Recommendations for a Coal to Nuclear Transition Using Small Modular Reactors

Examining Benefits, Challenges, and Steps Forward for Repurposed Coal Power Plant Sites

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Acronyms:

The following terms will be used throughout the paper. To ensure readability and brevity, acronyms will be used frequently. These acronyms can also be found in the primary cited sources covering this topic.

C2N - Coal to Nuclear
SMR - Small Modular Reactor
LCOE - Levelized Cost of Energy
ESP - Early Site Permit
CPP - Coal Power Plant
NPP - Nuclear Power Plant
NRC - Nuclear Regulatory Commission
CFR - Code of Federal Regulations
EPA - Environmental Protection Agency
DOE - Department of Energy
FERC - Federal Energy Regulation Commission
BWR - Boiling Water Reactor
PWR - Pressurized Water Reactor

Executive Summary:

As we transition to low carbon energy infrastructure, many coal power plants are expected to be decommissioned. Normally, these sites would not be repurposed. However, developments in SMR technology would allow former CPP sites to become nuclear plants, with a reduced construction time and potentially quicker deployment than a traditional NPP.

The increased availability of nuclear power alone provides many benefits, especially regarding energy availability and reducing emissions. When coupled with a C2N program, more local scale benefits can be realized. Any local community stands to benefit from such a program due to the influx of nuclear energy professionals and technicians, and energy availability. Furthermore, such a program would help ease the economic tensions that a low-carbon transition requires by restoring economic activity in a community that once was close to a fossil fuel power plant. While SMRs in a C2N may not meet the possible performance metrics of a purpose built NPP, it can help with a speedy deployment of clean energy in communities that would otherwise have been left behind.

Facilitating a C2N will have several hurdles in regulations and governmental guidance. While SMRs will be a critical component of a C2N, this technology is relatively new, with only one licensed design available. Furthermore, operating any nuclear plant must comply with NRC regulation under 10 CFR. In this document, we recommend revisions to Part 50 and Part 52 of 10 CFR that will facilitate operations of a plant with SMRs and the manufacturing of SMRs as well. There are additional obstacles for implementing a C2N with chief concern being coordinating efforts between state permit requirements that would satisfy NRC licensing stipulations. Ultimately, a C2N facilitated by SMRs should be conducted in a dedicated program or pathway under NRC review.

The success of a C2N transition will require close collaboration of state and federal governments in a regulatory framework that is dominated by federal statute but made more nebulous at state level. It will have wider reaching implications, ranging from the feasibility of wide SMR applications and stresses on our nuclear fuel infrastructure to international resiliency and security concerns. Most importantly, it can play a role in enabling a new national clean energy infrastructure that can keep up with growing electricity demands without leaving communities behind.

Background:

The concept of a C2N is taken seriously due to the tangible benefits it may offer, most of which are socioeconomic and local in their impact. The first and foremost I would like to point out is the increased cost savings and deployment speed. The reuse of a coal power plant site can bring in an estimated 15-35 [1] percent reduction in costs compared to establishing a traditional nuclear power plant. While perhaps not the most spectacular savings on first inspection, it is important to remember that nuclear energy provides the highest capacity factor for a non-carbon energy source. Additionally, it is capable of high energy output regardless of geography, time of day, and weather. In fact, typical nuclear plants have double the capacity factor of coal plants. While a SMR based proposal may not exactly meet the performance of large nuclear reactors, SMRs will remain well ahead of what even the most advanced coal furnace offers in terms of energy output and emissions. This is not accounting for the reduced timescale in construction due to reuse of an already zoned power plant site. While there will be a need for further technical feasibility evaluation, we cannot ignore the advantage of speed and costs in C2N. The combination of generally lower costs and reduced development time will have a significant impact on reducing the levelized cost of energy. The LCOE sensitivity to both development time and dollars per kilowatt hour promise a quickly developed and readily available source of affordable electricity.

