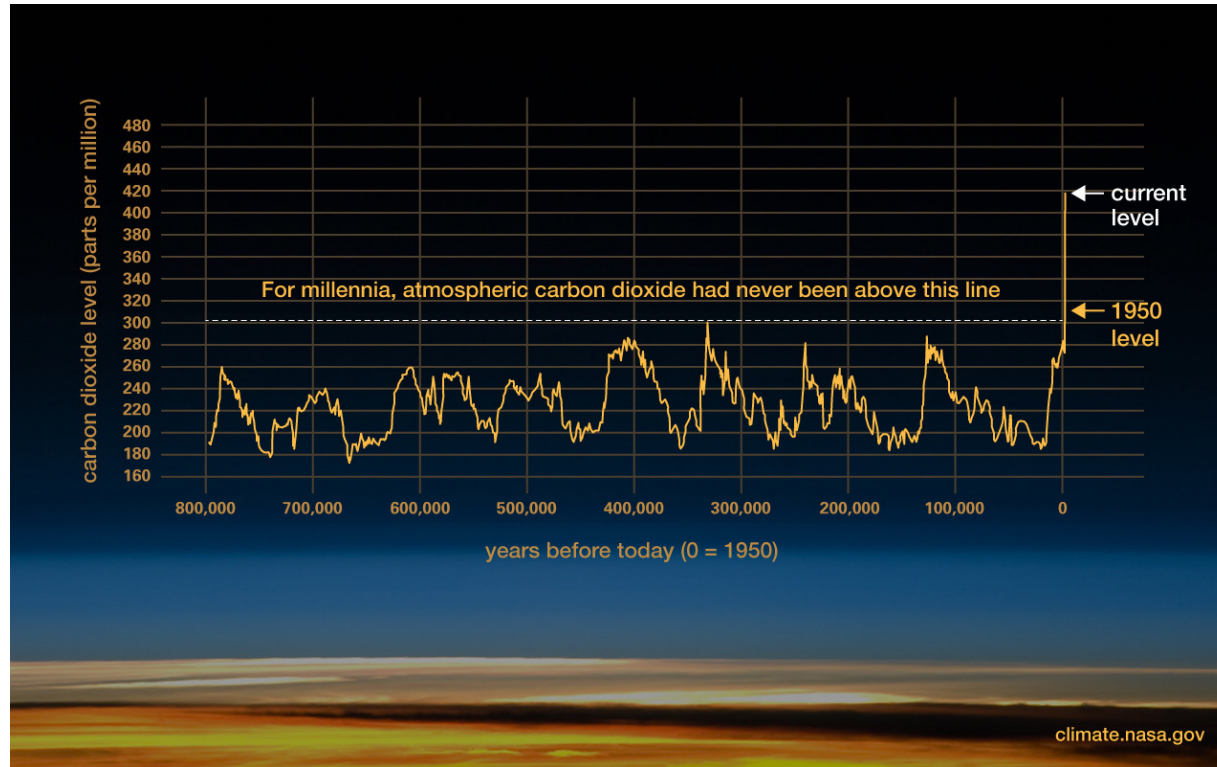
This lecture explains what carbonization is, addresses its causes and impacts. It then offers technological solutions to reduce CO2 emissions from the electric power sector which is responsible over 30% of global Carbon emissions. In order to address the reduction of carbon emissions from the electric power sector, a collaborative approach between the industrialized nation states and emerging economies is necessary. This will involve a portfolio of solutions with low-carbon generation from wind, solar, hydro and nuclear, storage, cross-border power transfer and advanced technology focusing on energy efficiency. This talk also discusses the IEEE Climate Change program and related activities.



