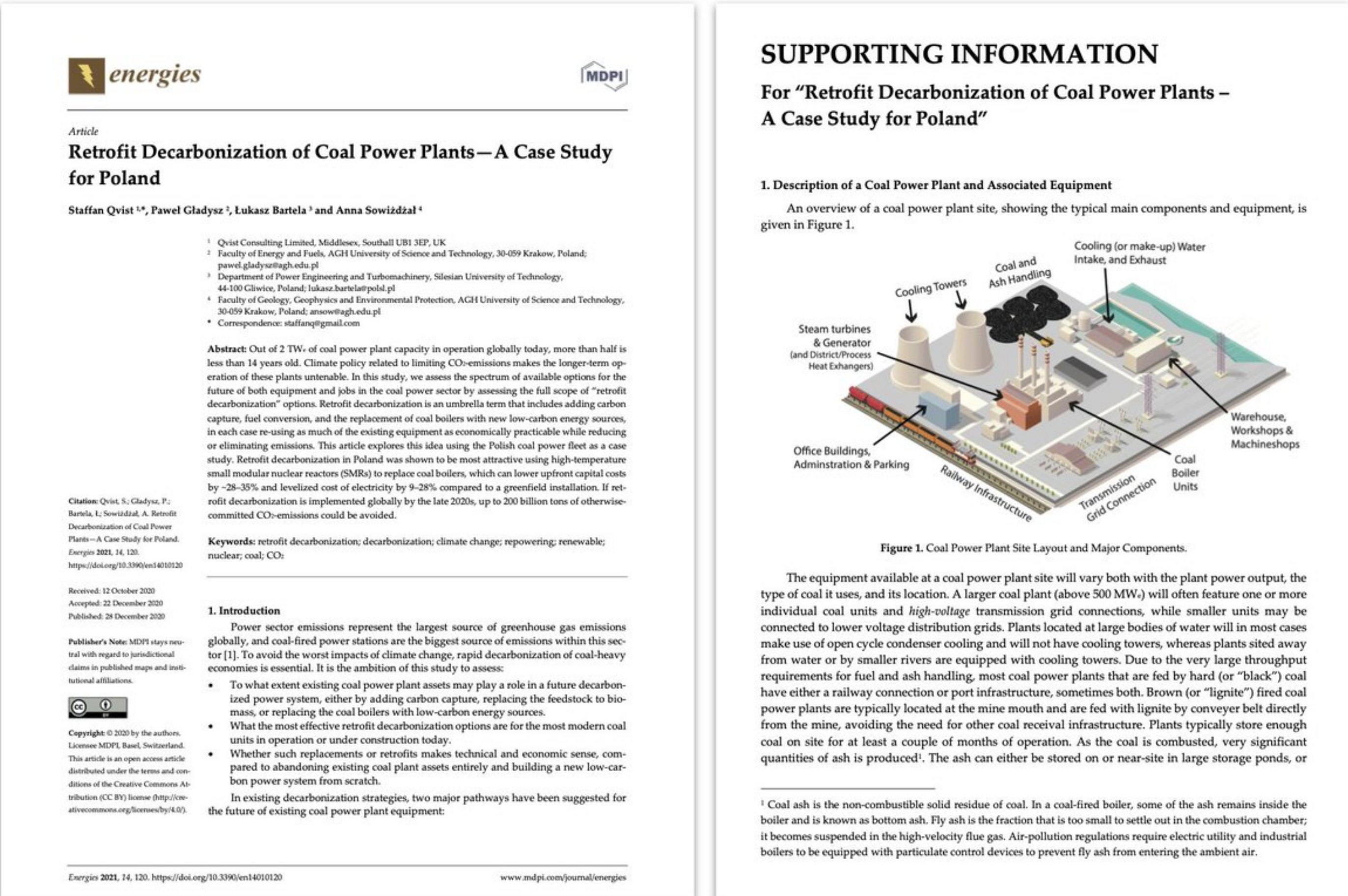
Twitter Thread by Staffan Qvist

Staffan Qvist
@QvistStaffan

[1/x] Happy to announce the publication of “RETROFIT DECARBONIZATION of COAL POWER” (open access https://t.co/JxrMtLS9gf, @energies_mdpi). A riveting 39-page article (+ 44p S.I.), obviously makes for excellent holiday/wknd reading :) Here's an attempt at a tweet-summary-thread!



energies MDPI

Article

Retrofit Decarbonization of Coal Power Plants—A Case Study for Poland

Staffan Qvist 1,*, Paweł Gładysz 2, Łukasz Bartela 3 and Anna Sowiżdżał 4

1 Qvist Consulting Limited, Middlesex, Southall UB1 3EP, UK
2 Faculty of Energy and Fuels, AGH University of Science and Technology, 30-059 Krakow, Poland; pawel.gladysz@agh.edu.pl
3 Department of Power Engineering and Turbomachinery, Silesian University of Technology, 44-100 Gliwice, Poland; lukasz.bartela@polsl.pl
4 Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, 30-059 Krakow, Poland; ansow@agh.edu.pl
* Correspondence: staffanq@gmail.com

Abstract: Out of 2 TW_e of coal power plant capacity in operation globally today, more than half is less than 14 years old. Climate policy related to limiting CO_2-emissions makes the longer-term operation of these plants untenable. In this study, we assess the spectrum of available options for the future of both equipment and jobs in the coal power sector by assessing the full scope of “retrofit decarbonization” options. Retrofit decarbonization is an umbrella term that includes adding carbon capture, fuel conversion, and the replacement of coal boilers with new low-carbon energy sources, in each case re-using as much of the existing equipment as economically practicable while reducing or eliminating emissions. This article explores this idea using the Polish coal power fleet as a case study. Retrofit decarbonization in Poland was shown to be most attractive using high-temperature small modular nuclear reactors (SMRs) to replace coal boilers, which can lower upfront capital costs by ~28–35% and levelized cost of electricity by 9–28% compared to a greenfield installation. If retrofit decarbonization is implemented globally by the late 2020s, up to 200 billion tons of otherwise-committed CO_2-emissions could be avoided.

Keywords: retrofit decarbonization; decarbonization; climate change; repowering; renewable; nuclear; coal; CO_2

Citation: Qvist, S.; Gladysz, P.; Bartela, Ł.; Sowiżdżał, A. Retrofit Decarbonization of Coal Power Plants—A Case Study for Poland. *Energies* **2021**, *14*, 120. https://doi.org/10.3390/en14010120

Received: 12 October 2020
Accepted: 22 December 2020
Published: 28 December 2020

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).