The DOE has identified many suitable sites for the deployment of SMRs in former coal plants, most of which are in the American Midwest and Southeast. These communities will greatly benefit from the introduction of SMRs for a C2N transition. First and foremost, this plan prevents what would have been the complete end of a major source of local tax revenue and economic development. Not only will a C2N bring back jobs, but it can also potentially bring back many more than there were before, with the DOE estimating up to four times increase in permanent jobs, beyond the temporary workforce necessary for construction. While claims of increased permanent jobs abound, it is important to note that these will not be the only employment opportunities that result from said project. To house, provide groceries, insure, and otherwise support these new community members will require an expansion of local firms and businesses. Developing the supporting infrastructure would be expected to hire more in the area too. Quickly, the influx of professionals will result in sustainable growth in this community. Given the economic troubles rural communities may face, especially in the Midwest and southeast, such influx will play an outsize role in not only mitigating the harms that decarbonization may play, but instead providing a new path to prosperity altogether. Indeed, given that many coal plants are sited away from higher population density areas, a C2N transition may be an energy decarbonization proposal that specifically

addresses the needs of rural communities better than more common ideas of rooftop solar permitting or the proliferation of electric cars and charging stations, which predominantly support suburban and urban residents.

The presence of a nuclear plant in the area is projected to provide a significant increase in the tax revenue for local governments. The DOE claims an increase of up to 92% [1] though the actual value will vary depending on state, county, and municipal regulations. This revenue increase should not be ignored, and in fact will help complement the increased prosperity through employment described earlier. Chronic underfunding and lack of availability of emergency resources and general infrastructure have been a major issue for many rural communities, which has been a contributor to their population decrease and difficulties with economic growth. The substantial increase in tax revenue that a C2N would provide would allow these issues to be rectified and addressed, further enabling local businesses and residents to improve their standard of living. An important point to make on this matter is that an increase in locally sourced revenue would allow local governments to spend as they see fit, not by imposition of an external governmental body. This will be an important point as many communities are keen to turn down external funding due to concerns about independence and control. While we can expect a temporary increase in money spent in the area due to construction of the plant and associated infrastructure, the tax revenue increase will be permanent and may not need to fund projects related to the plant operations.

While I have spent time outlining the increased availability of energy as an important benefit, it is necessary to point out the implications. Access to electricity is fundamental for all activities, commercial, residential, governmental, and so forth. When combined with renewables and storage options [2] households will benefit not only from a lower electricity bill which leaves more income available for shoring up financial stability or spending on other needs, but for some it may even be the factor of consistent electricity itself. With the increased temperatures from climate change, and examples of the increased grid load causing brownouts due to AC use, the availability of energy for a community may play an important role in its resilience, financial and otherwise. Commercial operations need large amounts of electricity across the board. Keeping lights on, maintaining servers, or even ensuring the LCD panel of a cash register stays on all contribute to a firm’s costs - which would be reduced by the availability of a lower energy bill. This doesn’t account for heavier uses, such as manufacturing. An increased quantity of electricity itself may be the last hurdle a firm needs to expand or begin operations in an area where power is especially unreliable. This is not far outside other proposed uses of SMRs - powering factories of remote communities.

The fulfillment of a C2N transition will make use of advanced technologies not yet deployed at scale. Small Modular Reactors will play a key role in such a plan, and these designs offer improvements over conventional reactors. Generally, most SMRs are specifically designed to rule out the possibility of a meltdown when coolant pumps are unpowered in addition to the baked-in design of the reactor vessel. This promises substantially improved safety, which will have two-fold effect: these can be sited closer to major population centers which increases the count of sites available for C2N and will also be more palatable in public awareness campaigns for projects. The latter point is especially important. Traditionally, public sentiment has stood as a major obstacle in the deployment of nuclear energy. In the NRC early site permit process, there are many steps that invite public commentary - simply ignoring community input will not be possible. Such an action would also stand despite the community-oriented benefits discussed above. This sentiment may change when the public is informed of the advances in SMRs that allow them to eliminate the risk of a meltdown by virtue of physical design. Communities will also be pleased to know that fueling and maintenance may not even need to be handled on site - a major premise of SMR deployment is the capacity for manufacturers to take the reactors offsite and service them in a factory. If such fueling is to be done, many SMRs offer design improvements to streamline and make the process substantially less risky. A faulty or depleted reactor could be moved in and out wholesale depending on design, bypassing the traditional means of taking out concrete fuel rod blocks by rail or truck. In general, SMRs offer safer nuclear power operations and address the most pressing of a community's concerns for safety.

One last point to address is that a C2N may mean the development of more energy options than simply nuclear energy. As it stands, nuclear energy provides reliable base load capacity. However, in times where even this is in excess, a nuclear plant could instead charge a battery bank or molten salt tank situated on site. This provides stored energy available for the community and even the plant itself. The practice of having nuclear energy provide base load power and the storage option providing peak support power reinforces the local energy grid. Depending on the local needs, it may even save money in the long run by eliminating the need for another power station. Such storage options can be placed within the exclusion zone around the plant sites, leaving it out of the way of the community and easily accessible to operations personnel. This is not to mention using the area for solar panels or wind turbines, though those don't promise the same resiliency as a storage option. While not explicitly in a C2N discussion, the potential to house and charge an energy storage option would be uniquely enabled by C2N and provide additional energy resilience to the community.

