BEST PRACTICES FOR HELE COAL POWER TECHNOLOGIES

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PETROCOAL, INDIA
FEBRUARY 2020

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SCOPE OF PRESENTATION

- Who we are, what we do and why we do it
- Strategic importance of the energy trilemma
- HELE coal power technology
- Global coal power trends
- Ongoing developments
  - Overall performance
  - Operational flexibility
- Where do we go from here?

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Technology Collaboration Programme
by iea

DR ANDREW MINCHENER OBE

General Manager

WHO ARE WE ?

IEA CLEAN COAL CENTRE

Technology Collaboration Programme by iea

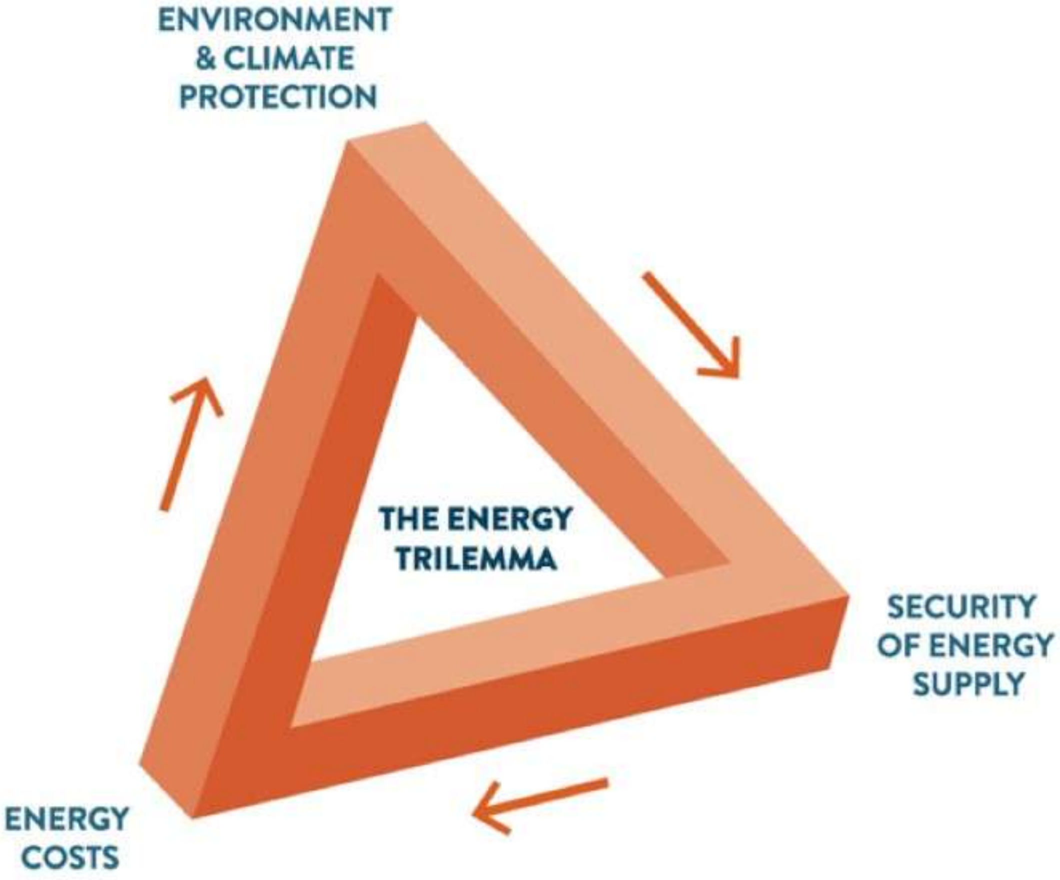
- The IEA Clean Coal Centre is part of a network of autonomous collaborative partnerships focused on a wide range of energy technologies known as Technology Collaboration Programmes (TCPs)
- The TCPs are organised under the auspices of the International Energy Agency (IEA), but the TCPs are functionally and legally autonomous
- We are funded by national governments (contracting parties) and by corporate industrial organisations (sponsors)
- We are dedicated to providing independent information and analysis on how coal can become a cleaner source of energy, compatible with the UN Sustainable Development Goals

WE SUPPORT THE SUSTAINABLE DEVELOPMENT GOALS

Our operating framework identifies and publicises the best practice in every aspect of the coal production, transport, processing and utilisation chain within the rationale for balancing security of supply, affordability and environmental issues, thereby countering any unwanted impacts to ensure the wellbeing of societies worldwide.

We consider policy and regulatory issues as well efficiency gains, lowering greenhouse- and non greenhouse-gas emissions, reducing water stress, financial resourcing, market issues, technology development and deployment, ensuring poverty alleviation through universal access to robust and reliable electricity, and social licence to operate.

STRATEGIC IMPORTANCE OF THE ENERGY TRILEMMA



This is the basis for every rational energy strategy in the world.

It represents an energy compromise as it is not sustainable to focus on one aspect without consideration of the others

COAL CURRENTLY PROVIDES 41% OF GLOBAL ELECTRICITY AND IS AN ESSENTIAL RAW MATERIAL FOR THE PRODUCTION OF 70% OF STEEL AND 90% OF CEMENT

