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DECARBONIZATION INITIATIVES AMONG LEADING POWER UTILITY PLAYERS

**Vlado Georgievski, Nevenka Kiteva Rogleva**

Faculty of Electrical Engineering & Information Technologies

Ss. Cyril and Methodius University in Skopje

vlado.georgievski1@gmail.com; nkiteva@feit.ukim.edu.mk

**Abstract:** Decarbonization of the power sector means reduction of its CO2 intensity, which is reducing the emission of carbon dioxide per unit of electricity generated. In order to meet the emission reduction targets pledged to the Paris Agreement on climate change, power utility companies need to develop strategies on how to decarbonize their generation assets. Companies must achieve carbon neutrality by 2050, which is necessary to meet the targets of the Paris Agreement of capping global temperature rise at 1.5°C, and also to meet the less ambitious 2°C target. Rapid decarbonization of the power sector is needed particularly as heat and transport sectors are electrified, creating an increase in demand for electric power. Decarbonization is being achieved by increasing the share of low-carbon energy sources, particularly renewables, and a corresponding reduction in the use of fossil fuels. Worldwide, renewables now produce a third of power capacity.

**Key words:** decarbonization, CO2 reduction, net-zero strategy, power utilities

# 1 INTRODUCTION

Decarbonizing our power generation sector is around one third of goal to achieve the Net Zero target and become carbon neutral in 2050. Every country and company must act, but the measures to be taken vary by region and country. Asian utilities must focus on decarbonizing thir coal assets, while Europe, North America and the Middle East should focus on gas. Furthermore, in developing economies that still tackle with electrification and energy independency, decarbonizing young fleets would be even bigger challenge for the utilities.

Decarbonizing is the only option to ensure long term survival of humanity and life on our planet. With CO2 prices continuously rising, utilities will have no other option, but to get ready for the change and start implementing it today. There are many different levers to decarbonize the fossil generation assets, but no ideal solution: major CO2 reduction levers have high CAPEX and OPEX costs, require O&M and staff changes, and rely on technologies yet not commercially available. On the other hand, cheaper and available measures focused on operations improvement and plant modernization can quickly impact the emissions, but still not enough to achieve zero.

In this paper, different generation decarbonization levers will be described and analyzed. In addition, a short review of the current energy crises and huge rise of the energy prices will be presented, a fact pushing companies even further to accelerate their decarb pathways. At the end, selected power utilities players from specific regions will be benchmarked, reflecting their decarbonization initiatives on the analyzed levers.

# 2 Decarbonization levers in power generation

Five different categories of decarbonization levers will be analyzed: 1. Operations improvement and equipment modernization, 2. Co-firing with lowcarbon fuels, 3. Retrofit for full fuel switch, 4. Implementation of CCUS, 5. Shutdown of fossil assets and building new plants.

**2.1 Operations improvement and equipment modernization**

Power plants are typically designed for a lifetime of between 25 and 35 years. It is not normally economic to retire plants prematurely and, in many countries, it is standard procedure to extend the life of a power plant to 40 years, with some units exceeding 50 years of operation. There has been much progress in plant life extension through refurbishing boiler parts, upgrading the turbines and adding flue gas cleaning to meet new emission regulations. Life extension is often possible due to the conservative nature of the original plant design and the fact that only a relatively small number of the components are life limited. Thus, while increases in national capacity may be met by the introduction of SC and USC plant, it is likely that the older, less efficient plant in the fleet would continue to dominate the capacity mix. Consequently, appropriate retrofitting of such units would improve their overall performance in terms of efficiency and emissions per unit electrical output. The potential to improve existing units through upgrade and retrofit normally requires an exhaustive examination of the major functions – the combustion process, the steam cycle and major balance of plant equipment. [1]

Efficiency improvement methods were identified for most components and systems, as summarised in Table 1. While it is unlikely that all of these improvements could be implemented at every plant, due to site-specific circumstances, the table does provide a useful indication of the significant potential for thermal efficiency improvement. In several cases, the suggested improvements offer potential efficiency increases of 1 percentage point or more. [1]

Table 1 Heat rate improvement levers by coal power plant [1]

|  |  |
| --- | --- |
| **Power plant improvements** | **Potential efficiency increase (percentage points)** |
| Air preheaters (optimise) | 0.2 to 1.5 |
| Ash removal system (replace) | 0.1 |
| Boiler (increase air heater surface) | 2.1 |
| Combustion system (optimise) | 0.2 to 0.84 |
| Condenser (optimise) | 0.7 to 2.4 |
| Cooling system performance (upgrade) | 0.2 to 1.0 |
| Feedwater heaters (optimise) | 0.2 to 2.0 |
| Flue gas moisture recovery | 0.3 to 0.7 |
| Flue gas heat recovery | 0.3 to 1.5 |
| Coal drying (installation) | 0.1 to 1.7 |
| Process controls (installation/improvement) | 0.2 to 2.0 |
| Reduction of slag and furnace fouling | 0.4 |
| Soot blower optimisation | 0.1 to 0.7 |
| Steam leaks (reduce) | 1.1 |
| Steam turbine (refurbish) | 0.8 to 2.6 |