Findings:

Considering the benefits of a C2N just discussed, there is the obvious question of why this hasn't been done yet.

For most C2N projects, the deployment of SMRs will be a necessity. However, at present, only one SMR design has been licensed by the NRC [3]. Although it is encouraging that the NRC has begun examining reforms, this process will take time. While many firms are actively developing SMR designs, their fundamental nature as a newly deployed concept leaves some in industry hesitant to submit for NRC review, especially considering the expensive hourly review costs, according to an NRC official [16]. The NuScale SMR design that has been approved is also a light water design - while there are SMR concepts that use more exotic or advanced coolant types, the fact that the first and only licensed design relies on a proven technology demonstrates the relative infancy of widely deployed SMR use. This is the fundamental nature of a groundbreaking technical application. While NuScale has begun clearing a regulatory pathway, other firms will still face typical new technology design hurdles such as supply chain cost increases and expensive research hurdles [4]. Further development of and wider deployment of SMRs will be critical to facilitate C2N projects in the future.

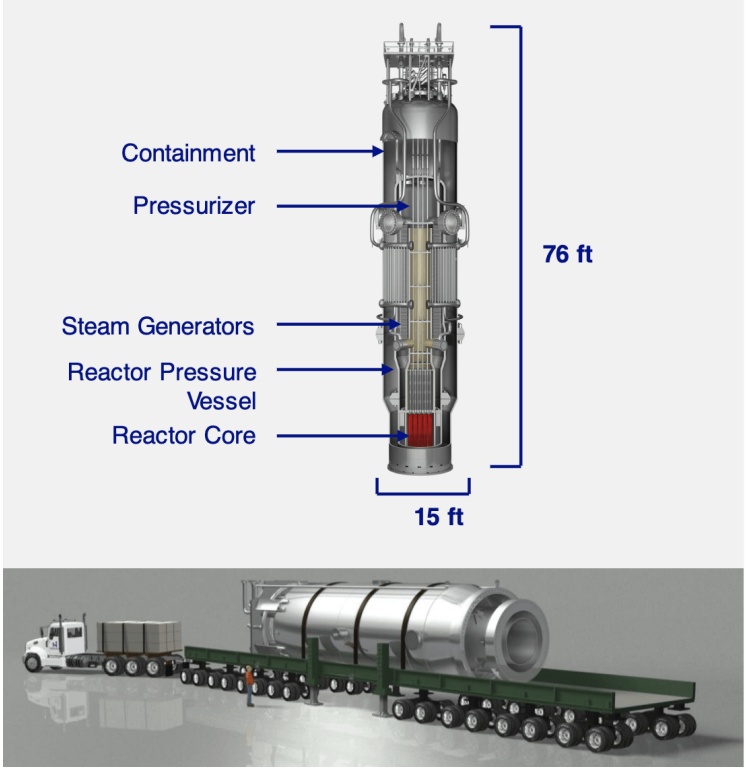

Fig. 1 [5] NuScale SMR Diagram and Transport Option

Federal law specifies that there are several licensing requirements for nuclear power plants [6]. First, a reactor itself must be designed and licensed - this has been done with the NuScale design. An Early Site Permit must be established that meets NRC requirements regarding plant resiliency, proximity, emergency resources, and more. A construction license must be given to the plant as well as an operations license for the plant and reactor. There exists a combined license for the operations and construction, but this is a path with its own financial risk despite the advantage in speed and timeline synchronization. For manufacturers, there is also a manufacturing license that governs how long a reactor design can be produced. While these licenses have means of renewal and transfer, they must be addressed for a successful C2N project.

Already, we have observed that design licensing presents one roadblock for SMR deployment. The manufacturing license, while not in the purview of a local power utility, will impact the costs and availability of SMRs. This license may limit the ability of a manufacturer to bring down costs through scale for any of their reactors, which in turn limits how many engineers and professionals will be trained to operate, and service said design, impacting costs and timelines which will make their effects felt in a C2N project.