IT IS SET TO REMAIN A SIGNIFICANT AND INTEGRAL PART OF THE GLOBAL ENERGY MIX FOR WELL INTO THE FUTURE

DIFFERENT REGIONS HAVE DIFFERENT ENERGY OPTIONS AND ARE AT VARIOUS STAGES OF INDUSTRIAL DEVELOPMENT

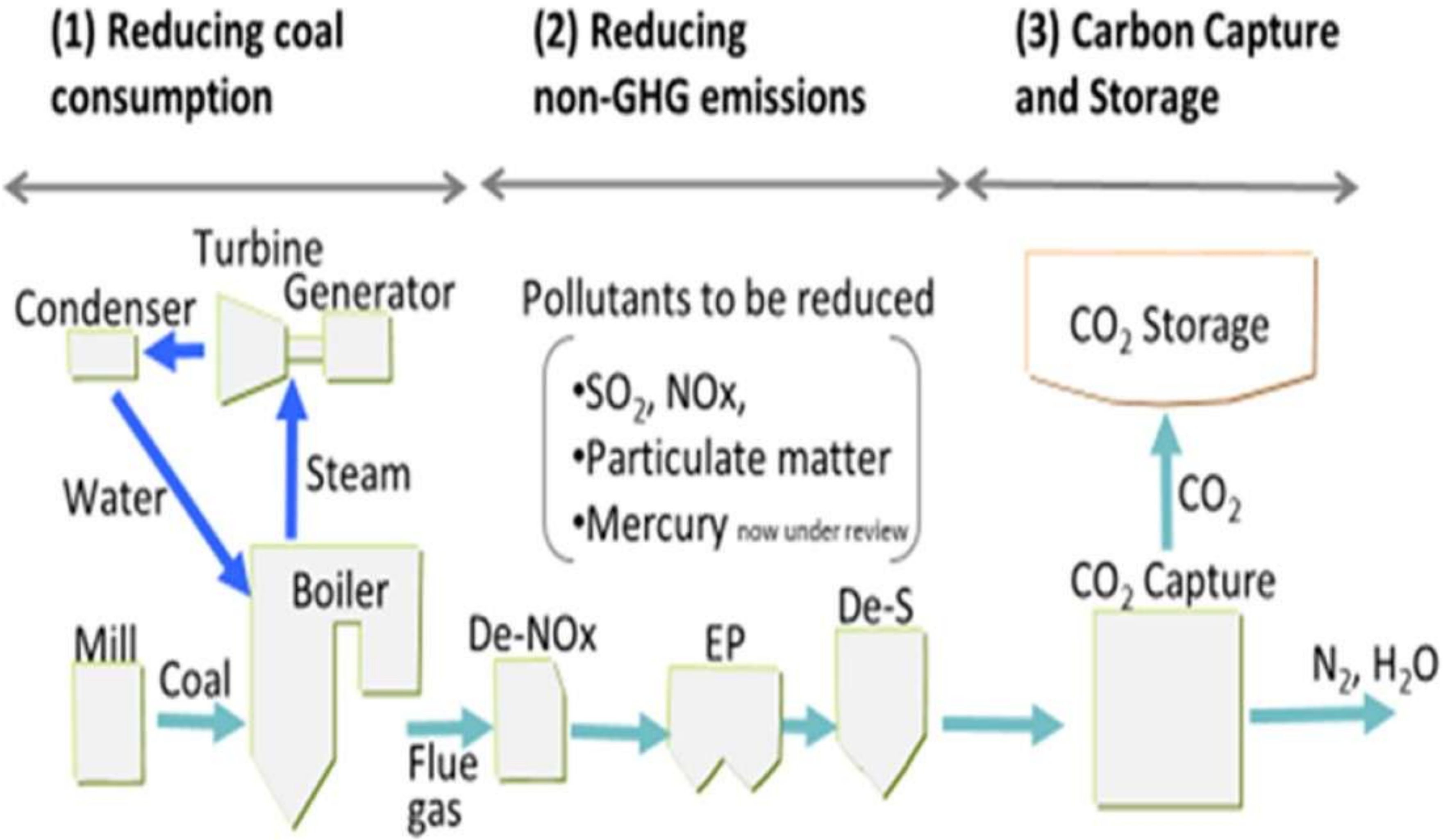
THEY HAVE DIFFERENT PRIORITIES FOR ENSURING A SUSTAINABLE FUTURE

REGIONAL ACTIVITIES (IEACCC 2019)

- USA is increasing use of shale gas, closing old coal power plants and achieving major energy efficiency gains. It is at the forefront for demonstration of CCUS.
- Within Europe, EU countries have strong targets for carbon neutrality by 2050, with a policy driven programme to close coal power plants, while introducing very significant levels of intermittent renewable power. Likely outcome is not clear. At the same time, non-EU countries approach not readily defined.
- Middle East is now including coal power within the energy portfolio
- Africa is pushing to introduce both advanced coal and renewable power
- In Asia, while there has been considerable introduction of renewables, the focus remains with coal power, with financial support especially from China and Japan, together with exciting energy and environmental technology advancements, which include major CCS/CCUS initiatives