Carbonization is Challenging Climate Sustainability

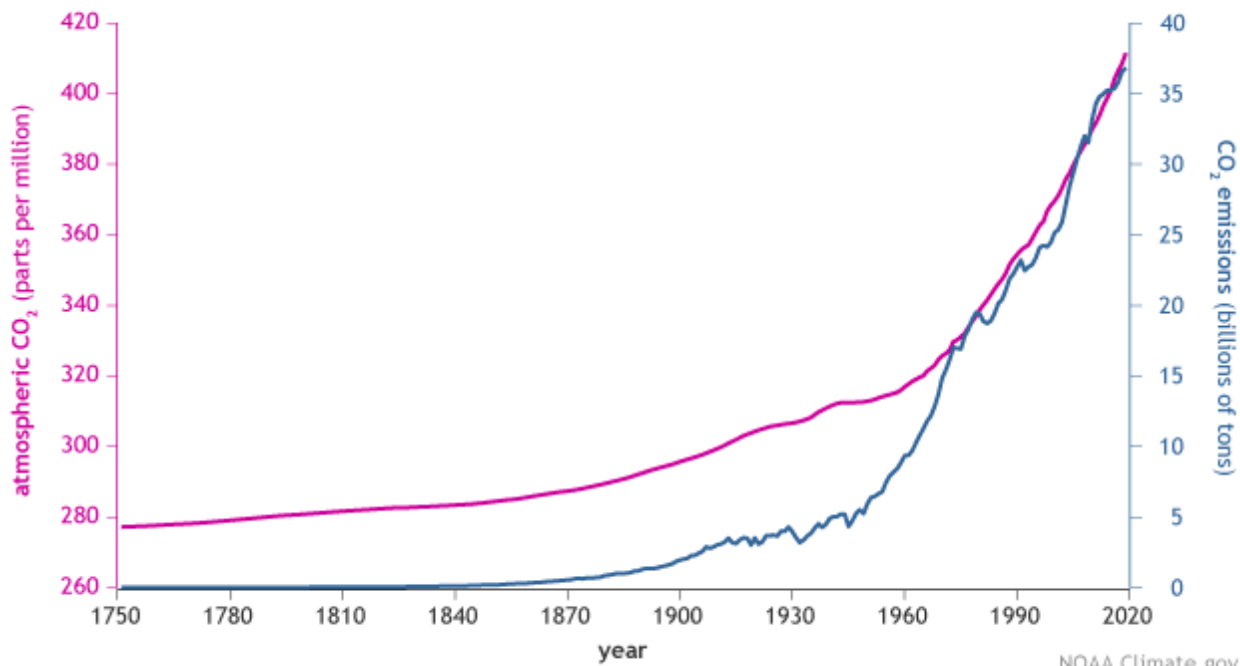


What is Carbonization?



Source: NASA https://climate.nasa.gov/climate_resources/24/graphic-the-relentless-rise-of-carbon-dioxide/

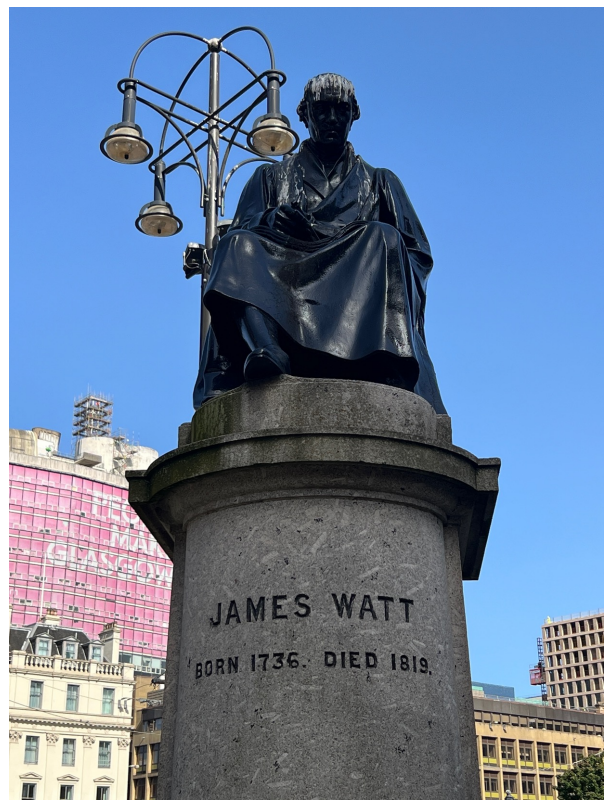
CO₂ in the atmosphere and annual emissions (1750-2019)



Source: State of the Planet

<https://news.climate.columbia.edu/2021/02/25/carbon-dioxide-cause-global-warming/>

NOAA Climate.gov
Data: NOAA, ETHZ, Our World in Data



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Impacts of Carbonization

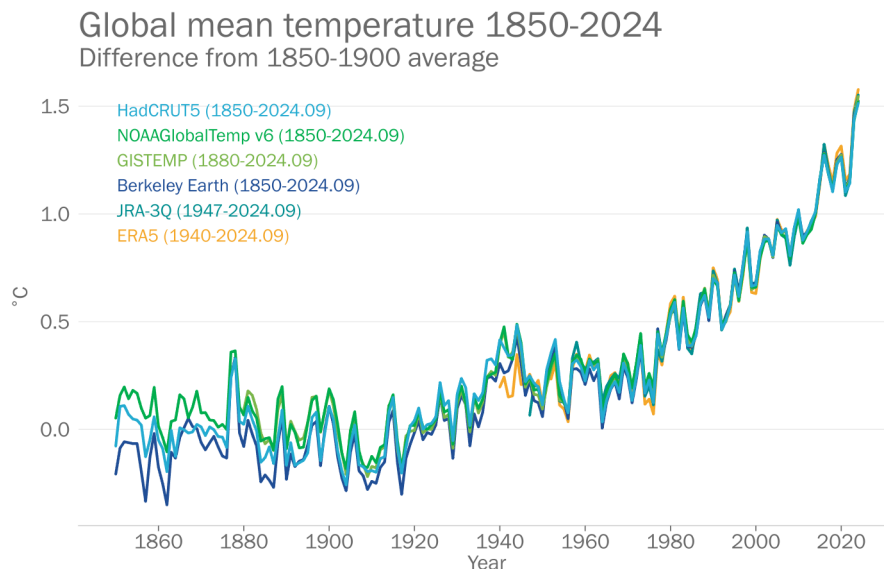
Global mean temperature 2024 was the warmest year on record