Depending on the reactor design and total power output, there may be increased permitting requirements for resource use. Specifically, the EPA may be involved in

water use for the plant depending on contamination or even raw quantity [7]. This will be a set of Federal regulations that the project must either remain in compliance with from the coal operations days, or even renew and reapply for if water requirements are set to increase with the power output. It is important to note that SMR design, and core coolant, ultimately impacts water needs. While water will be necessary as an intermediary for transmission to the grid, the use of a more exotic coolant can rule out the risk of radioisotope contamination such as in a BWR.

Transmission permitting will play an integral role in a C2N project. Given that many projects anticipate higher energy output than in coal operations, new and refurbished transmission lines will need to be installed. Depending on if the coal plant has been decommissioned and for how long, factors such as scrapping, weathering, or even theft can necessitate the installation of new transmission infrastructure beyond what would normally have to be added for an output increase. This is an especially important point since the premise of a C2N lies in reducing costs and complexity by reuse of the local coal power plant infrastructure.

Safety remains at the forefront of nuclear energy licensing and operations. While traditionally the site requirements for plants have been static, the increased incidence of severe weather events, along with a more developed understanding of plate tectonics, means that updates to Early Site Permit requirements may limit the availability of potential C2N sites or at minimum increase the costs for some, not to mention the disastrous prospect of a site permit requirement update ruling out the site of a project under construction. Ironically, while nuclear energy can play a role in transitioning away from fossil fuels, the consequences of climate change have already begun forcing closures of nuclear energy plants [8]. While extensive technology exists to mitigate risks beyond the inherent safety improvements of SMRs, this is not a prospect to be ignored especially as the incidence of droughts and wildfires become more common in years to come.

Public opposition and NIMBYism, the traditional bane of nuclear energy plants, will again present an obstacle. These sentiments will persist regardless of the technical and economic benefits. Furthermore, the public at large remains divided on the subject. There are stark differences by gender and political affiliation, with those in support and opposition nearly at the same strength in national polling [9]. There will be two domains of public opinion that need to be addressed in any nuclear energy development.

The most significant obstacle to any C2N project may not lie with the NRC or public, but with the jurisdiction of the locations itself. State and local permitting requirements will hold ultimate determination if the project goes ahead [10]. While

Federal permit and license requirements from the NRC and EPA will need to be met, there are a plethora of construction, transmission, land use, site, and emergency management permits controlled by state and local governments that every project must satisfy. While we should not expect outright hostility, in fact the pioneering project in Wyoming is finding much support [11], this remains a critical obstacle. While the utility that will eventually operate this nuclear plant, being situated in the state will no doubt be aware and used to said requirements, it will make a national structure for facilitating a C2N transition much more decentralized and less straightforward to implement, if such a prospect is even necessary in the first place.

For any planned reforms, the current regulatory structure must be accounted for. As it stands, nuclear power plant operations are heavily regulated by the NRC. However, said plant must comply with a multitude of regulations set by states and localities for a variety of factors so legally operate. Emergency resources, right of way, water use, land and construction for non-NRC facilities, environmental reviews, and many other elements are dictated below Federal oversight. Furthermore, the prospect of reusing coal sites will involve the EPA's statues. For plant sites that have coal ash on site or any other outstanding issues with air or water pollution, any C2N process must account for both these additional regulations and any associated corrective actions. Such a prospect might make a transition much more difficult for these sites, if not rule it out entirely.

Nuclear energy will play an important role in a carbon-free energy grid. With current technology, renewable energy sources such as solar and wind are not capable of satisfying the energy demand curve:

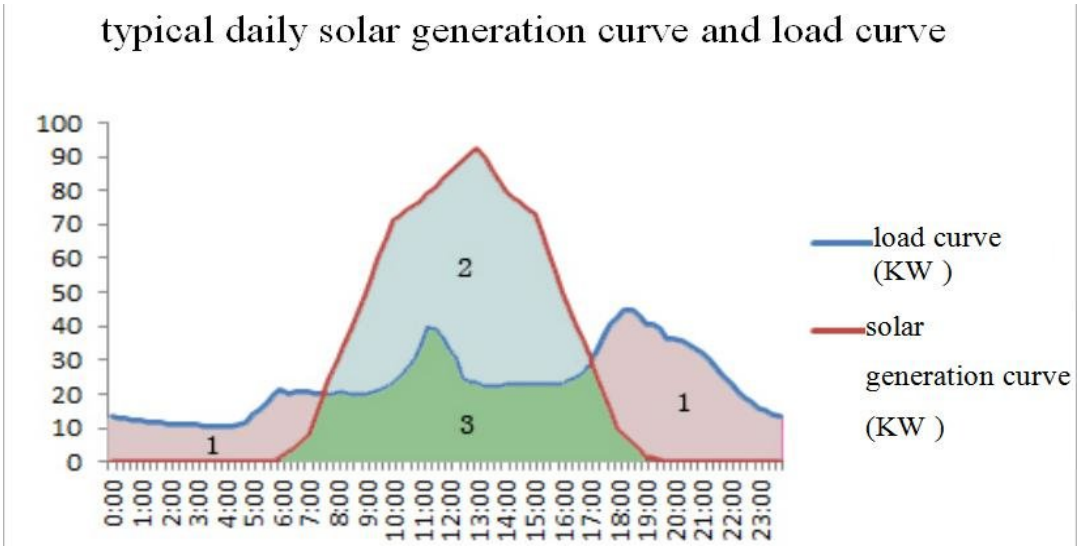

Fig. 2 [9] The Daily Demand Curve with Solar Energy

As seen, the solar supply curve will not track with load, undersupplying at many points and oversupplying at others. While it is possible to store the captured energy in battery banks or molten salt, the technology and adoption isn't there yet. Instead, nuclear can fill the gap in solar output, supplying energy needs at and above minimum demand. This is the niche coal plants currently occupy in our energy infrastructure.

Recommendations:

Reform Priorities:

1. **NRC Considers Local Level Requirements for the ESP**
2. **NRC Amends Title 10 CFR, Chapter I, Part 52 (a)(1)(ix) to support reactor mobility**
3. **Local authorities should grant exemptions for storage and renewable energy facilities.**
4. **NRC revises 10 CFR Part 52.153 (a) so that an SMR can be transported and installed in a facility that meets ESP and other requirements if site requires minimal construction.**
5. **NRC reforms 10 CFR Part 52.173 to accommodate longer SMR production runs.**
6. **Local authorities waive permits when ESP is granted, coal plant still active, and/or minimal construction necessary.**
7. **Incorporate permitting into National Interest Electric Transmission Corridor Designation Process**
8. **Provide financial incentives to power utilities and SMR manufacturers**

To successfully promote a C2N transition of coal power plant sites, a **very clear regulatory framework and path must be established**. This pathway must also comply with established federal regulation of nuclear power under NRC oversight, with special emphasis on early site permit, design license, and manufacturing license compliance.

1. **Enable the NRC to substitute state and local requirements in the early site permitting process**.

For any properly decommissioned coal plant, or active coal plant expected to undergo transition, that is in regulatory compliance, NRC early site permitting should be allowed to accept state and local standards as substitutes for NRC mandate if they meet or exceed the nominal NRC requirements. While the early site permitting process will have specific clauses related to nuclear emergency readiness state and local agencies cannot permit for, other elements that would include the exclusion zone radius that are up to standard should be included. Given the wide range of non-Federal power plant standards, the most realistic pathway would be for states to submit waivers for ESP requirements based on their own laws that would comply, allowing for speedier review. Given the multitude of requirements that would require waivers, and the fact that the

NRC personnel will be limited in capability at this point, these standards should be collected in a dedicated program. Such a program would have all substitution requirements from states available for review in one document or set of documents, with personnel available to review state submissions and render judgment with commentary. **Such a system would be preferable to an ad-hoc measure that concerns itself with each C2N ESP application**, where standards for exemption may vary to the point that substitution in practice could slow the process. This level of work will not necessarily start from scratch; the Idaho National Laboratory GIS data process that identified many suitable C2N sites could serve as a starting point that helps regulators determine which lower-level area requirements should take priority [17]. An explicit program, or at least process, to identify which state and local requirements satisfy ESP statutes can help facilitate sitting reviews for these C2N capable coal plant locations.

Regardless of whether a “suitable substitution” practice or program is implemented, the siting process for a C2N transition can still be expedited. This is simply the **proposal to give consideration for the site review of a coal plant site to be given priority over other new site proposals.** In addition to giving the ESP for said project a quicker review, it will also incentivize industry to place greater emphasis on selecting former coal plant sites, allowing the idea of a C2N to gain traction outside of regulatory agencies and think tanks.

In addition to these general practice reforms, there are federal regulations that ideally can be directly amended in future regulation. The adoption of SMRs, playing a critical role in C2N, would benefit greatly from the following changes:

(2) The NRC should amend Title 10 CFR, Chapter I, Part 52 (a)(1)(ix) to include the possibility of swapping reactors.