HELE COAL POWER SYSTEMS

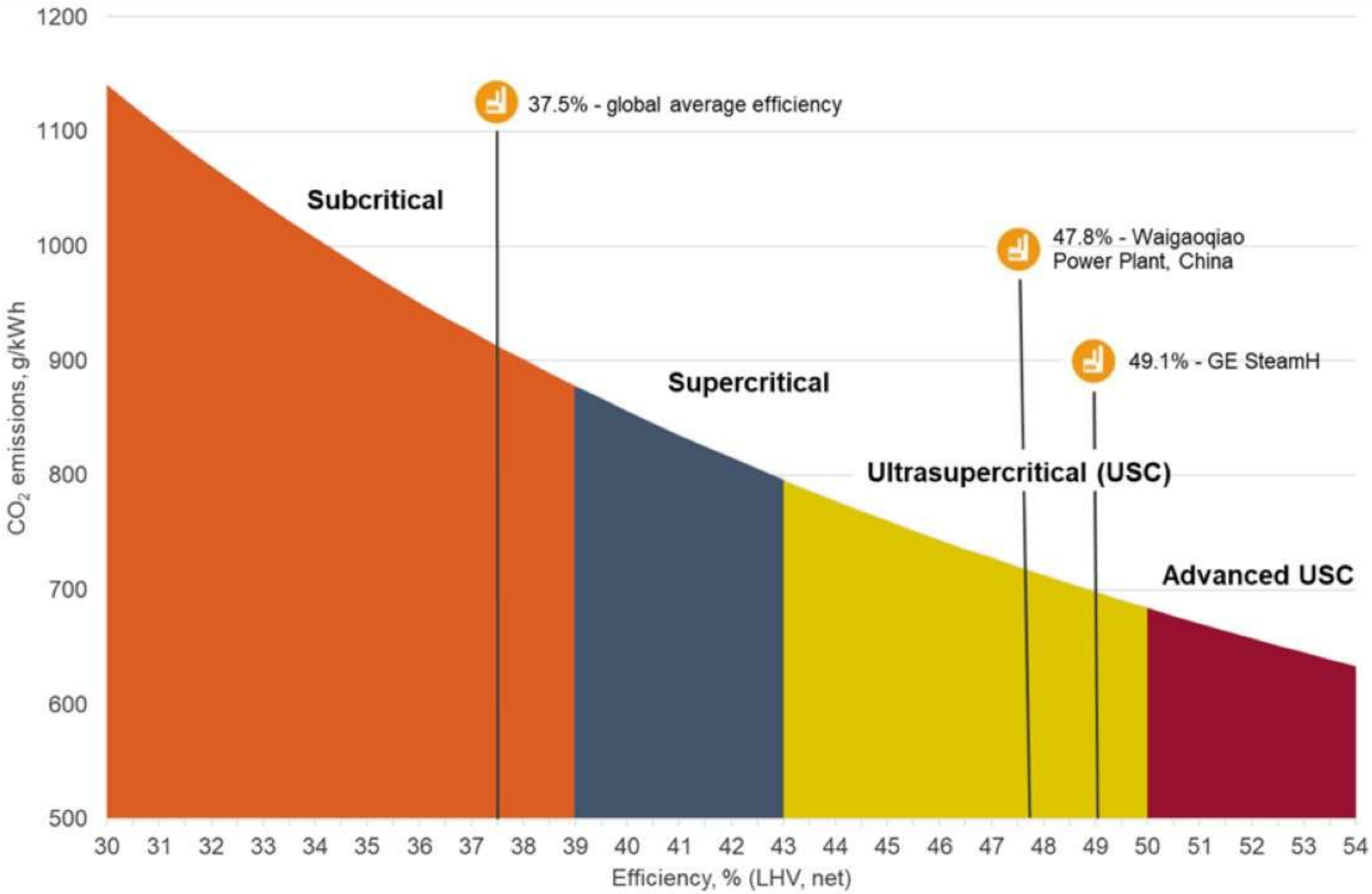
SCHEMATIC OF A HELE COAL POWER PLANT



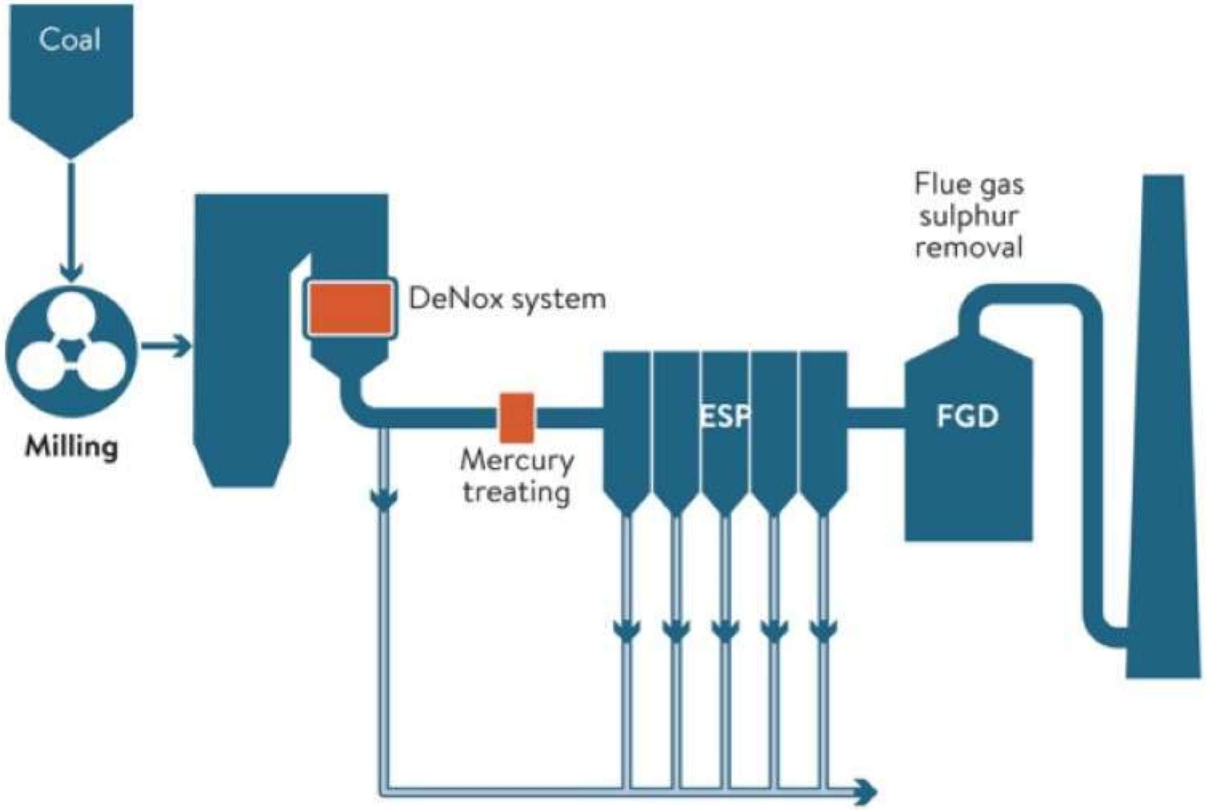
HELE EFFICIENCY & CO_2 EMISSIONS (IEACCC 2019)

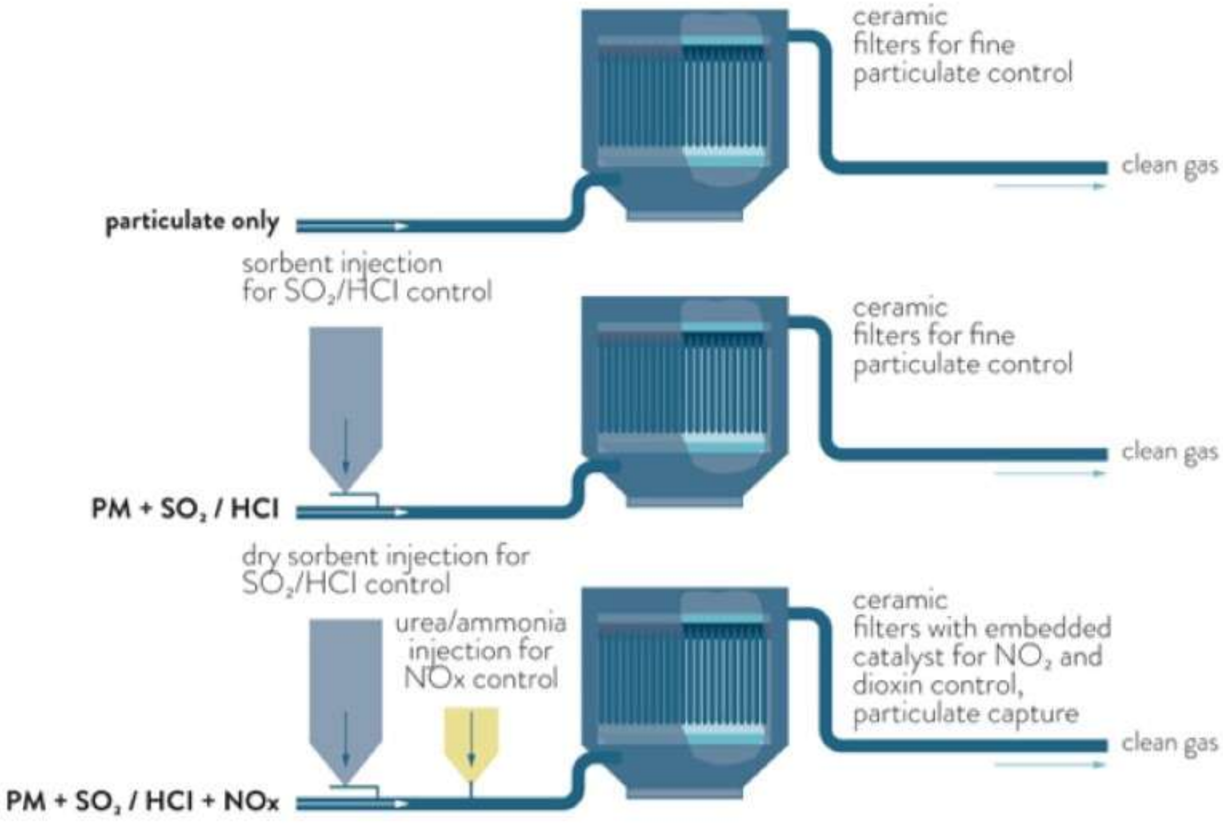
Potential for ~2 Gt of CO_2 savings if global average efficiency is brought to state of the art

USC not strictly defined – broadly refers to use of material advances since the 1990s



AIR QUALITY AND EMISSIONS CONTROL





- HELE coal power systems have state of the art emissions control devices to remove particulates, NOx and SO_2
- Multipollutant control technology offers the scope to combine all individual devices in to a single integrated system, which will reduce the land footprint and reduce the capital cost, thereby providing another step to zero pollutant emissions

USC COAL POWER CAPACITY WORLDWIDE

(PLATTS, JUNE 2018)

REGION	IN OPERATION (MWe)
	2018
Asia	224203
Europe	19208
Middle East	0
Eurasia	300
North America	665