1. Introduction

Power sector emissions represent the largest source of greenhouse gas emissions globally, and coal-fired power stations are the biggest source of emissions within this sector [1]. To avoid the worst impacts of climate change, rapid decarbonization of coal-heavy economies is essential. It is the ambition of this study to assess:

- To what extent existing coal power plant assets may play a role in a future decarbonized power system, either by adding carbon capture, replacing the feedstock to biomass, or replacing the coal boilers with low-carbon energy sources.
- What the most effective retrofit decarbonization options are for the most modern coal units in operation or under construction today.
- Whether such replacements or retrofits makes technical and economic sense, compared to abandoning existing coal plant assets entirely and building a new low-carbon power system from scratch.

In existing decarbonization strategies, two major pathways have been suggested for the future of existing coal power plant equipment:

Energies **2021**, *14*, 120. https://doi.org/10.3390/en14010120 www.mdpi.com/journal/energies

SUPPORTING INFORMATION

For “Retrofit Decarbonization of Coal Power Plants – A Case Study for Poland”

1. Description of a Coal Power Plant and Associated Equipment

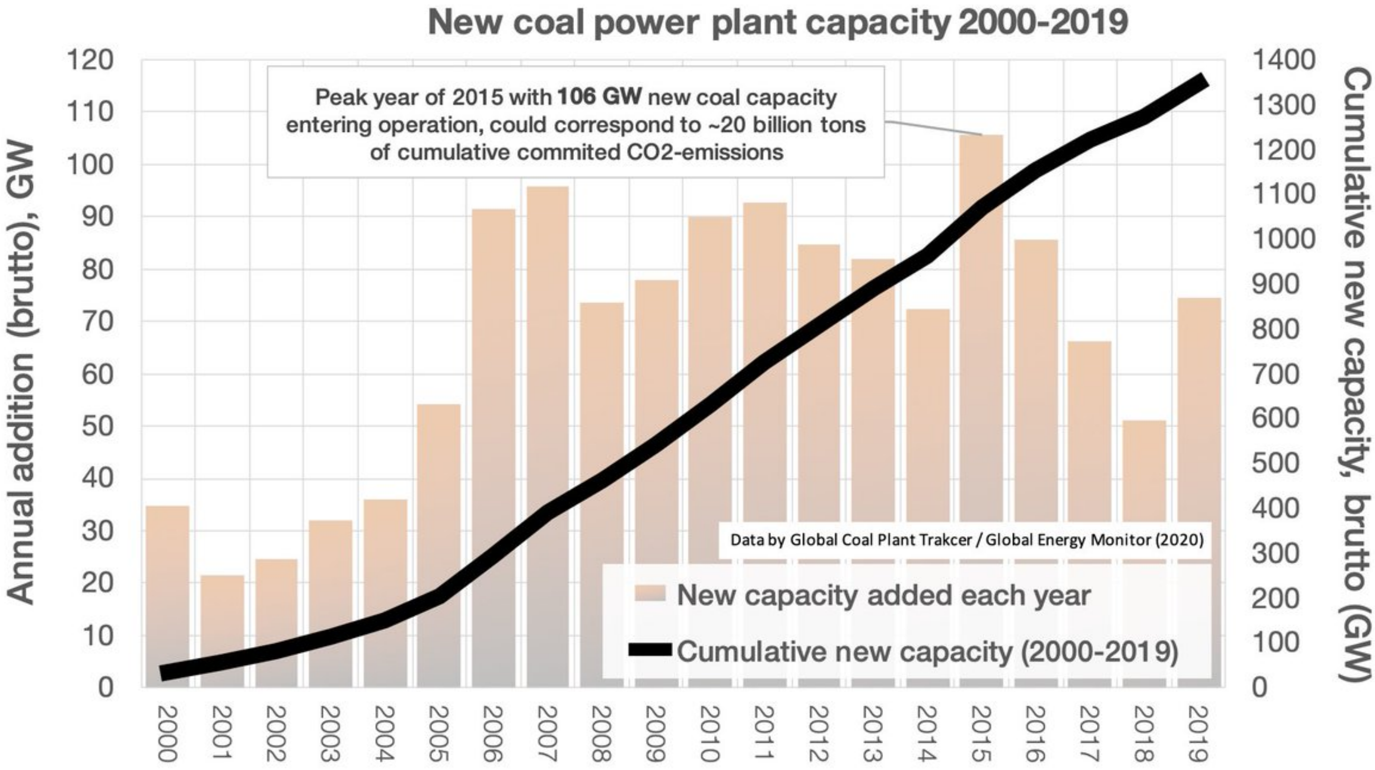
An overview of a coal power plant site, showing the typical main components and equipment, is given in Figure 1.

Figure 1. Coal Power Plant Site Layout and Major Components.

The equipment available at a coal power plant site will vary both with the plant power output, the type of coal it uses, and its location. A larger coal plant (above 500 MW_e) will often feature one or more individual coal units and *high-voltage* transmission grid connections, while smaller units may be connected to lower voltage distribution grids. Plants located at large bodies of water will in most cases make use of open cycle condenser cooling and will not have cooling towers, whereas plants sited away from water or by smaller rivers are equipped with cooling towers. Due to the very large throughput requirements for fuel and ash handling, most coal power plants that are fed by hard (or “black”) coal have either a railway connection or port infrastructure, sometimes both. Brown (or “lignite”) fired coal power plants are typically located at the mine mouth and are fed with lignite by conveyer belt directly from the mine, avoiding the need for other coal receival infrastructure. Plants typically store enough coal on site for at least a couple of months of operation. As the coal is combusted, very significant quantities of ash is produced[1]. The ash can either be stored on or near-site in large storage ponds, or

[1] Coal ash is the non-combustible solid residue of coal. In a coal-fired boiler, some of the ash remains inside the boiler and is known as bottom ash. Fly ash is the fraction that is too small to settle out in the combustion chamber; it becomes suspended in the high-velocity flue gas. Air-pollution regulations require electric utility and industrial boilers to be equipped with particulate control devices to prevent fly ash from entering the ambient air.