Source: NETL (2008), *Reducing CO2 Emissions by Improving the Efficiency of the Existing Coal-Fired Power Plant Fleet*, DOE/NETL- 2008/1329, NETL, Pittsburgh, PA, [www.netl.doe.gov/energy-analyses/pubs/CFPP%20Efficiency-FINAL.pdf.](http://www.netl.doe.gov/energy-analyses/pubs/CFPP%20Efficiency-FINAL.pdf)

In general, unit heat rate can be improved by improving boiler combustion efficiency and turbine cycle efficiency, and by reducing auxiliary power use. Note that heat rate improvements are generally not additive and depend on many site-specific factors.

**2.2 Co-firing with low carbon fuels**

Co-firing with low carbon fuels refers to the simultaneous combustion of a low carbon fuel and a base fuel to produce energy. Here it is analyzed co-firing coal with biomass or green ammonia, and co-firing gas with green hydrogen.

**2.2.1 Co-firing coal with biomass**

Biomass co-firing consists of burning biomass along with coal in coal-fired power plants. Co-fi ring can play an important role in increasing the use of biomass in power generation and reducing greenhouse gas (GHG) emissions because only a relatively modest incremental investment is needed to retrofit existing coal plants or build new co-fired plants. Compared to power plants burning 100% biomass, co-firing offers several advantages, including lower capital costs, higher efficiency, improved economies of scale and lower electricity costs due to the larger size and the superior performance of modern coal power plants. [2]

The net electric efficiency of a co-fired coal/biomass power plant ranges from 36-44%, depending on plant technology, size, quality and share of biomass. While a 20% co-firing (as energy content) is currently feasible and more than 50% is technically achievable, the usual biomass share today is below 5% and rarely exceeds 10% on a continuous basis. A high biomass share means lower GHG emissions. It is estimated that 1-10% biomass co-firing in coal power plants could reduce CO2 emissions from 45 million to 450 million tonnes per year by 2035, if no biomass upstream emissions are included. [2]

**2.2.2 Co-firing coal with ammonia**

Ammonia co-firing consists of burning ammonia along with coal in coal-fired power plants. In 2017 the Japanese Chugoku Electric Power Corporation successfully demonstrated the cofiring of ammonia and coal, with a 1% share of ammonia (in terms of total energy content) at one of their commercial coal power stations (120 MW). Using ammonia as fuel raises concerns about an increase in NOx emissions, but the demonstration managed to keep them within the usual limits and to avoid any ammonia slip into exhaust gas. Higher blending shares of up to 20% ammonia in energy terms might be feasible with only minor adjustments to a coal power plant. In smaller furnaces with a capacity of 10 MW thermal, blending shares of 20% ammonia have been achieved without problems, and in particular without any slippage of ammonia into exhaust gas. So far serious scrutiny of the co-firing concept is limited to Japan.  In the fullness of time, the demand side of the concept may take root in other countries.  The supply side, however, could have near-term global relevance. [3]

 Technical feasibility of ammonia co-firing proven since 2017 (Mostly in Japan): IHI and Chugoku Electric tested 20% ammonia co-firing in Mizushima coal power plant (156 MW), IHI demonstrated the co-firing of ammonia and coal in a fuel mix composed of 20% ammonia in 2018.

**2.2.3 Co-firing gas with hydrogen**

Hydrogen firing technology enables power plant owners to decarbonize their existing Gas Turbine Combined Cycle (GTCC) plants by converting them to hydrogen co-firing, or even making them 100% hydrogen firing in the future. Using hydrogen as a fuel in gas turbines plays an important role in the decarbonization of the energy sector. It’s a market need driven by regulation. Natural gas with hydrogen derived from chemical industry is emerging as a key fuel for burning in gas turbines. Gas turbines can burn hydrogen with some modifications in burner and combustion systems. NOx emissions increase if H2 percentage increases but the increase is still several order of magnitudes lower compared to conventional diffusion burners. The risk of flashback is similar to that of liquid fuels. [4]

Mitigation differs depending on H2 amount in the fuel. The flame speed is ten times higher compared to natural gas. More compact flames in DLE burners (dry low emissions) lead to slight increase in NOx compared to natural gas. [4]

Case Study of on-going co-firing projects: EnergyAustralia is integrating one of GE’s advanced gas turbines to operate with a blend of natural gas and hydrogen with commercial operations scheduled to begin in 2023/2024.