TREND TOWARDS USC AND SC COAL POWER

(PLATTS 2019)

- The global coal power fleet is now some 2030 GW, with , some 700 GW of new capacity installed since 2010

- A further 153 GW of new capacity is being built in 32 countries (Africa, Middle East & Asia)
  - 80.4 GW of ultra-supercritical (USC)
  - 53.7 GW of supercritical (SC)
  - 15.4 GW of subcritical (mainly small units)

- Some 274 GW in the planning stage across 60 countries, with 75% in Asia

SIGNIFICANT ADVANCES UNDERWAY FOR HELE COAL POWER

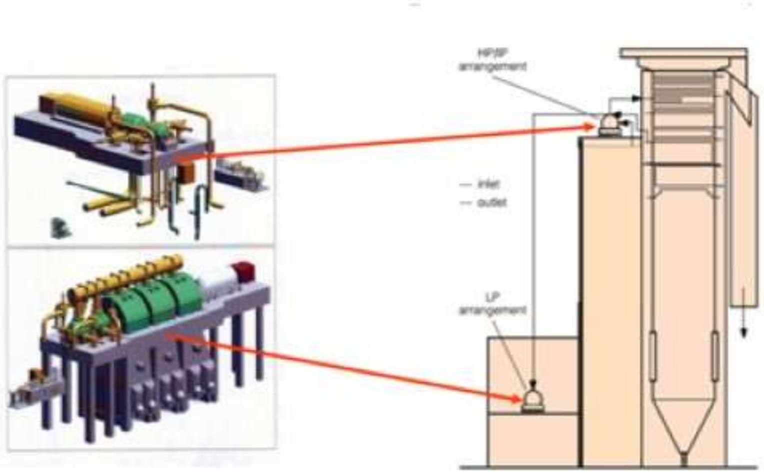
TOWARDS >50% CYCLE EFFICIENCY

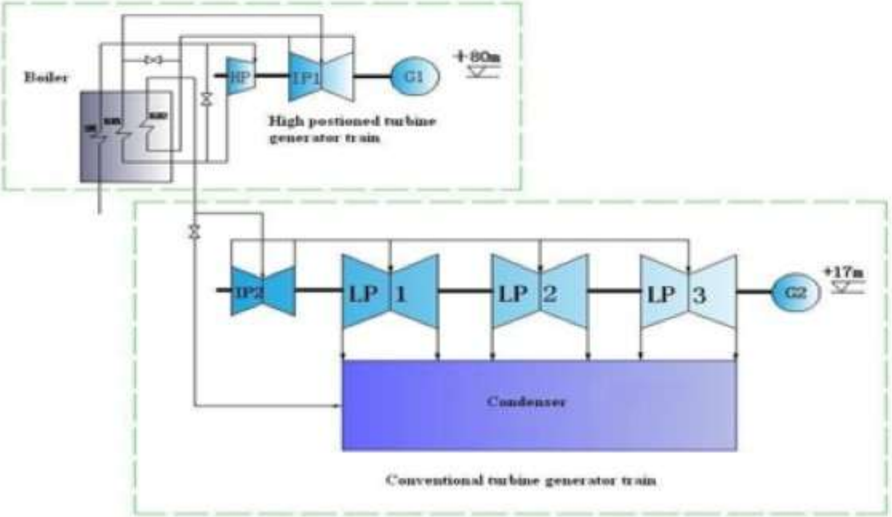
Programme	Steam temperature	Target efficiency (%, lhv, net)	Programme start date	Demonstration plant date and size
EU	700°C	50	1998	2021 (500 MWe)
USA	760°C	45-47 (hhv)	2000	2021 (600 MWe)
Japan	700°C	>50	2008	2021 (600 MWe)
China	700°C	46-50	2011	2021 (660 MWe)
India	700°C	>50	2011	2025 (800 MWe)

AN ALTERNATIVE APPROACH (YAO 2017)

Pingshan 1350MWe double reheat USC with adapted steam turbine layout

- Rated output : 1350MWe
- Rated main steam flow : 3229T/h
- Max main steam flow : 3416T/h
- Main steam pressure/reheat steam I pressure/reheat steam II pressure : 30MPa/9.17MPa/2.25MPa
- Main steam temperature/reheat steam 1 temperature/reheat steam 2 temperature : 600℃/610℃/620℃
- Cooling water temperature : 19℃





MEANS TO ACHIEVE HIGH FLEXIBILITY FOR STABILISATION OF THE GRID WHEN INTERMITTENT ENERGY SOURCES ARE INCLUDED

WHAT HAS TO BE DONE

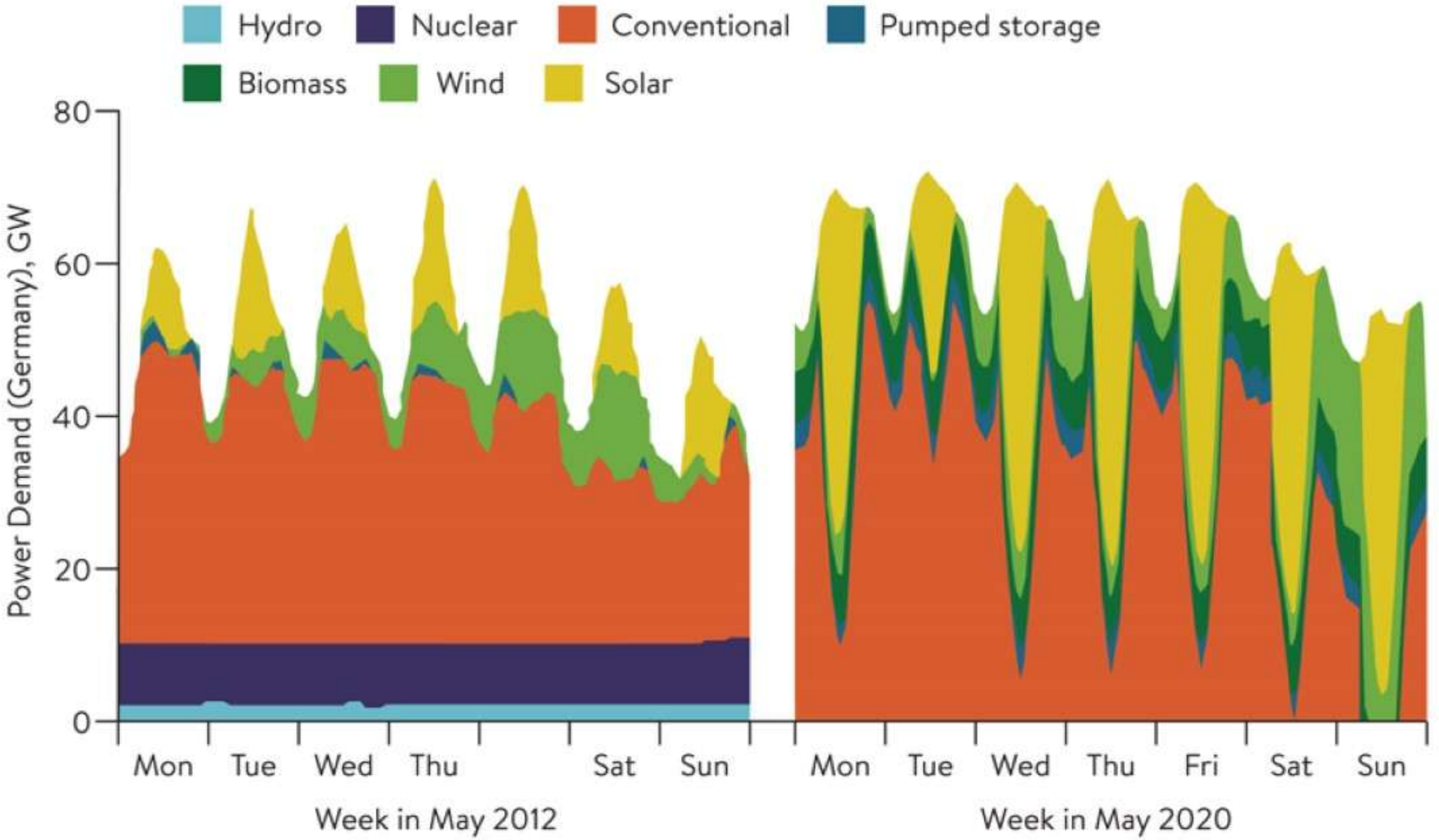
- The need for flexible operation is increasing
- Flexible operation impacts all plant areas
- Optimisation of I&C is the most cost-effective way and should be a precondition for other measures
- New operational procedures and practices are important