[2/x] Out of ~2 TWe of coal power plant capacity, more than half is less than 14 years old. Can this infrastructure play a role in decarbonized power systems or must it all be stranded? We try to look at ALL options in this work, supported by @EnvDefenseEuro & Rodel Foundation.



[3/x] Capacity-averaged age of all coal power in operation today is ~18 years. Committed emissions from existing and under-construction coal power is ~300 GTCO2-eq (294 is our central estimate, IEA say ~328). Each new 1 GW-plant commits to ~0.2 GT additionally.

An estimate of the "**committed future emissions**" that *could result* from any new or existing power plant can be obtained from the following equation:

$$\sum CO_2eq[\text{kg}] = P[\text{MW}_e] \times 8766 \times \overline{\text{CF}}[\%] \times \left(T_\text{p}[\text{years}] - T_\text{eff}[\text{years}]\right) \times E_i \left[\frac{\text{kgCO}_2 eq}{\text{MWh}}\right] \qquad (1)$$

Where P is the power level in megawatts electric (MW_e), 8766 is the average number of hours in a year (including leap years), $\overline{\text{CF}}$ is the average capacity factor from today until the end of plant operation, $T_{physical}$ is the total number of years that the plant will operate and $T_{effective}$ is the apparent current age of the plant in comparison with a new asset of like kind.

Equation 1 can give a rough estimate for the committed emissions per 1 GWe of new coal plant capacity. We can apply a $\overline{\text{CF}}$ of ~50%, E_i of around 850 $kgCO_2$/MWh and T_p of 55 years. T_{eff} for a new plant is by definition zero. The possible committed emissions from such a plant are therefore ~200 million tons of CO_2. Varying the values of parameters of $\overline{\text{CF}}$, T_p and E_i in reasonable ranges ($35\% < \overline{\text{CF}} < 50\%$, $40\text{ y} < T_p < 65\text{ y}$, $800\text{ kgCO}_2/\text{MWh} < E_i < 1050\text{ kgCO}_2/\text{MWh}$) gives a span of 100-300 million tons of CO_2.

[4/x] We define the term RETROFIT DECARBONIZATION to include _anything_ done to keep existing some coal plant equipment in operation (>5 % of org. plant capex), approx. maintaining its function (>50 % of org. annual generation) while eliminating emissions (<50 gCO2-eq/kWh).

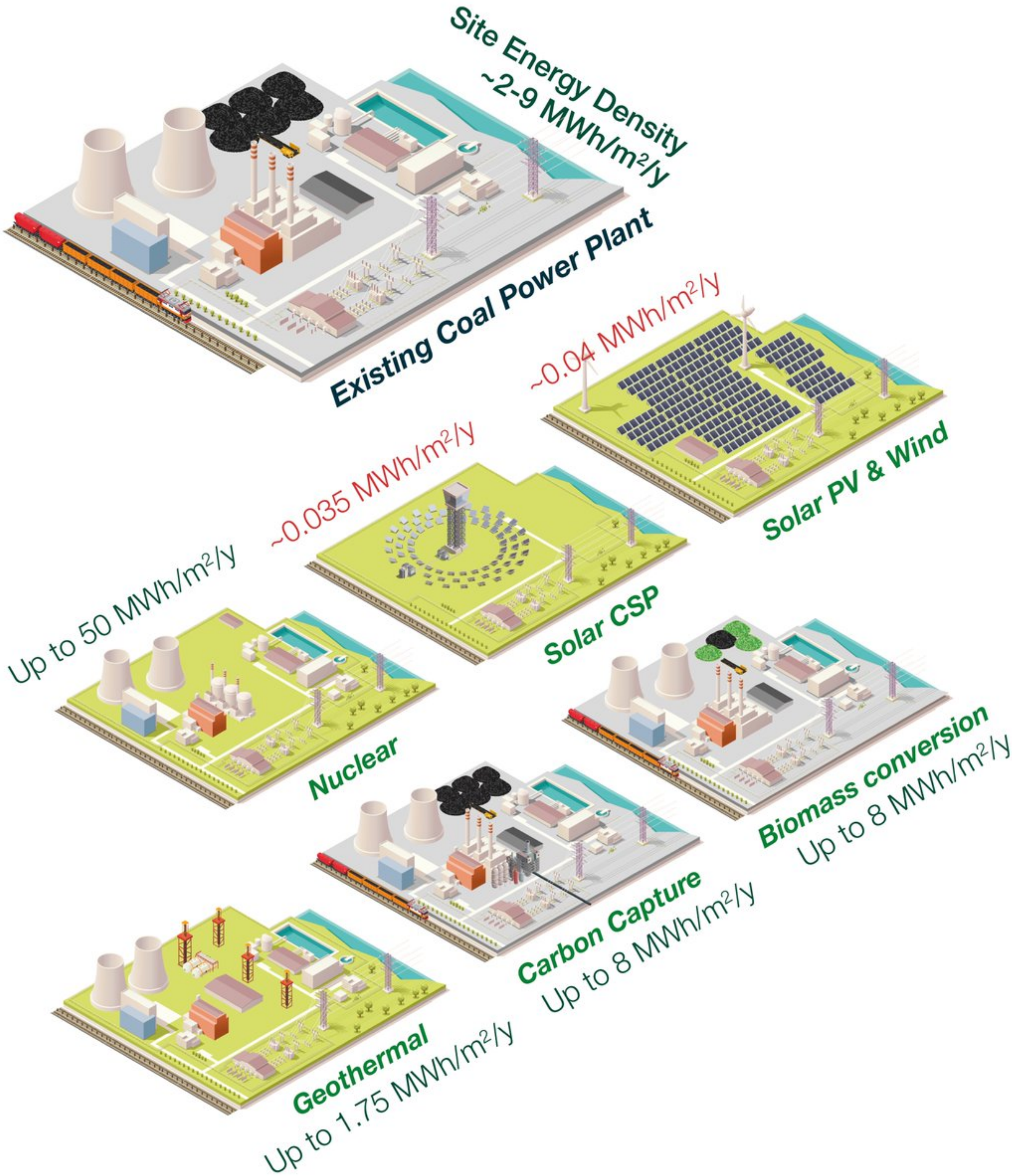
"**Retrofit Decarbonization**" of coal power is an umbrella term that encompasses:

- The repowering of a coal power unit with a new low-carbon energy source
- The conversion of feedstock from coal to a *sustainable sourced* biofuel
- The retrofit installation of carbon capture at a coal power unit