Global mean temperature
January-September 2024
 $1.54 \pm 0.13^{\circ}\text{C}$

Note that a single year above
 1.5°C does not mean that we
have passed the warming levels
in the Paris Agreement

On track to be the warmest year
in all six datasets

The past 10 years 2015-2024
are the 10 warmest years on
record



Source: World Meteorological Organization

State of Global Water Resources

- 2023 marked the driest year for global rivers in over three decades.
- Highly elevated temperatures in 2023 and 2024 with widespread dry conditions contributed to prolonged droughts.
- Hydrological cycle has accelerated and become more erratic and unpredictable.
- 3.6 billion people face inadequate access to water at least a month per year and this is expected to increase to more than 5 billion.



Climate-change Impacts



Vehicles are stranded after a heavy downpour in Zhengzhou city, central China's Henan province on Tuesday, July 20, 2021. Heavy flooding has hit central China following unusually heavy rains, with the subway system in the city of Zhengzhou inundated with rushing water. (Chinatopix Via AP)

The Associated Press



The Palisades Fire tears through a neighborhood in Pacific Palisades, Los Angeles, driven by strong winds on Tuesday, Jan. 7, 2025.

Source: <https://apnews.com/article/los-angeles-wind-wildfires-climate-change-weather-42b55ae1e66b56a6375300e448f01946>

Fire in Los Angeles

January 2025

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A beach house is engulfed in flames as the Palisades Fire burns along Pacific Coast Highway in Malibu, Calif., on Jan. 8, 2025.

Source: <https://abcnews.go.com/US/worst-fire-pacific-palisades-experts/story?id=117507457>
Agustin Paullier/AFP via Getty Images



Flooding in Bangladesh – August 2024



Heat Wave in Delhi – May 2024



Flooding in Spain in 2024



Droughts in 2022



<https://idsb.tmgrup.com.tr/ly/uploads/images/2022/07/08/217454.jpg>

Dry riverbed in **Italy** (Po River) due to worst drought in 70 years, June 2022



The Jialing Riverbed at the confluence with the Yangtze River is exposed due to drought on August 18, 2022 in Chongqing, **China**.

Reduce Carbon Emissions from Electricity Production



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Reduce Carbon Emissions

1. Use less electricity, energy efficiency
2. Use low carbon fossil fuel power plants
3. Use H₂ & other storage technologies
4. Accept some nuclear
5. Promote cross-border power transfer
6. Electrification: EVs, heat pumps
7. Promote more renewables

Customers Controlling Buildings Optimized for Savings

Energy savings from air conditioning control: 10-15%

Energy savings from lighting control: 15-20%



Energy Efficiency Applications

Consider light bulbs

- Provide more energy efficient applications and tools globally
- The amount of electricity required to run an LED light bulb is less than 15% of what is needed to run an incandescent light bulb producing the same amount of light



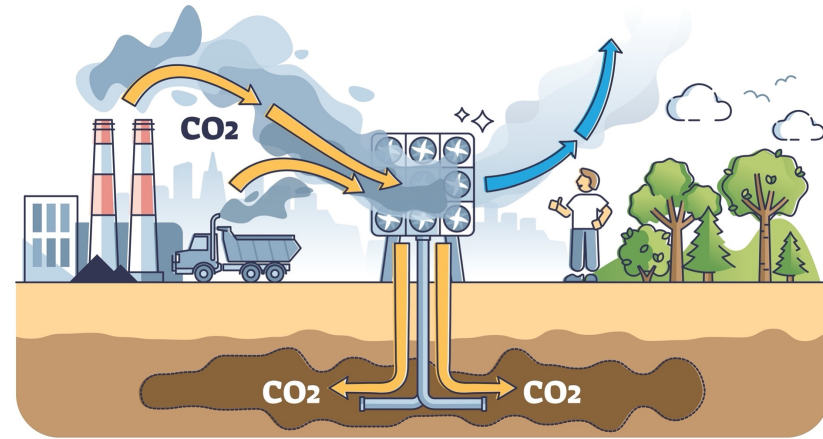
Highly Efficient Fossil-fuel Power Plants



- Combined Cycle Gas/Steam Power Plant
- Ultra-supercritical steam power plant

Carbon Capture & Storage Systems (CCS)

- Direct Air Capture (DAC) can help ensure that emissions created during the energy generation phase will not be emitted into the atmosphere
- These technologies have the potential to significantly reduce carbon emissions in energy systems across the board