**2.3 Retrofit for full fuel switch**

Retrofitting is the process of modifying existing systems with new technology or features, such as improving the efficiency of power plants, increasing output, or reducing emissions. Here, it is analyzed retrofit in aspect of using an existing coal or gas power plant with adjustment to accommodate new fuel type. Different fuel retrofits are possible: coal to biomass, waste or natural gas, and gas to green hydrogen.

**2.3.1 Retrofit coal to biomass and coal to gas**

Large-scale coal power plants typically employ the pulverized fuel combustion technology. When converting to biomass, the firing principle remains the same, but new mills and burners, suited to biomass fuels, substitute with the coal ones. The biomass demand for such converted plants is huge – a single unit may require more than one million tons per year – and these quantities are generally secured through imports. Currently, wood pellets are the standard biomass choice in such conversions, since their high energy density and good fuel properties offer both economic and technical advantages. Since biomass is considered carbon neutral, full fuel switch from coal to biomass would reduce the total CO2 emissions. [5]

A natural gas plant takes up significantly less land area than an equivalent coal power plant due to the omission of spacious coal and ash handling areas. Natural gas arrives in a pipeline and leaves no ash behind when combusted. It is therefore highly space efficient. New or converted natural gas boilers with added carbon capture can easily fit in to any existing coal power plant, and the net site annual power output can be maintained even with the addition of capture equipment. However, only coal plants relatively close to an existing natural gas transmission pipeline are applicable for this type of retrofit. [6]

**2.3.2 Retrofit gas to hydrogen**

Converting natural gas into hydrogen on-site with sorbent enhanced steam reforming reduces overall carbon emissions by 98% and eliminates the need to add a more expensive carbon capture system to the back-end of the power production process. Case Study of on-going gas turbines developments: Siemens Energy is supplying two gas turbine packages that will eventually operate on 100% hydrogen for the Leipzig Süd district heating power plant in Germany (2030), Mitsubishi M701F natural-gas-fired turbine, Hydrogen-to-Magnum Project, which aims to convert one gas turbine unit in the Vattenfall power plant, in the Netherlands, to run on 100% hydrogen by 2027. Biggest challenge is reducing flashback, where the rapid combustion speed of hydrogen means the flame can shoot back up the incoming fuel nozzle.

**2.4 Implementation of CCUS**

CCS offers the means to achieve deep reductions in CO2 emissions from coal-fired power plants and other large energy-intensive fossil fuel sectors. The CCS process comprises three integrated stages, namely: 1. capture and subsequent compression of the CO2 2. the transport of the CO2, usually as a supercritical/dense phase fluid 3. its subsequent utilisation or injection into the selected geological formation. [1]

All CCS options incur costs and reduce the efficiency of the plant. Fitting CCS to a power plant requires additional capital investment for the CO2 capture and compression equipment, the transport infrastructure as well as the equipment associated with storage. In all cases, CO2 capture will use additional energy for the capture and subsequent compression of the CO2, reducing the overall process efficiency and also increasing the amount of fuel used to achieve a given power generation output. Consequently, the cost of capturing CO2 will be lowest if this is done in large plants that operate at high thermal efficiencies and can best integrate the CO2 capture process to limit, as far as practicable, the energy penalties. The technique can be applied both to new plants, where the additional process equipment can be designed for maximum integration, and to existing plants as a retrofit application. In the latter case, key requirements are the need for adequate space at the power plant site to incorporate the additional equipment, which will be extensive, and the reasonable proximity of a CO2 storage site. Capital costs are expected to decline once this technology is demonstrated and then deployed on a significant scale. [1] Based on learnings from current developments and expected economies of scale, CCUS project cost is anticipated to range between $75-$100 per tonne of CO2 captured by 2030, meaning the total market value of the sector could reach $55 billion annually by 2030. [6]

**2.5 Shutdown of fossil assets and building new plants**

This lever has multiple sublevers captuing all the possible variations, but is based on decommissioning existing coal or gas-fired plant and replace with a plant with less or zero CO2 emissions. Some of the variations for coal fired power plants are as following: 1. Coal to Gas, 2. Coal to Gas + CCS, 3. Coal to PV, 4. Coal to PV+Wind, 5. Coal to PV+Wind+Battery. Same levers can apply to gas fired power plants: 1. Gas to PV, 2. Gas to PV + Wind, 3. Gas to PV + Wind + Battery, 4. Gas to 100% Hydrogen.