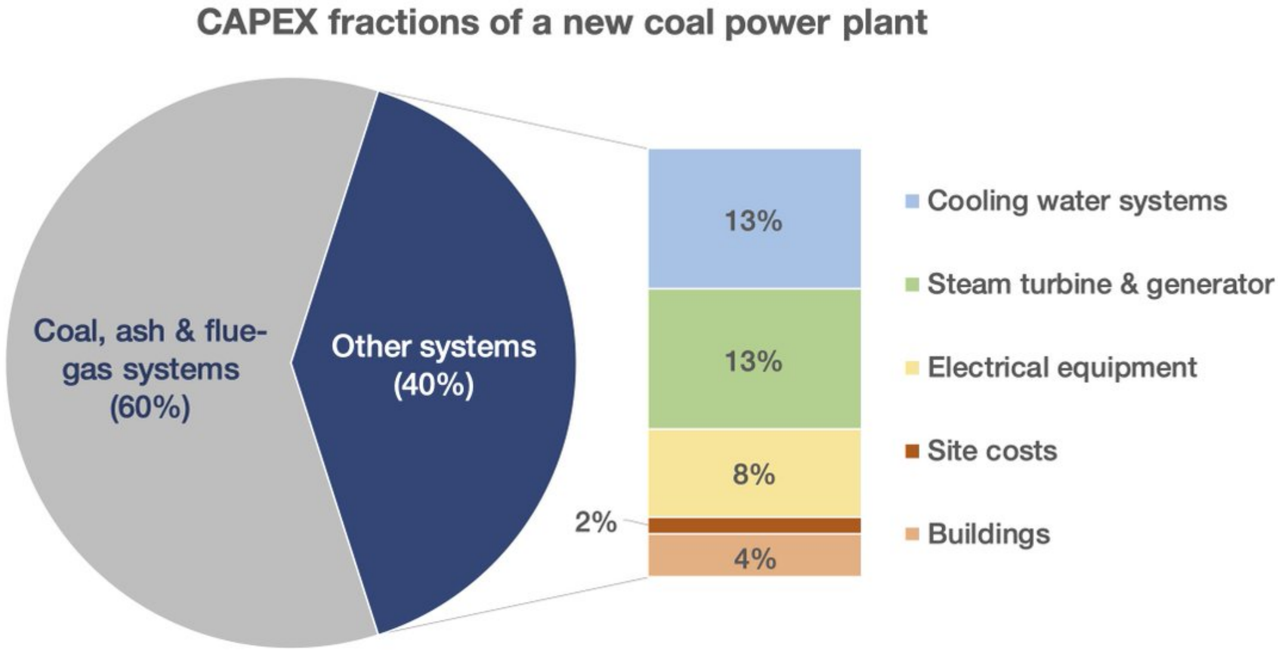
To qualify as a retrofit decarbonization project, the decarbonized plant must fulfil the following objectives:

1. Lifecycle emissions lower than 50 gCO_2-eq/kWh
2. Maintaining an annual energy production (electricity and/or heat) of at least 50% of the reference value of the coal unit within the existing site footprint. (>1 $MWh_e/m^2/y$)
3. Existing coal plant equipment, representing at least 5% of original plant capital expenditure (CAPEX), is re-utilized and remains in operation at the retrofit decarbonized plant.

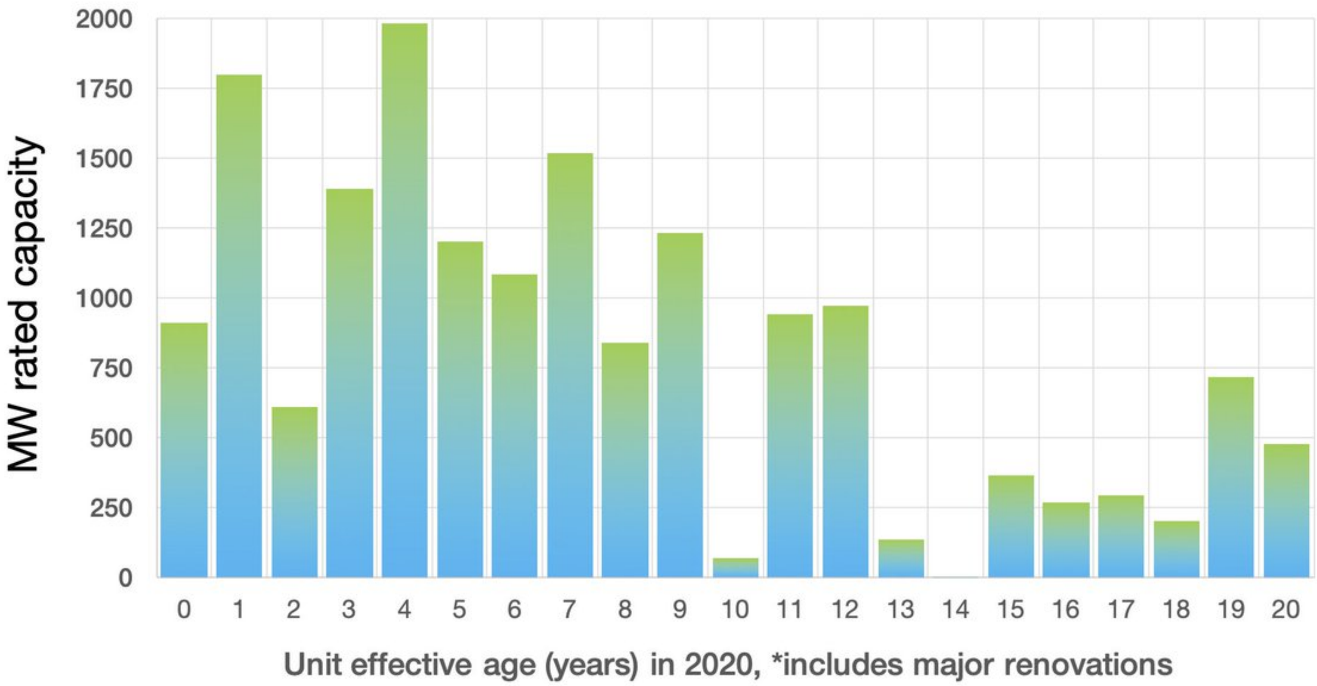
[5/x] Many retrofit options were assessed (some shown here). Emissions reqs. put tough pressure on biomass & CCS. Putting wind & solar at former coal sites is a great idea, but power dens. diff. mean they don't qualify as retrofit decarb. What really works? Geothermal & Nuclear!