Hydrogen and Storage Solutions

Optimize renewable energy solutions being integrated into energy grids



- Low-carbon hydrogen will help emerging economies to meet climate goals in and of itself
- Provide for diverse energy portfolios
- Improving resilience
- Lowering costs
- Storage solutions serve as optimizers for other renewable energy solutions
- Ensure that electricity generated during off-peak hours does not go to waste

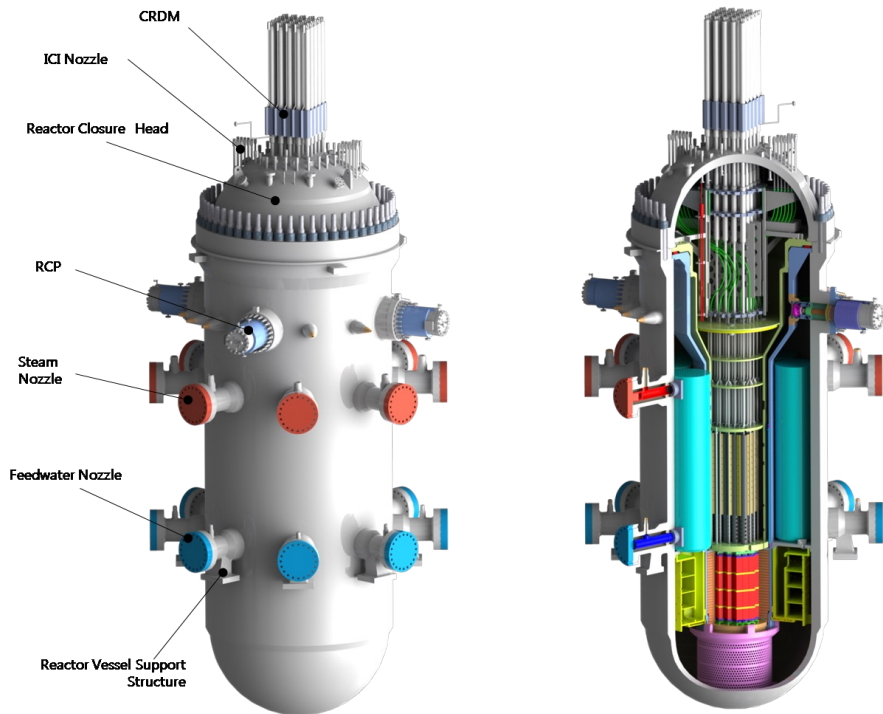
Advanced Nuclear Technologies

Diverse solutions to address climate change

- Advanced nuclear technologies, such as small modular reactors (SMRs)
- Smaller and can be built more quickly than more traditional nuclear reactors
- Ramping up the development of SMRs can help to produce energy when and where needed
- This energy could be integrated into existing power grids helping to provide improved resiliency while simultaneously reducing emissions

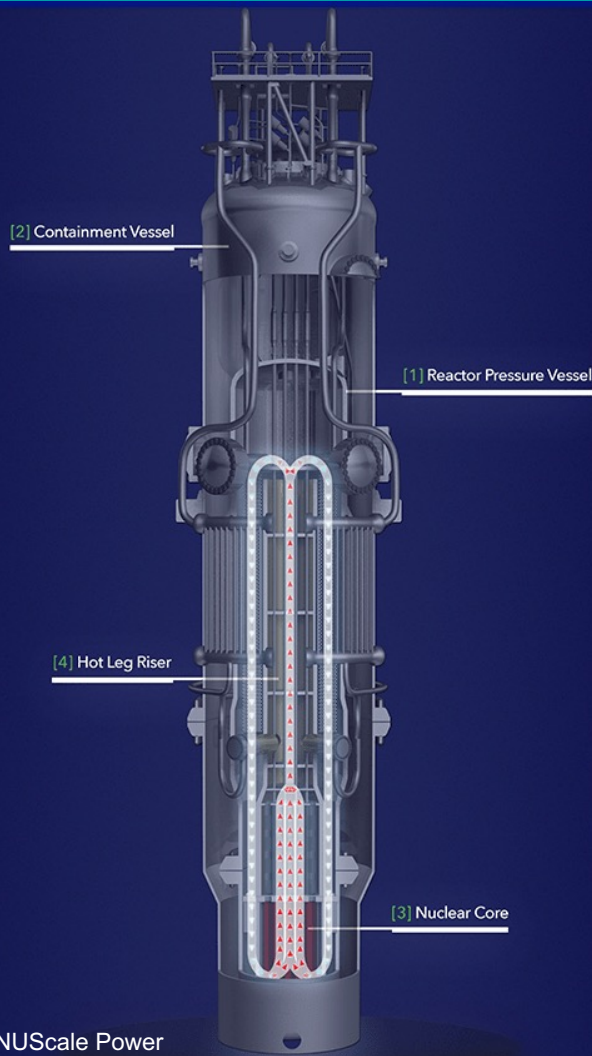


Small Modular Reactors (SMR)