At present, the regulatory language for a safety assessment implies the understanding that a singular immobile reactor design will be present. This will not always be the case in a SMR based C2N transition. The reactors can be swapped in and out depending on design, which will entail a powering down operation, movement out of the containment building of the powered down reactor, moving in of new reactor, and powering up of the new reactor. This regulation should ideally be amended to account so that movement in and out of new reactors should not require new safety certification, only that the certification should be granted on the premise of all available reactors operating at the same time. However, this will also mean that the regulations in Part 52 should be updated to account for the unique risks associated with the movement in and out of the containment building at different levels of fueling. Although the imposition of another set of safety review may prove onerous to utilities, it will help reduce the difficulty of fueling

associated permitting by providing plant operators with an operations path that does not involve site nuclear materials and fuels processing whatsoever. **Title 10, Chapter I, Part 52, Subparts A and C require additional examination focused on SMRs**. Based on the author's reading and understanding, these sections could use more language that accounts for SMR deployment. In a C2N case where the utility has not already selected the final SMR design, the project should begin with the early site permit process specified under subpart A, ideally including the reforms identified earlier. In the case that a utility has already selected a SMR design, it would be advised that the project be subjected to the combined license process specified in subpart C which will likely lead to a shortened timescale. In practice, most utilities and operators would opt for the latter portion as it would allow for quicker deployment, and therefore a quicker return on investment. Establishing in writing that a C2N transition would go down one of two paths depending on SMR selection would help establish guidelines once the process begins of adopting SMRs at scale.

There are considerations for site permitting beyond the nuclear element. The exclusion zone of any power plant will remain unsuitable for population by regulation and likely contamination from coal combustion residuals. However, this does not necessarily mean such land cannot be used for other purposes.

(3) State and local authorities should grant permit exemptions for storage and renewable energy facilities sited in the exclusion zone of a plant with an approved early site permit.

The value of a nuclear power plant is its consistent output of energy 24/7. This power output will not necessarily match the consumer's daily demand curve. At times when the plant's output is in excess, the power could be used to recharge battery banks or molten salt tanks that could be used during peaking hours when the nuclear plant's output alone cannot meet the demand of consumers. Additionally, solar panels and some wind turbine designs could be sited within the exclusion zones in substitution or conjunction with these storage options. **Allowing this would turn the former coal plant site from a simple base load power plant to a versatile power plant that would improve the energy resiliency of the local grid and provide much more dispatchable energy.** While construction permitting will still be necessary for such facilities, the early site permit should rule out state and local site permitting entirely. Although the ESP is tailored for a nuclear power plant, its requirements and clauses set a high standard of safety for the public and safety of the plant itself due to the unique risks that nuclear energy may pose. Battery banks, molten salts, solar panels, wind turbines, and other clean energy technologies pose their own risks. However, the need to ensure nuclear safety sets a standard that should be more than manageable for these other

technologies. Furthermore, by allowing such clean energy projects to be sited with the nuclear plant, it provides developers with an alternative to the conventional option of sitting these on their own land. Providing utilities and developers with land already cleared for such facilities will undoubtedly speed deployment by ensuring they themselves might not need to jump through local permitting hoops and risk NIMBY intervention - not to mention the possibility of bypassing local prohibitions. With all the effort to establish a safe nuclear energy site, we should ensure that the full energy potential is unlocked.