EXAMPLE OF SITUATION IN GERMANY

Flexibility more important than efficiency?

Current renewables share is 41%, with 65% expected by 2030

Plans to phase out nuclear by 2022, coal by 2038



Estimated power demand in May 2012 and in May 2020 (Morris et al., 2012).

INSTRUMENTATION AND CONTROL (I&C)

Older systems behave differently during full load and part load

I&C upgrade improves accuracy, reliability and speed of control

The least costly solution to improve flexibility & should be a precondition for other measures

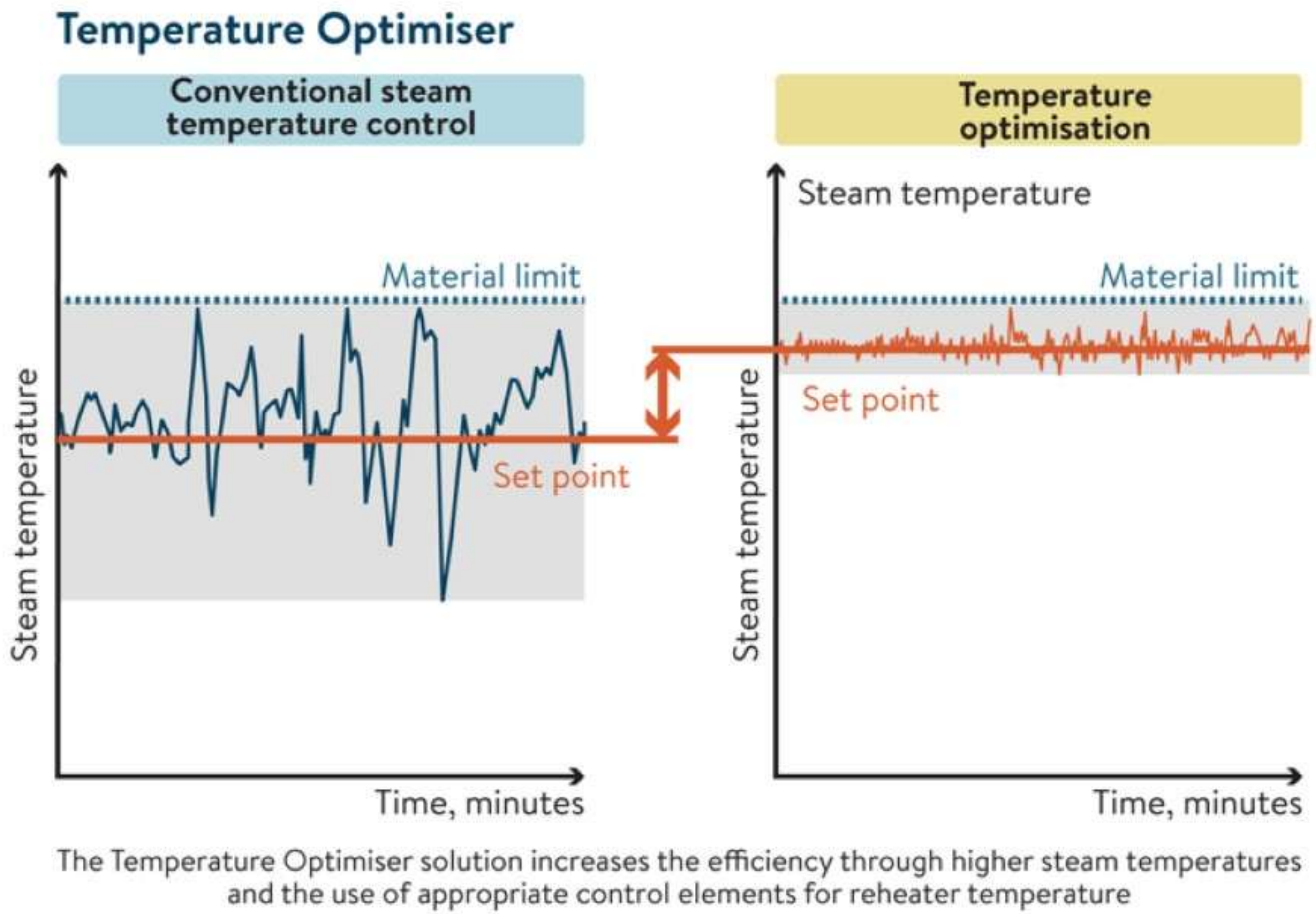


Image: Example of temperature optimisation using Siemens SPPA-P3000 system (Chittora, 2018)

LOW MINIMUM LOAD

Minimum load as low as 10% is possible

Means to achieve it centre on the boiler, fuel supply and combustion systems

- stable combustion is key (ensuring coal quality, correct air/fuel ratio, flame monitoring, tilting burners, low excess air, auxiliary firing with a dried lignite ignition burner)
- operation with a lesser number of mills, or smaller mills, and top-level burners
- indirect firing
- economiser or feedwater heater bypass
- thermal storage for feedwater heater

Heilbronn power station, Germany

Photo: Kreuzschnabel Wikimedia Commons

LOW MINIMUM LOAD

New units - evaporator design:

- internally rifled or ribbed tubing (permits reduced fluid flow rates without metal overheating)
- vertical tube evaporators have several advantages over spirally wound types (lower pressure drop, simpler structure making their installation and maintenance easier, ash can fall off more easily)

Image: MHPS Internally rifled evaporator tube (Yamamoto and others, 2013)