20m tall, 2.7m dia. 590 tons LWR
4.95% enrichment. 50 – 60 MWe

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Cross-Border Energy Transfer

No Transition without Transmission

As we are in this fight together, our solutions should be collaborative to secure better outcomes for all countries, regardless of location

The International Energy Agency (IEA) has identified three main modes of cross-border energy integration:

Bilateral
Multilateral
Unified



Some Case-specific Examples

Gulf Coordination Council Interconnection

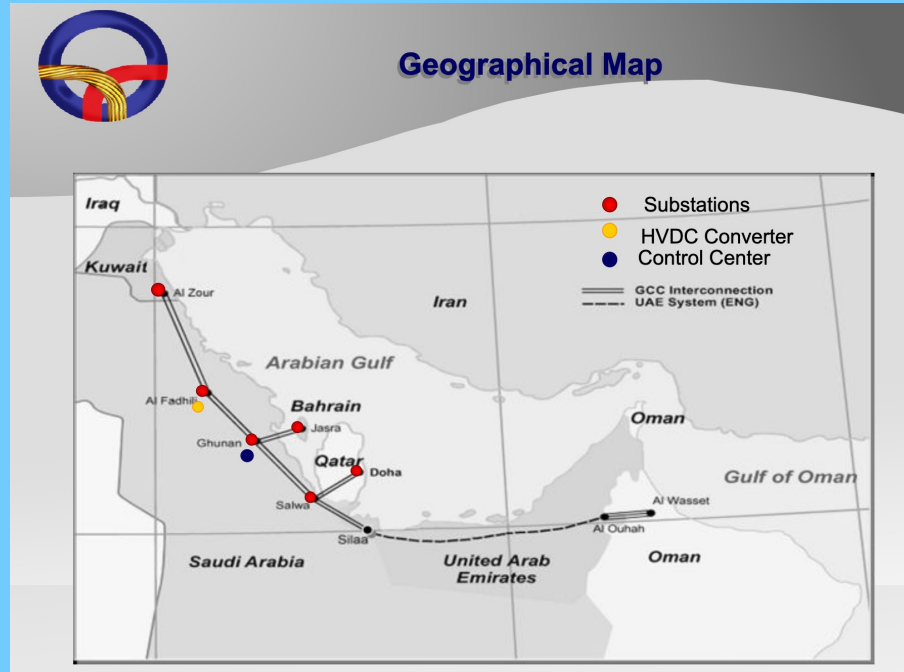
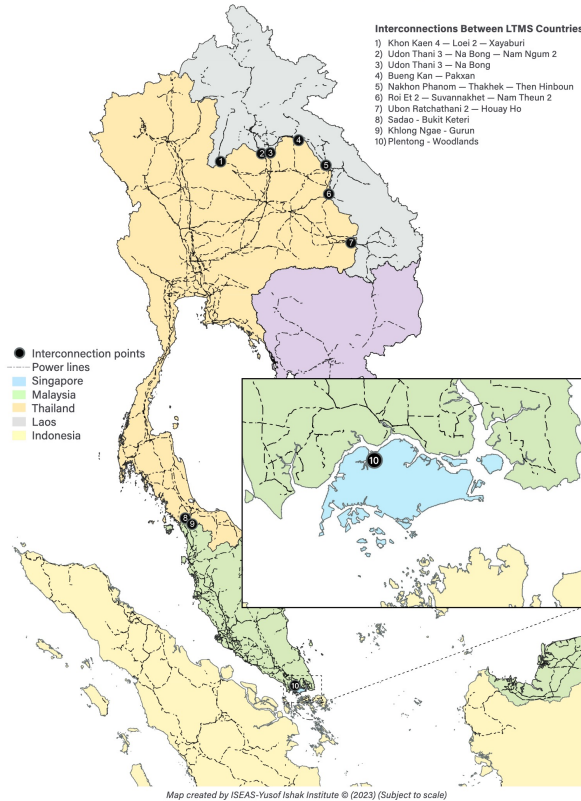


Figure 4. The Lao PDR-Thailand-Malaysia-Singapore Power Integration Project



Laos-Thailand-Malaysia-Singapore LTMS Interconnection

ACCELERATING THE ASEAN POWER GRID 2.0

Lessons from the
Lao PDR-Thailand-Malaysia-Singapore
Power Integration Project (LTMS-PIP)

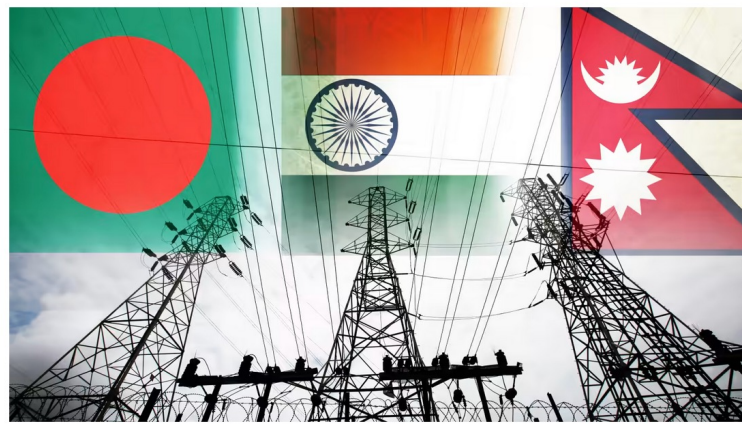
Policy Report

Vietnam has opted to boost hydroelectricity imports from Laos

The limited electricity transmission capacity from the south to the north poses a major challenge.