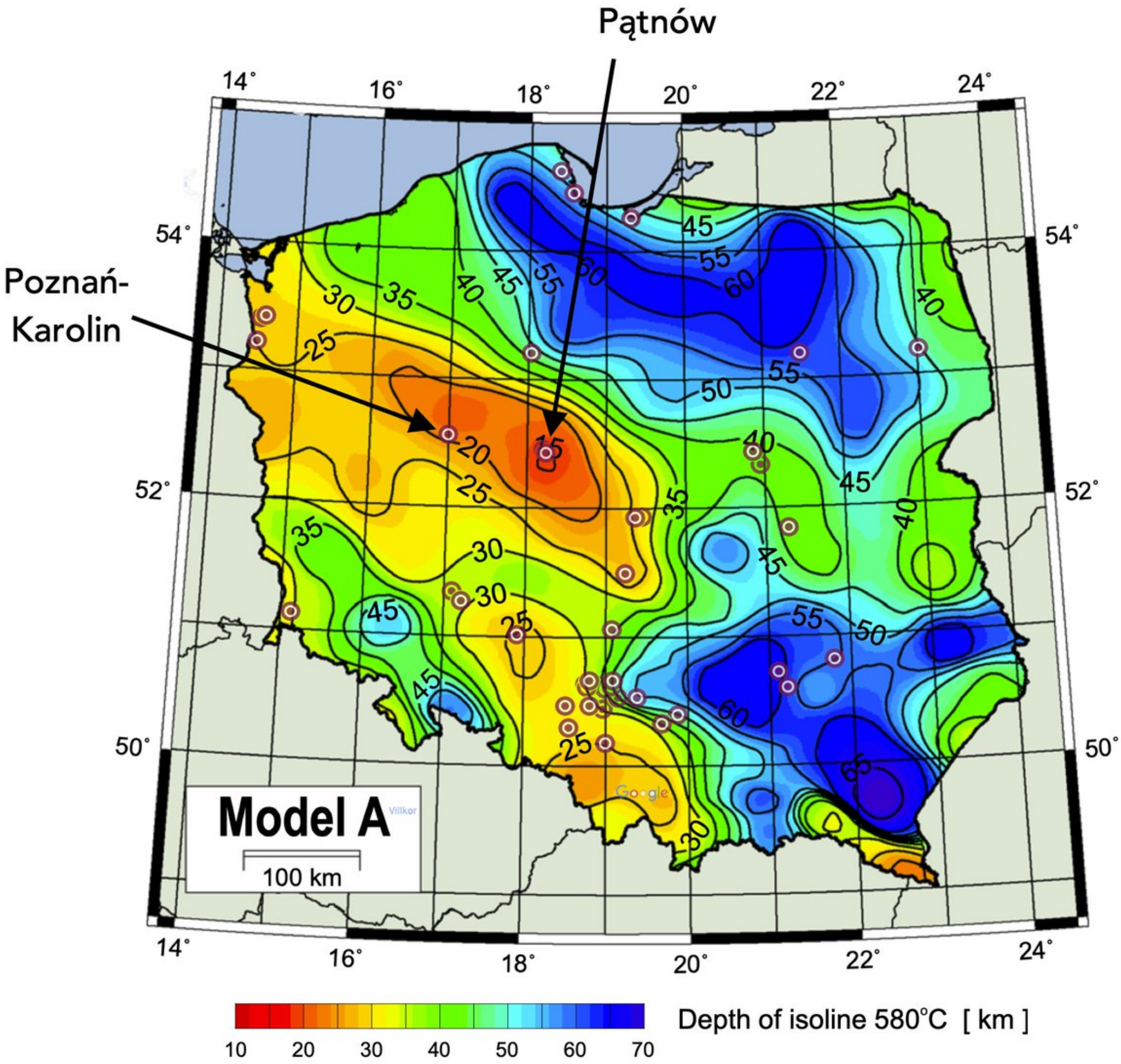
[6/x] Integration with existing equipment (and the state of that equipment!) determines savings vs. greenfield project. Re-using site + general buildings + grid can "save" up to 14-20% of org. coal CAPEX, re-using everything not related to the combustion of coal, up to 40-50 %.



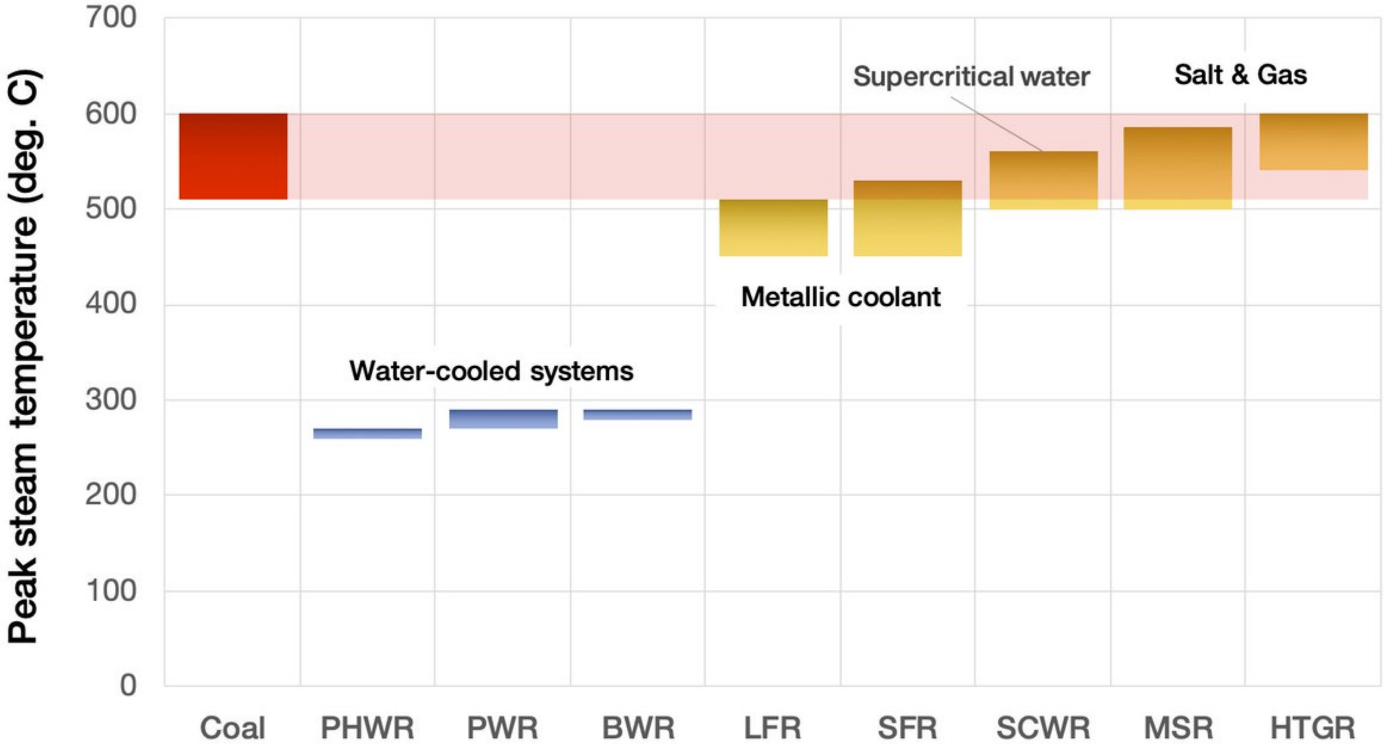
[7/x] Determining the potential of the idea requires the detailed characterization of the existing coal power plant fleet, including effective age, sites, steam conditions etc. We made a detailed survey of Poland for the case study, applying constraints for age and size.