START-UP IMPROVEMENTS

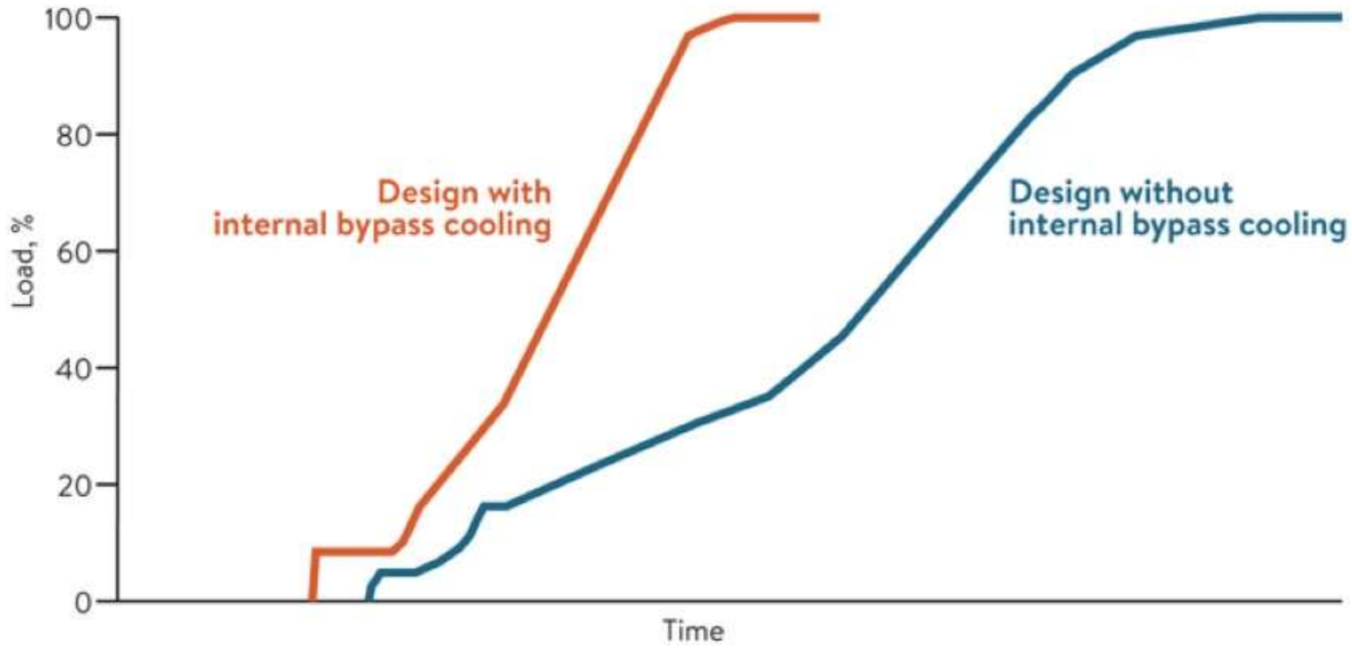
Start-ups are complex, expensive and increase damage to components

Means available to reduce the adverse impacts of start-ups:

- In a boiler:
    - Reliable ignition (plasma and electrical)
    - Reducing the thickness of thick-wall boiler components (using new materials, increasing number of headers or separator bottles, designing pressure parts for shorter life at MCR)
    - External heating of thick wall components
    - Cleaning of the boiler deposits (modern soot blowers)

RAMP RATE IMPROVEMENT

- Mill storage capacity
- HP internal bypass cooling
- Thermal storage for the low pressure or high pressure feedwater
- Sliding pressure for more rapid output changes
- Frequency control
  - HP stage bypass (1%/sec)
  - turbine throttling
  - condensate throttling
  - additional turbine valve
  - feedwater heater bypass



Ramp-up rates achieved with and without the internal bypass cooling (Siemens, Chittora, 2018)

IMPROVING FLEXIBILITY THROUGH PLANT MANAGEMENT

- Maintenance strategies are a key for cycling plants
  - Reactive - failure based
  - Preventive - interval based
  - Predictive - condition based digital approach
- Fleet approach
- Modification of operating procedures or implementation of new ones

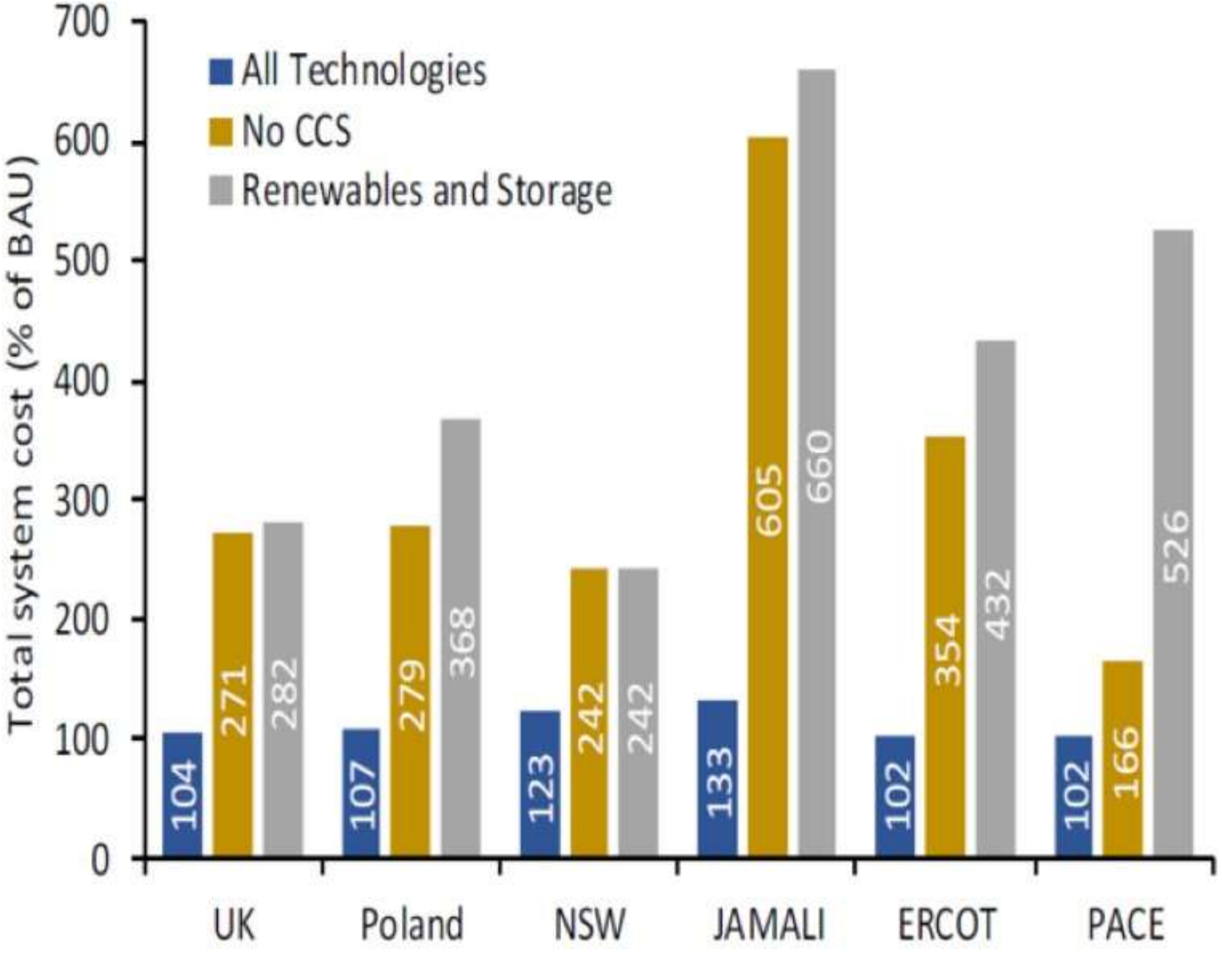
WHERE MIGHT WE GO FROM HERE?