It is easier and more cost-effective to import hydro-electricity from Laos to shore up power supply for the North, given the shorter transmission distance.

Nepal needs to attract investment by developing a market outside



Bangladesh, India and Nepal are expected to soon finalize an agreement that would allow power sharing across Indian transmission lines. (Source photos by AP and Reuters)

In Nepal electricity demand is less in summer than in winter
It is opposite in India and Bangladesh due to high air conditioning load

Electrification: EVs, heat pumps

Electric Mobility: When 50% of all vehicle in the US are EVs, then US electricity consumption will quadruple

Challenge: Public acceptance of a much larger infrastructure



Heat pumps replacing boilers and furnaces

Challenges:

- Availability of technologies to deploy
- Shortage of technical manpower to do the job



Wind Energy in Saudi Arabia

Dawmat-al-Jandal Wind Farm

KSA's first wind farm

Capacity: 400MW

Turbines: 99 Vestas V150 4.2MW

Online: 2022

Generation: 1.4 TWH/year

Electricity: 1.99 cents/KWH

CO₂ avoided: 10⁶ tonnes /year



Wind Energy in Saudi Arabia, contd.

KSA's largest wind farm

Capacity: 600MW

Turbines: 80 Envision EN-171/7.7MW

Online: Under construction 2026

Expected: 4.2 TWH/year

Electricity: 1.56 cents/KWH

CO₂ avoided: 3.2 million tonnes/year



Al-Ghat Wind Farm

Solar Energy in Saudi Arabia



Solar Photovoltaics



Solar Thermal

Al Shuaibah Solar PV

Al Shuaibah 1 (ASB1)

Capacity: 600 MWac

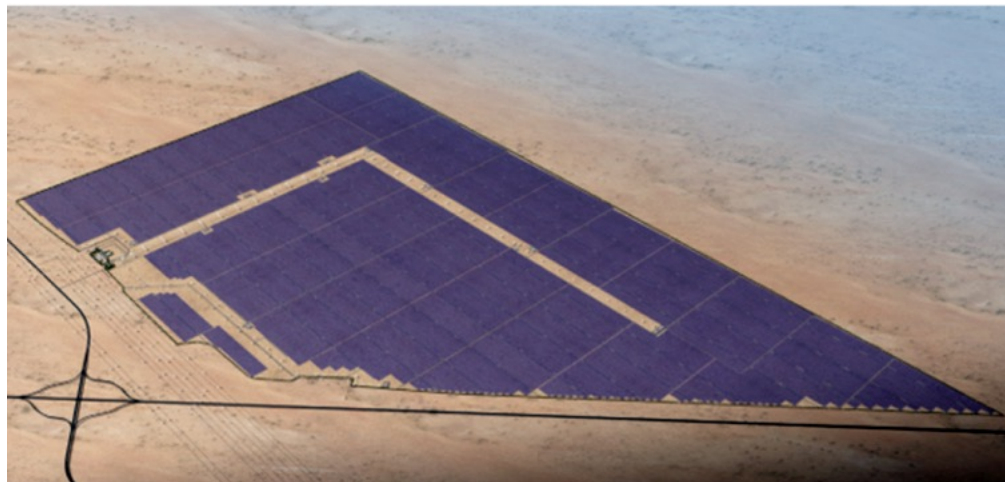
Online: November 2024

Al Shuaibah 2 (ASB2)

Capacity: 2060 MWac

Online: February 2025

Est. Offset: 2.4 million tonnes CO₂/yr



Source: <https://www.acwapower.com/en/projects/shuaibah-pv-ipp/>

Sudair Solar PV IPP

Capacity: **1,500 Mwac**

Area: approx. 25 km²

Online: September 2023

Offset: 2.9 million tonnes CO₂



Source: <https://www.acwapower.com/en/projects/sudair-pv-ipp/>

Location: N25.79, E45.56

Al Khafji Solar PV Powered Sea Water Reverse Osmosis (SWRO) Desalination Plant

Solar PV

Capacity: 20 MWac

SWRO

Capacity: 60,000 m³/day

Serving: 150,000 people

Offset: 16,000 bbl/day



Lowest Renewable Energy LCOE in the world

Al-Shuaibah-1 600MWac solar PV and the Al-Ghat 600MWac Wind farm are expected to have the lowest LCOEs in their class globally when they come into operation, i.e., 1.04 cents/KWH and 1.57 cents/KWH respectively.