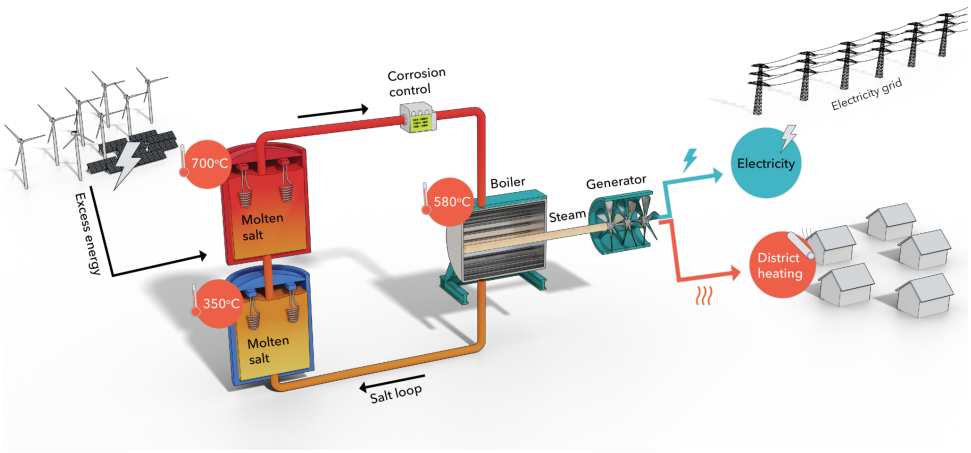

Fig. 3 [13] Molten Salt Storage in Conjunction with an Intermittent Power Source

(4) The NRC should revise 10 CFR Part 52.153 (a) so that an SMR can be transported and installed in a facility that meets ESP and other requirements if a full construction permit of the site is not necessary.

Although this will likely be a rare case, it should be accounted for. Part 52.175 (c)(1) may require further examination, not only to deal with the exceptional cases described above, but also to address the possibility of the manufacturer's establishment of a separate fueling and maintenance facility. While still an early concept, some SMR manufactures may eventually develop separate facilities if the demand is high enough that a factory will be too focused on production to economically fulfill other duties.

(5) The NRC should reform 10 CFR Part 52.173 to accommodate SMRs being manufactured at scale for a production run that can span years.

The manufacturing license could have the validity time extended beyond 15 years. A more practical accommodation would be to reduce the time period before expiration of the license from 3 years to a much shorter period. This latter change would have a significant impact on the operations for a SMR manufacturer - for smaller and less

established firms, a 3-year lockout would have a major impact on the timeline to finance operations, and therefore costs of reactors in the wider market along with the firm's own survivability. Furthermore, delays in other areas such as factory maintenance and fuel permitting may cut into the effective time of a manufacturing license, which may cause the lockout period to have proportionally greater impact on viable manufacturing lifetime. Once more SMR designs have been certified, the manufacturing license period should immediately be reformed. Continuing to address this, Part 52.177 (c) should be amended so that the manufacturing license renewal process should also be amended with a reduced locket so not to conflict with the above regulation. These reforms will be especially critical to the manufacturers of SMRs - even if C2N transition projects are not underway, a less stringent manufacturing license will allow reactors to be available for the multitude of other purposes that exist.

Beyond the reforms to federal regulations specified here, there are actions available at state and local level that need to be undertaken for the success of C2N projects. However, because of the wide range of lower-level requirements and the emphasis of this paper on federal elements, the following recommendations will be more founded on general principles:

Transmission permitting will play a critical role in a C2N transmission, just as if not more important than any work with SMRs. However, unlike SMR regulations, the process of permitting and construction of electrical transmission will occur under the purview of state and local governments. Furthermore, given that many C2N projects will result in higher energy output than the prior coal plant, it is likely that transmission will need to be upgraded to account for this.

(6) State and local authorities should waive permits when advised by the NRC, when a C2N project is active under any of the following conditions: an ESP has been granted, the coal plant is still active, or only upgrades to existing infrastructure is necessary.

In the event waivers are not possible, then authorities should still place priority on reviewing the permits. Additionally, when considering permits for the facilities they should reciprocate NRC acceptance of state requirements in previously discussed reforms. Even if there is no expedited or waiver process, the acceptance of stringent NRC site permitting regulations when they satisfy state requirements would assist the speed of transmission infrastructure permitting. This should also apply in the case for storage and other renewables on site, though in that case it is hoped acceptance of ESP standards will assuage the worries of state and local regulators or supersede them entirely if such is an obstacle to energy development.

(7) If no success is still to be found, then rolling into National Interest Electric Transmission Corridor Designation Process [15] could provide another path should that venture succeed.

While pending, this venture under the FERC may help expedite the deployment of necessary transmission to the C2N project and it may be worth examining rolling this into such a venture.

A public awareness campaign, conducted by state and local interests, would also facilitate a C2N transition. This would help address the public's fears and misconceptions of nuclear energy while providing a means of resisting NIMBY sentiment. State governments can enlist the support of local postsecondary institutions, NGOs, and community groups to communicate the realities of the project. While not a simple undertaking, research indicates that public opinion in recent years is beginning to round a corner [14], reducing the slope of this uphill battle.

(8) Governmental bodies should provide financial incentives to power utilities and SMR manufacturers to support a C2N transition.

A simple tax break or licensing fee exemption would help reduce some of the financial barriers to this process while also signaling government support for this endeavor.