[8/x] Geothermal heat can be used to repower existing coal plant steam cycles. However, very high-temp (very deep-drill) sources need to be tapped close to existing plants. In Poland, this can conceivably become possible at the P■tnów site (580C at 15 km) in the future.

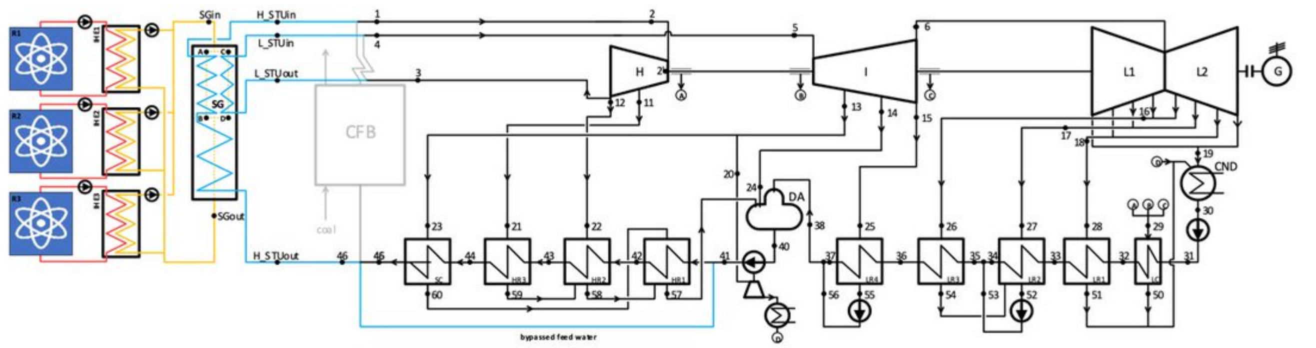


[9/x] Nuclear heat can be used to repower full coal steam cycles at any location, but direct/full integration requires advanced high temp. systems (not water cooled) with minimal EPZ (at site-boundary). More extensive turbine modifications could make LWR SMR repower possible.