Al-Shuaibah-2 2060MWac solar PV is expected to have 1.79cents/KWH

Solar

◆ As low as **1.04 cents/kWh** (Al Shuaibah project)

Wind

◆ As low as **1.57 cents/kWh** (Al Ghat project)

Source: Vision 2030 Annual Report 2024 Kingdom of Saudi Arabia

Renewable Energy Deployments in the Kingdom of Saudi Arabia

2024

Total installed renewable energy capacity in 2024 was **6.55 GW** consisting of:

- **6.15 GW** Solar PV from 9 operational projects and
- **400 MW** wind from a single farm.\

2025-2026

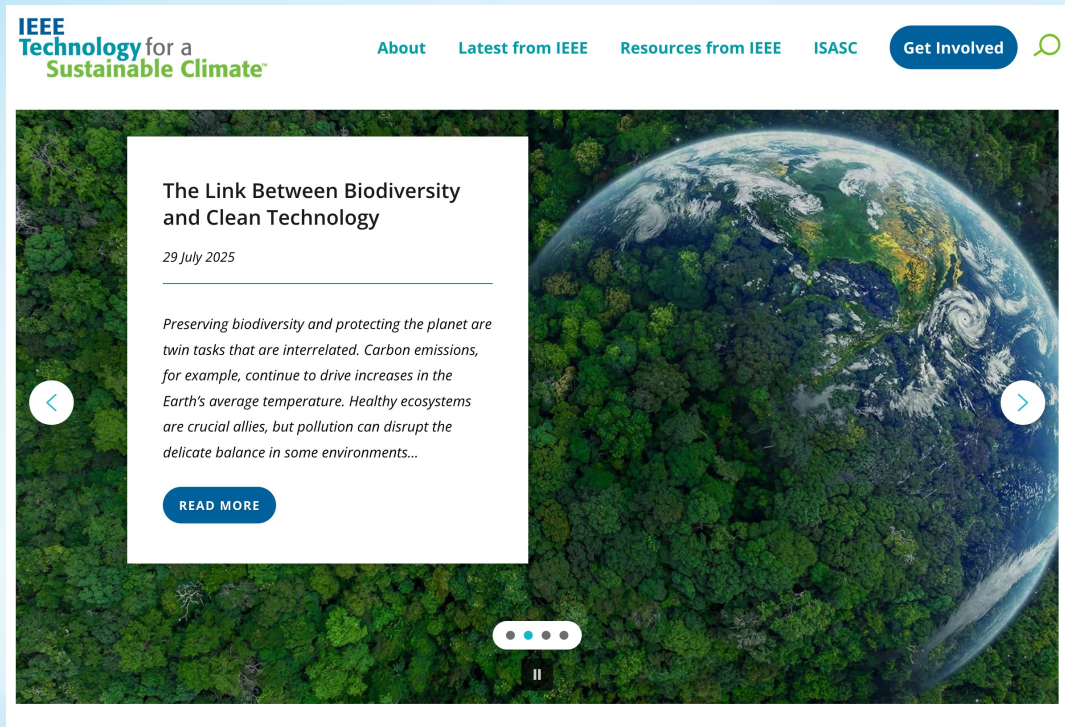
The total installed renewable energy capacity is expected to reach **12.7 GW** by the end of 2025 and **20 GW** by the end of 2026.

KSA Vision 2030

- Provide **50%** of the energy mix using renewables with the balance coming from natural gas.
- Achieve total installed renewables energy capacity of **130 GW** mostly from Solar PV (**58.7 GW**) and Wind (**40 GW**)
- Reduce carbon emissions by 278 million tonnes annually