ROLE AND VALUE OF CCS FOR A SUSTAINABLE ENERGY FUTURE

(IMPERIAL COLLEGE 2019)

- CCS technologies are essential for managing a transition to a least-cost and reliable net-zero electricity system
- The role and value of CCS changes in different regional contexts due to differing energy system characteristics (e.g. availability of renewable power and electricity demand profiles)
- Greater than 90% CO2 capture rates can be readily achieved and improve deployment prospects for CCS by increasing its capacity factor
- CCS adds value in all power systems, and is uniquely valuable when deployed together with intermittent renewables

CCS CAN PROVIDE A STRONG BENEFIT FOR NET ZERO CARBON POWER SYSTEMS (IMPERIAL COLLEGE 2019)



- CCS provides a strong positive financial benefit in all of the net-zero scenarios investigated
- Incorporating CCS allows for an electricity system with a very low marginal cost relative to the BAU scenario
- Conversely, excluding CCS was found to increase the total system cost by a factor of two to seven, depending on the case study and scenario.
- The deployment of CCS (in coal, gas, and biomass applications) is unequivocally vital to a least cost transition to a net zero emissions electricity grid, which is the driver towards a broader decarbonisation agenda

TRANSFORMATION IS NOT LIMITED TO POWER PLANTS

- Electrification of transportation and heating
- Digitisation of electricity grids
- Flexibility
- Smart grids and virtual power plants
- Blockchain and distributed generation
- Demand side management to manage VRE
- Battery storage
- Carbon capture, utilisation and storage

SUSTAINABILITY IS NOT JUST ABOUT CLIMATE CHANGE (FOSTER 2019)

- International policy debates on climate change are driven by OECD countries and organisations, and are centred on limiting emissions of greenhouse gases by reducing fossil fuel consumption and pushing the use of intermittent renewables
- However, the energy challenge for the 2030 Sustainability Agenda is driven by national priorities such as development, quality of life, employment, energy security and trade balances, which are crucial to developing countries
- We have to achieve a balanced energy strategy that will provide a realistic way to achieve a 1.5°C target while addressing the key issues that developing countries need to focus on

COAL HAS BEEN AROUND FOR A LONG TIME AND HAS SUCCESSFULLY FACED MANY CHALLENGES THROUGH INNOVATIVE TECHNOLOGICAL DEVELOPMENTS

THE CHALLENGE NOW IS TO MAINTAIN A ROLE IN THE POWER SECTOR AND AT THE SAME TIME SEEK FURTHER SUSTAINABLE OPPORTUNITIES

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THANK YOU FOR LISTENING

ANY QUESTIONS?

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ADDITIONAL INFORMATION AVAILABLE VIA FOLLOWING SLIDES

HELE COAL POWER IN JAPAN AND CHINA

Isogo USC power plant near Tokyo

Waigaoqiao No. 3 USC power plant in Shanghai

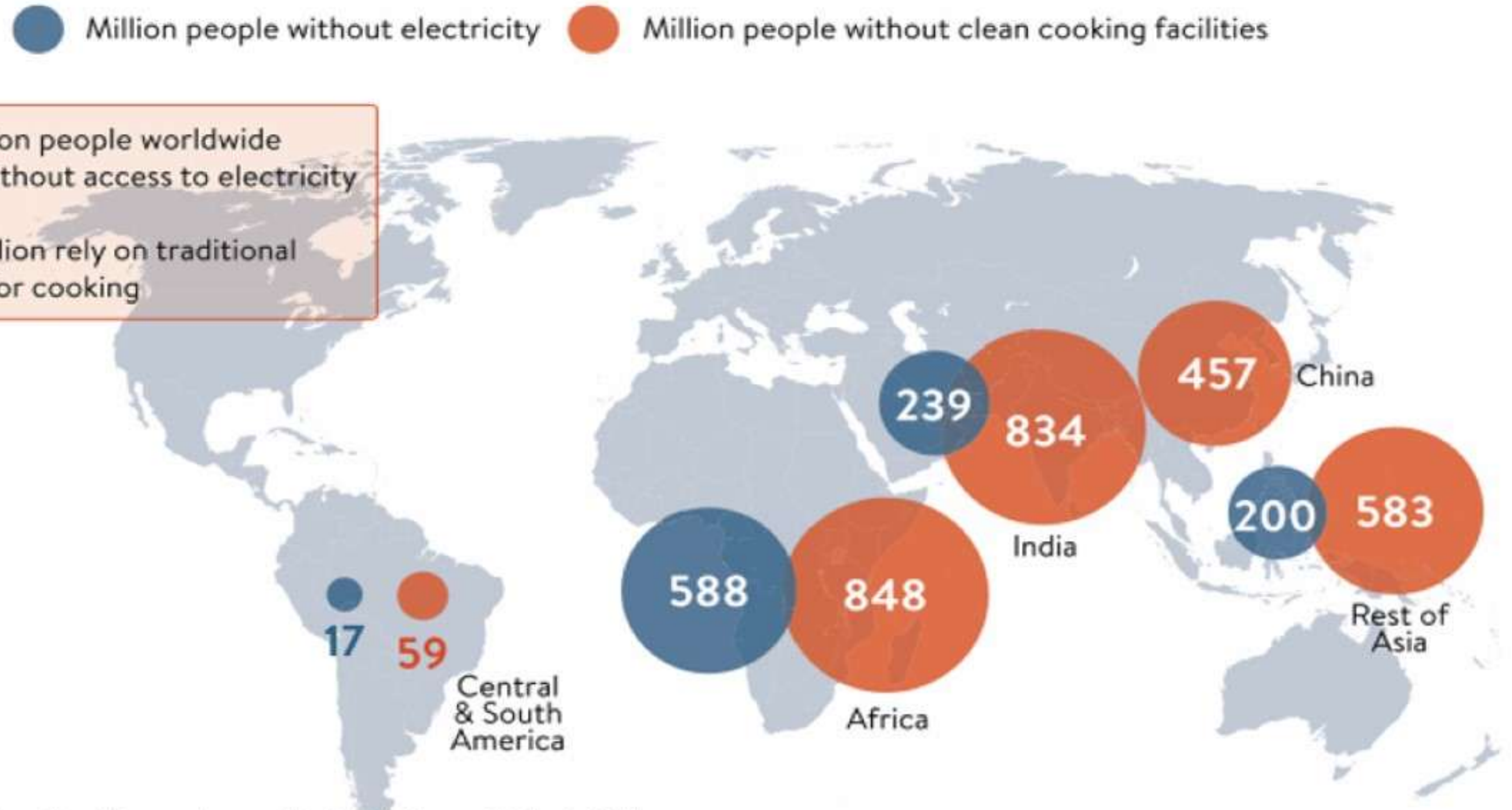
ASIA DOMINATES THE ENERGY SCENE

Population Density - (Via Imgur https://imgur.com/gallery/yci7C) Sep 2013

ENERGY POVERTY IS STILL WITH US

Over one billion people live without access to electricity

- 1.1 billion people worldwide live without access to electricity
- 2.8 billion rely on traditional fuels for cooking