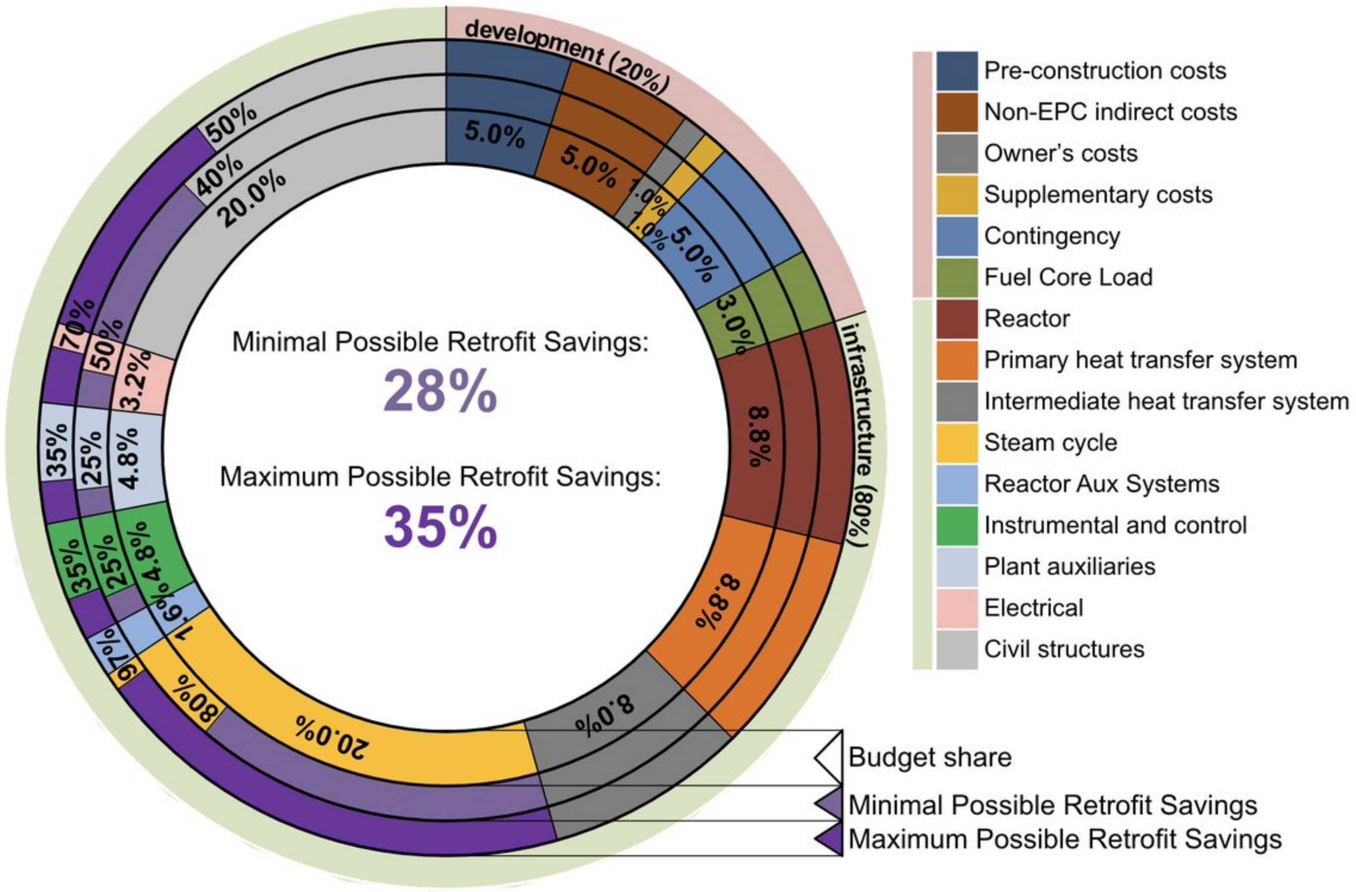


[10/x] We studied combinations of full integrations of three advanced SMRs: HTR-PM (@Tsinghua_Uni, CHNG), KP-FHR (@KairosPower) & "generic-MSR" -and three coal units. All can be done with minor modifications, saving costs vs. greenfield. Three technical papers on this coming soon

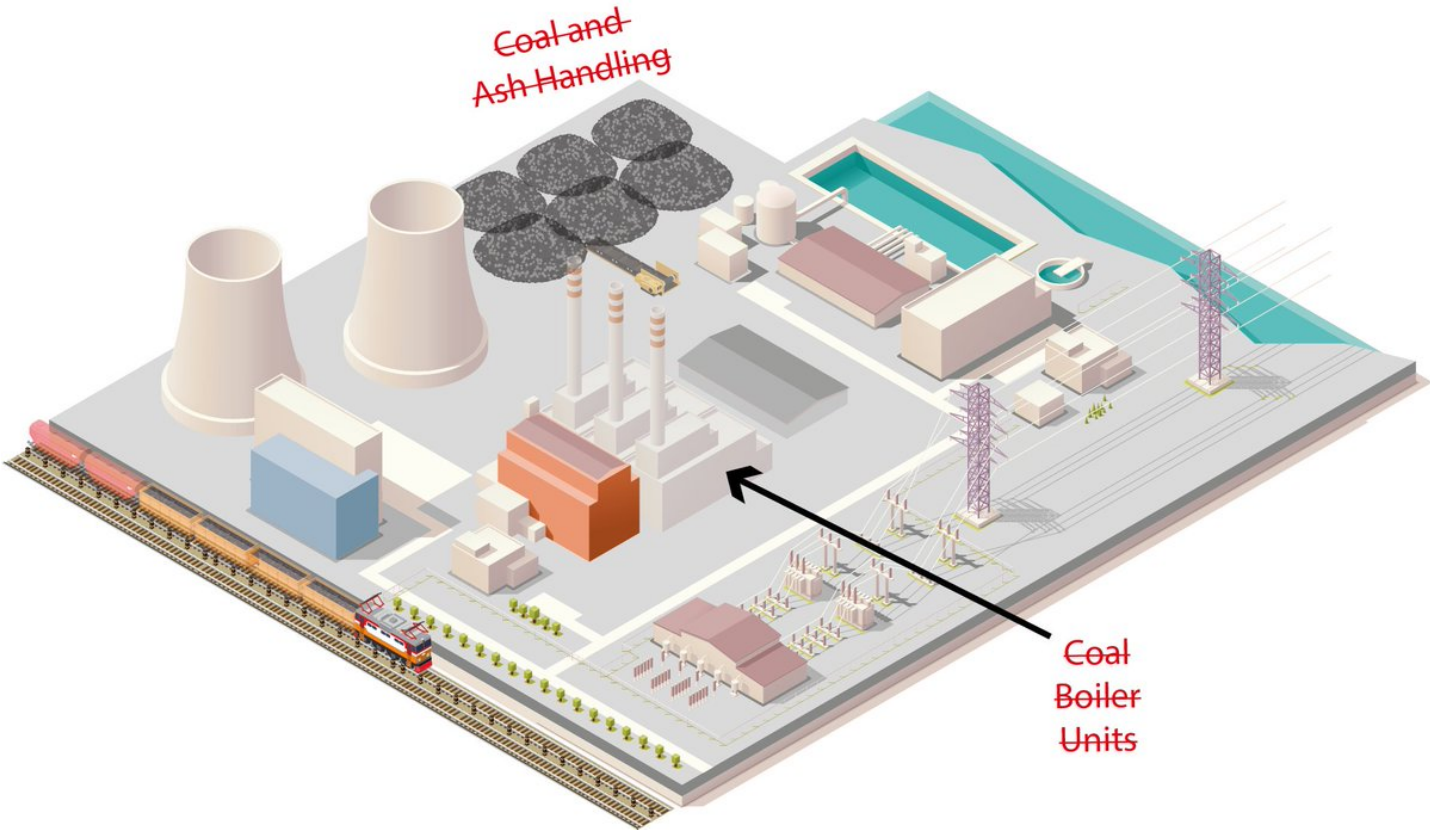
3 x KP-FHR coupled to Łagisza B10 (460 MWe)