Ultimately, any C2N transition will be required to follow regulations and permitting set at all levels of government. A formal program that sustains cooperation and contact between the NRC and state regulators will be effectively necessary. While the EPA and FERC may be involved depending on project and site, the NRC should hold clear oversight in the C2N process.

Difficulties for Reforms:

While there is the expectation that the NRC retains primacy, any C2N process will still involve multiple federal level regulators. The EPA will play an important role in coal plant and water resource management, which may complicate efforts to issue ESPs or construction licenses.

State and local government permitting will still play a decisive role. While this document outlines the need to advise them to support this venture, there is never a guarantee that such bodies will do so.

Although the movement of entire SMRs has been advised, such an action may not be feasible for every site depending on the state of local infrastructure and transportation permitting.

Local resources will have a significant impact on the permitting at both federal and more local levels. Water availability, emergency response, transportation, population, environmental protection, and many other factors can present obstacles.

SMR availability is still the ultimate constraint. More firms must apply for design licenses, and more of such licenses will need to be issued in the years ahead. Upon that, manufacturing licenses need to be issued. This may reveal many more regulatory and operational issues than initially anticipated, leaving C2N as viable only with traditional reactors until SMRs are widely available.

Further Considerations:

Nuclear fueling is tightly regulated by the NRC. Fears of weaponization and accidents remain a persistent concern among the public, even if they are convinced of the safety in the plant itself. While nuclear waste transport is standardized and the protocols are developed, the lack of a nuclear waste repository will make the issue of waste management more prevalent in time. Although prior recommendations included the possibility of SMRs being wholly removed and replaced for fuel processing outside of the community, this may prove to be a process difficult or expensive enough that tolerating the additional hurdles of fueling licensing would be preferable, in which case 10 CFR sections regarding fueling (which must be approved before the plant is operational and fueled) will need examination. The nature of fueling, how much is consumed, and how much is handled, will depend on the specific design of the SMR.

SMRs are still a novel advanced nuclear technology. While this document is written in the context of a water cooled SMR, designs using more exotic coolant such as Helium, molten salt, or liquid metals are possible. These coolant types will also determine the nature of the fuel, be it material or enrichment, compounding concerns above.

Improved safety is a cornerstone of SMR design. While conventional nuclear reactors must conform to meticulous waste release and meltdown protocols specified in 10 CFR, SMRs may eventually prove to need less stringent requirements. However, this process will take years of proven safe operation and is not yet viable - even during the design licensing process, the NuScale design gained attention for safety concerns from the NRC.

Interest in a C2N using SMRs is not exclusively American. Many countries around the world that traditionally have not had widely developed nuclear programs are considering a C2N that will allow them to meet climate commitments quickly. Furthermore, recent events have highlighted the need for energy security and independence, where hostile actors have minimal control over energy imports and resources [18]. This is a particularly potent concern in eastern Europe. Furthermore, international interest in SMRs would provide a market for American manufacturers if domestic demand is lagging or inadequate to justify a production run that would improve affordability. This would also open international collaboration: in the realm of education, technology exchange, or even security. Such measures could even promote a partner program between our universities.

Although we have emphasized a C2N using SMRs, such a venture is still possible with conventional nuclear technology. Recommendations such as siting permit waivers, building public support, and even financial incentives will still apply. Although the utility will lose out on the benefits of modularity and a wider expertise pool associated with a standard SMR design, this may prove to be a viable alternative if SMR development proves too slow, or the situation is unique enough to make a full-scale reactor economical.

Conclusion:

Responding to the threat of climate change requires action; the development of new technology and clearing a regulatory path forward will be necessary. A C2N using SMRs offers a unique opportunity to quickly deploy affordable base load zero-carbon energy without leaving communities near coal power plants out of the picture. While perhaps not as technically optimized as a dedicated plant, this provides a new purpose to the often abandoned and even contaminated land around CPPs that can facilitate, if not renewal, then new opportunities in nearby communities that would otherwise have been ignored in the clean energy transition.

The recommendations in this document are not the only reforms available to speed this process. They advise what measures need to be taken now. The expanded availability of SMRs for more than just power plant operations may catalyze new opportunities stateside. The reuse of coal power plant sites for cheap nuclear power may rule out the need for more coal power entirely. More cooperation between federal and state energy regulators may serve as the springboard for enabling other unique clean energy projects. A community more informed about nuclear energy technology may be open to opportunities in the clean energy transition and perhaps even, ready to lead it.

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