Source: International Energy Agency, Worldwide Energy Outlook 2017

DEVELOPMENTS IN AFRICA

Country	Recent developments
Botswana	600MW IPP plus some other subcritical and CFBC projects announced
Kenya	Construction of 1 GW plant should begin in 2024
Malawi	Construction of 300MW plant underway
Morocco	1GW USC plant construction underway
Mozambique	Development of 300 MW plant initiated
Nigeria	Plan to use coal to meet 30% of national power demand
Tanzania	300 MW plant development initiated
Zimbabwe	Proposal for 2.8 GW plant

DEVELOPMENTS IN THE MIDDLE EAST

- Some utilities turning to coal power to meet rising demand, boost energy security, and reduce gas imports
- Egypt, Oman, Iran, Jordan, and UAE have coal projects at various stages of development
- Some countries aim to diversify energy mix, limit emissions, and improve resilience through economic diversification

Country	Recent developments
Egypt	Current proposals for four/five coal-fired power projects (total 15.6 GW) with 9.8 GW capacity expected by 2025
UAE/Dubai	2.4 GW Hassyan plant being built, first USC plant in the Middle East. DEWA plans two more to bring CCT capacity to 3.6 GW by 2030. FEWA considering 1.8 GW USC plant
Oman	Government considering up to 3 GW of CCT-based capacity by 2030, with first by 2024
Turkey	Biggest user of coal-fired power, with 18.5 GW Country has 37 GW of coal capacity in planning

DEVELOPMENTS IN ASIA (1) (IEACCC 2019)

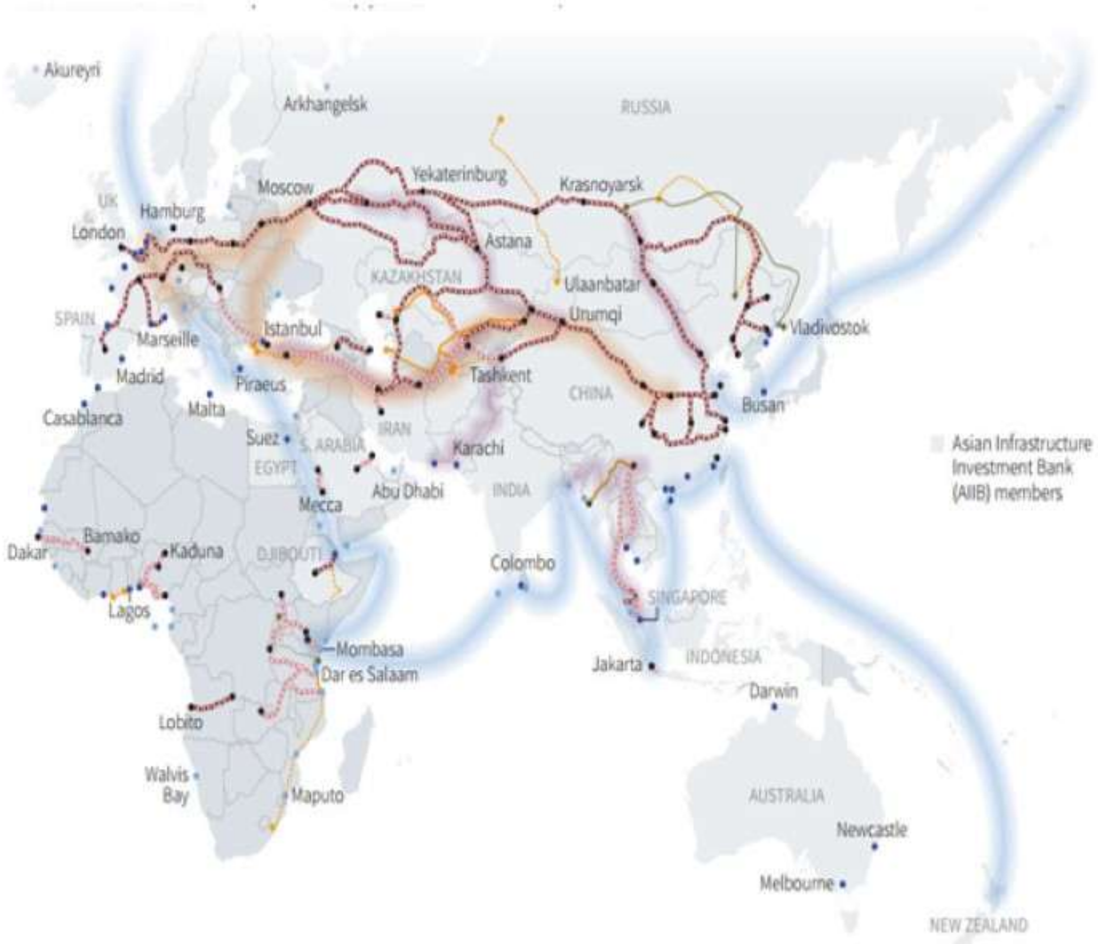
Country	Recent developments
Bangladesh	Massive upturn in coal power capacity, with plans for 60 GW US$ 20 billion funding from China, India, Japan with all projects in development being USC
China	6 GW of new HELE coal capacity in 2019 and 5 GW in 2020 just by China Energy Significant coal power increase in country with major developments externally
India	Coal will continue to maintain market share despite increase in renewables. Government initiatives promoting SC, USC and AUSC technologies with first USC plant commissioned in 2019
Indonesia	Plans to add 35 GW of capacity by 2024 with some 54% of coal-fired plants. New USC units being developed

DEVELOPMENTS IN ASIA (2)

Country	Recent developments
Malaysia	Two 1 GW USC plants recently came on line, with two more under construction
Pakistan	Government tackling energy shortage via Chinese-financed coal plants to provide some 30% of power demand
Philippines	First 500 MW SC plant operational by end of 2019 More projects planned including SC, USC and CFBC
Japan	Around 12 new USC coal power plants being developed or proposed in range 600 to 1000MW
Vietnam	Coal forecast to provide over 50% of country's power by 2028 More than 70 coal power projects planned

CHINA BELT AND ROAD INITIATIVE

(BROOKINGS.EDU)



- US$ 1tn programme to boost economic and trade ties in 71 countries
- Equivalent to a quarter of global GDP via investments in energy and infrastructure using Chinese expertise and technology
- China has invested in 67.9 GW of new coal-fired power in BRI countries since 2014
- Between 2014 and 2017, six Chinese banks participated in US$ 25.7 bn worth of syndicated loans for electricity projects in BRI countries - US$ 10.2 bn (40%) was for coal-fired generation

- s.com/article/us-china-power-coal/china-energy-to-expand-ultra-low-emission-coal-fired-power-executive-idUSKCN1UD0J9