This methods typically require higher upfront CAPEX to build a new plant or invest in renewables parks. The levers are more market competitive in countries with very high CO2 and gas prices.

**3 2022 energy prices accelerating the need for decarb pathway**

The European Union first proposed a cap on the price of gas and electricity in March, after energy prices took off when Russian – Ukraine conflict started. While some suppliers produce their own energy, most of the price that electricity firms pay is set by financial markets, where producers, utility firms and speculators compete based on supply and demand. [8]

Electricity producers are paid the same price despite having vastly different expenditures. Gas power stations are much more expensive to run than wind or solar farms and, therefore, tend to set the overall market price. [8]

Current German import prices reaching above 400 EUR/MWh for natural gas and above 580 EUR/MWh for coal (July 2022 [9]) were the factors for the year-ahead contract for German electricity reaching €995 ($995) per megawatt hour at the end of August. [8]

Moreover, with CO2 prices also being currently high (65 EUR/ton, Sep/2022, [10]) and expected to double in the next decade (111 EUR/ton, Dec/2030 [10]), power utilities not only need to set a decarbonization strategy, but also rapidly accelerate it, focusing on low carb fuels power generation to avoid and sooner fossil asset phase out.

**4 power utilities decarbonization initiatives benchmark**

Based on the analyzed levers, a research has been conducted and 13 selected companies’s strategies were reflected on their ongoing or planned decarbonization initiatives, measures and projects. The utilities immediate plans emphasize moving from coal to renewables, especially in Europe and USA. The selected companies were diveded by regions as following: US based: Duke Energy, Next Era, Evergy, EU based: Fortum, Uniper, Engie, Enel, RWE, Orsted, Asia and RoW based: CLP, NTPC, Tepco, Eskom.

Table 2 Decarbonization Initiatives across major Power Utilities

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Region** | **Company** | **Power Plant Actions** | **Diversifying from fossil fuel** | **Carbon Capture** |
|  |  | **Coal to Gas** | **Coal to Biomass** | **Coal Divestment** | **PV and Wind** | **Energy Storage** | **Ammonia, H2** | **CCS** |
| **US based** | Duke Energy | ◯ | ◯ | ⚫ | ⚫ | ⚫ | ◐ | ◐ |
| NextEra | ◐ | ◯ | ◐ | ⚫ | ⚫ | ◐ | ◯ |
| Evergy | ◯ | ◯ | ⚫ | ⚫ | ◯ | ◯ | ◯ |
| **EU based** | Fortum | ◯ | ⚫ | ⚫ | ⚫ | ⚫ | ⚫ | ◯ |
| Uniper | ⚫ | ◯ | ⚫ | ⚫ | ⚫ | ⚫ | ◯ |
| Engie | ◯ | ◐ | ⚫ | ⚫ | ◐ | ◐ | ◐ |
| Enel | ◯ | ◯ | ⚫ | ⚫ | ⚫ | ⚫ | ◯ |
| RWE | ◯ | ⚫ | ⚫ | ⚫ | ⚫ | ⚫ | ◯ |
| Orsted | ◯ | ◯ | ⚫ | ⚫ | ⚫ | ⚫ | ⚫ |
| **Asia and RoW based** | CLP | ◯ | ◯ | ◯ | ⚫ | ◯ | ◐ | ◯ |
| NTPC | ◯ | ◯ | ◐ | ◯ | ◯ | ◐ | ⚫ |
| Tepco | ◯ | ◯ | ◯ | ⚫ | ◐ | ◐ | ◯ |
| Eskom | ◯ | ◯ | ◯ | ⚫ | ◐ | ◐ | ◯ |

*Legend:* ◯ *No evidence of investing;* ◐ *Testing;* ⚫ *Investing*

**5 Conclusion**

The number of countries announcing pledges to achieve net zero emissions over the coming decades continues to grow. But the pledges by governments to date – even if fully achieved – fall well short of what is required to bring global energy-related carbon dioxide emissions to net zero by 2050 and give the world an even chance of limiting the global temperature rise to 1.5 °C.

Based on the companies’ decarbonization initiatives, we can conclude that Europe and US are phasing out coal and investing into renewables and low carbon technologies, Japan is focusing on green hydrogen and ammonia solutions, where India, Africa and China still need to push the coal phase out strategy further and focus on investing into low carbon generation.

Moreover, with the impact of current energy crises and soaring energy prices, power utilities (especially EU based), will need to accelerate the phase out of their coal and lignite assets and decomission all their fossil fueled assets by 2050 in order to meet the requirements of the Paris Agreement and save the planet from ireversable climate catastrophe. With coal phasing out in 2030 in most EU countries, and gas being a costly option, investments into renewables and low carb technologies will be inevitable.

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