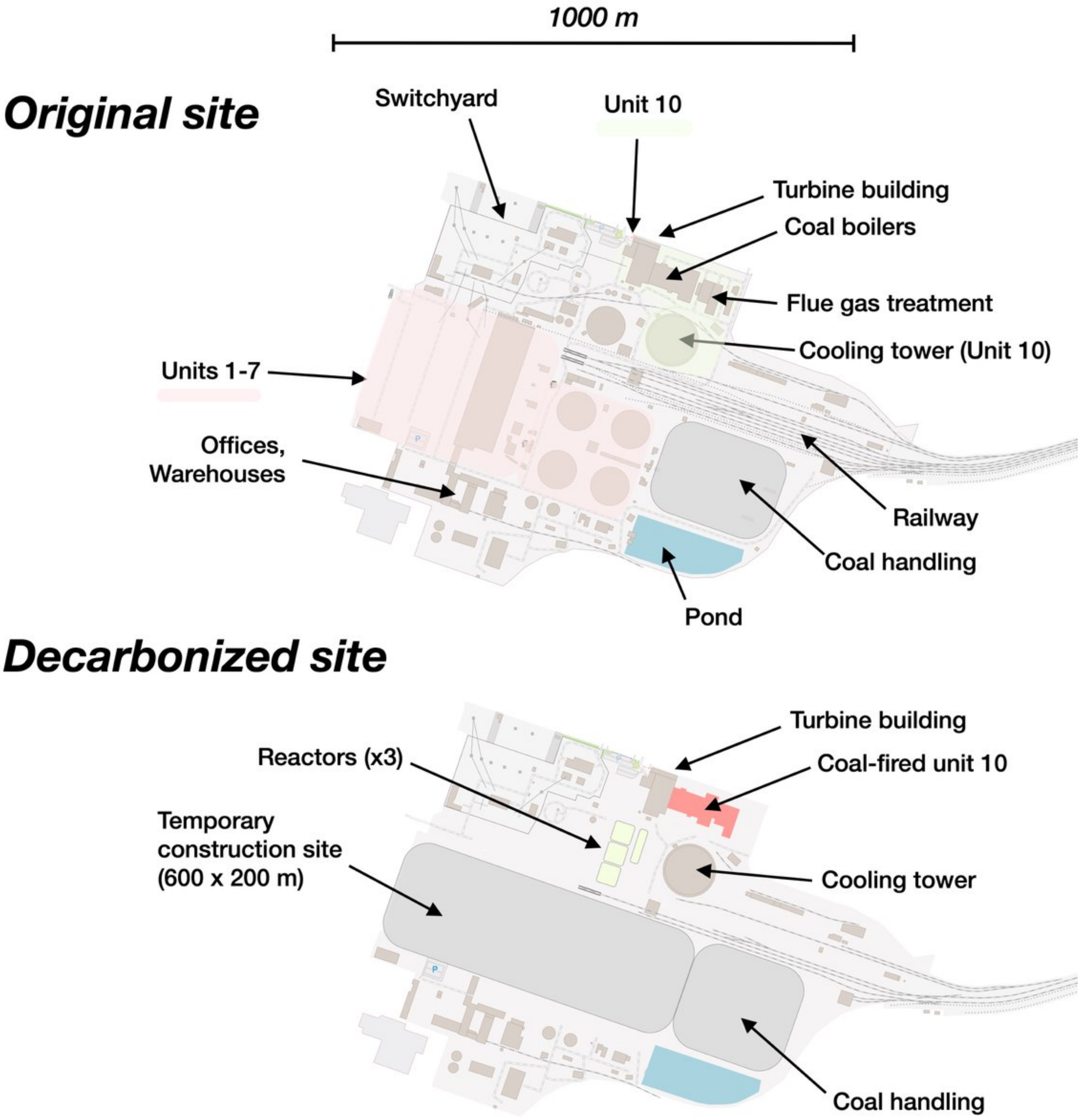
[11/x] Net cost savings in terms of avoided (deferred) upfront CAPEX is ~28-35 %, translating to a reduction of LCOE of ~9-28 % vs. greenfield. If greenfield costs are very high, retrofit costs are lower but still high. If greenfield costs are competitive, retrofit even more so!



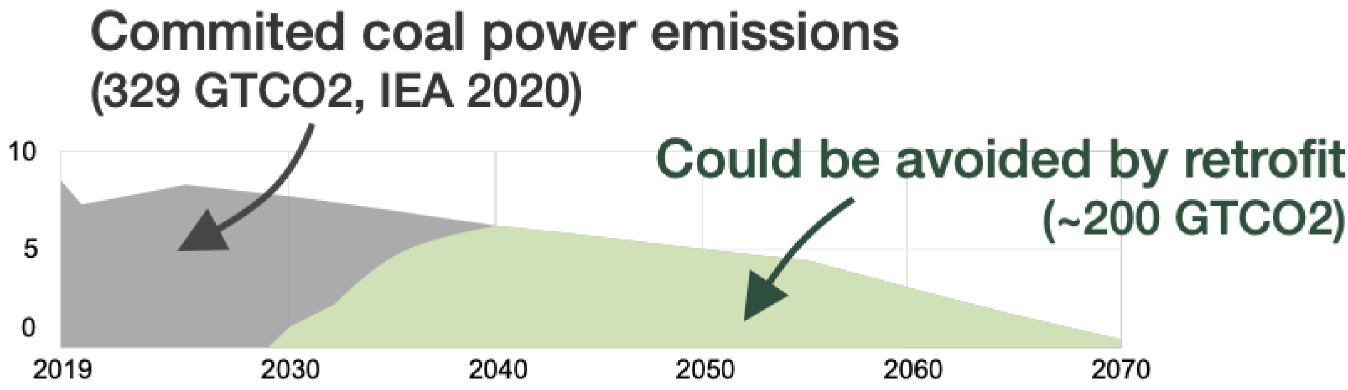
[12/x] What would the process of retrofit decarbonization look like step-by-step? Somewhat simplified illustration: 1. Decommission & clean-up coal-related equipment. 2. Establish construction site & build 3. Live happily firm-low-carbon ever after :)



[13/x] We looked in detail particularly on whether the required construction sites could be established, and how site layouts would work with retrofit. Some examples layouts for SMR here (■agisza, Po■aniec, Kozienice, Chorzów), even more detailed work on this to follow.



[14/x] "Decarbonisation is about two things: Building stuff and closing stuff" (Quote Prof. @emilygrubert). Coal power retrofit is an idea that could do both in one fell swoop! It CAN also make the firm power component of a decarbonized power system cheaper and quicker to build.



[15/x] VERY exciting new round of work beginning now! Includes: studying modifications to accept lower grade steam (opening up for lower temp geothermal and LWR SMRs), detailed case studies across China, implementation study for Polish industrial co-gen and much more!

[16/x] Thanks to @PawelGladysz, @BartelaUkasz & A. Sowi■d■a■ for great work! Thanks @EnvDefenseEuro & Rodel Foundation! Thanks to Quadrature Climate Foundation for supporting the next phase (w. @cleanaircatf). Questions or want to contribute? Please contact me! Happy new year!

[17/x] Finally many thanks to @bryworthington, who initiated this work!!