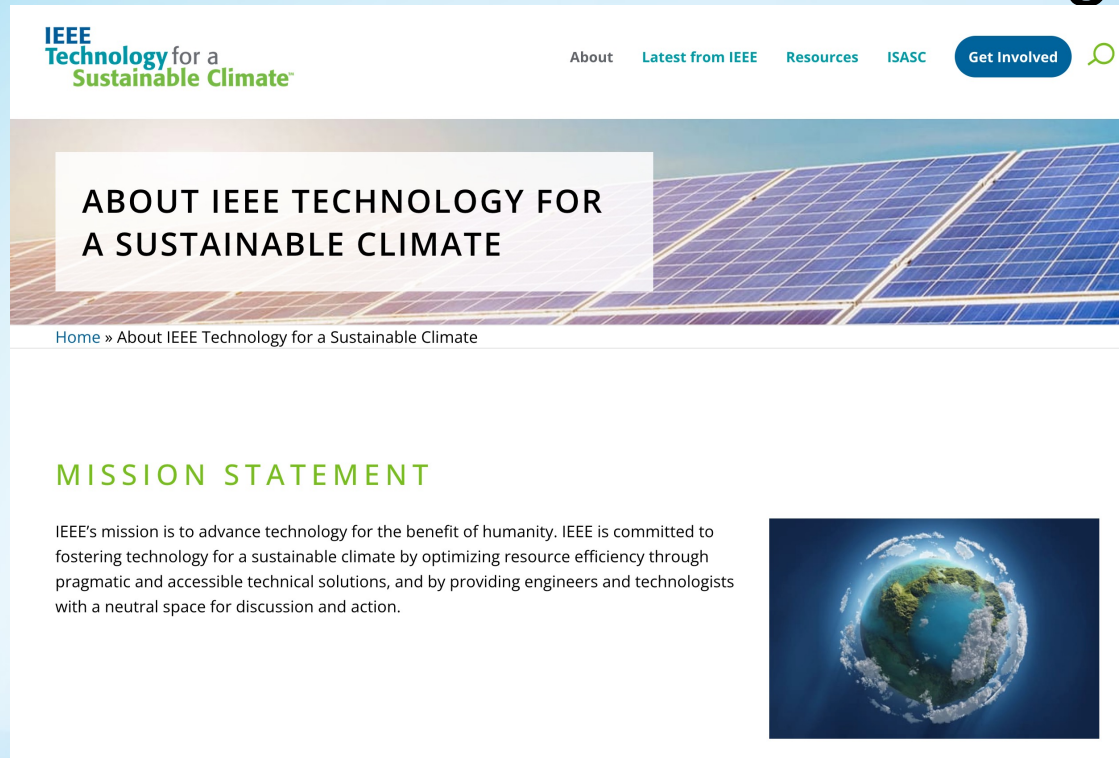
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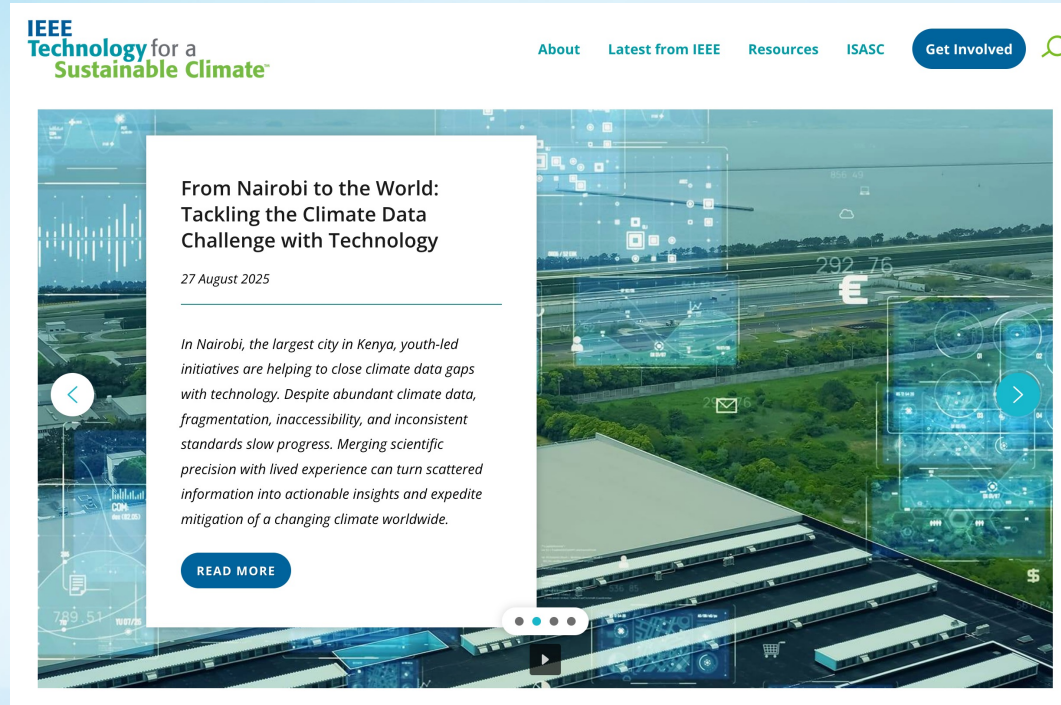
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Charting a Technology Roadmap Achieve a Sustainable Climate

The IEEE-ITU Symposium on Achieving a Sustainable Climate (ISASC) aims to leverage digital transformation and emerging technologies to boost environmental efficiency. The 1st Symposium, held in December 2024, brought together global leaders to initiate a collaborative roadmap for climate action. A second Symposium is being planned for 16-17 December 2025, with a new program that provides an update on progress of the collaborative Technology Roadmap.

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PROGRAM

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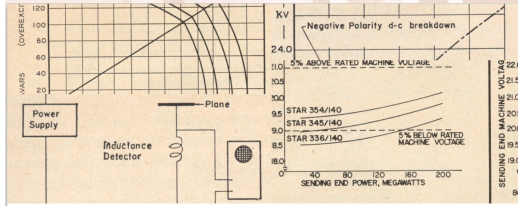
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