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The Hydrogen Hubs Conundrum: How to Fund an Ecosystem

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Recent federal legislation provides $8 billion to develop at least four hydrogen hubs, but little guidance. DOE should focus its funding on the capital costs of hydrogen production and infrastructure, while generally eschewing operating expenses and support for end users.

KEY TAKEAWAYS

- DOE must fund the hydrogen production plant at the core of each hub at a cost of about $250 million–$500 million each, with a 50 percent private sector cost share.
- Capital expenditures on associated infrastructure, such as hydrogen delivery systems, should also be supported by DOE, using the same 50 percent cost share.
- As the core plant ramps up, DOE may need to support its operating expenses to accelerate the growth of sustainable end-use markets. But it should be careful not to extend these subsidies much beyond when the plant reaches full-scale operation.
- DOE should also avoid subsidizing infrastructure operations, and it should not subsidize end users except to seed specific markets temporarily. Ongoing subsidies are inconsistent with the hubs' mission of demonstrating sustainable markets.
- DOE funding should not flow through each hub's organizing entity to specific hub projects. Instead, the organizers should include all related projects in their proposals, but DOE should fund projects directly, set the terms, and oversee them.
- Finally, DOE should explore ways to help de-risk hubs and associated demonstration projects in other ways. For example, the volatility of energy prices presents a key risk. DOE should explore ways to insure or hedge against this and other risks.

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INTRODUCTION

In November 2021, Congress passed a massive package of direct federal investments in low-carbon energy systems as part of the Infrastructure Investment and Jobs Act (IIJA, also known as the bipartisan infrastructure law). The IIJA's inclusion of more than $20 billion to support pilot and demonstration projects was particularly noteworthy, a major step toward filling the biggest gap in the U.S. clean energy innovation ecosystem. The law also established a new office in DOE, the Office of Clean Energy Demonstrations, to oversee these projects thus address a significant gap in its management structure.[1]

The largest program in this portfolio is the Regional Hydrogen Hubs program (known as H2Hubs), funded at $8 billion over five years. This sum vastly exceeds prior investments in the field. DOE intends to create at least four and likely eight or even more of these hubs. Given hydrogen's versatility as an energy carrier, with the potential to contribute to electric power, transportation, energy storage, industrial heat, and other uses, H2Hubs represents a bold initiative to accelerate innovation that would make it a core component of the nation's energy mix.

This briefing examines the overarching strategic challenge facing DOE as it seeks to implement the program: defining what a hub is and what elements of it warrant federal support. Future briefings will explore other aspects of the program.

WHAT IS A HYDROGEN HUB?

What is a hydrogen hub, anyway? Section 813(a) of the IIJA defines a "regional clean hydrogen hub" as "a network of clean hydrogen producers, potential clean hydrogen consumers, and connective infrastructure located in close proximity."[2] Clearly, Congress understands a "hub" to be much more than a single major hydrogen production facility: It explicitly included downstream users and the infrastructure to connect them to the facility. (Similar thinking is also embedded in the law's new program for Direct Air Capture hubs.[3])

However, the Notice of Intent (NOI) published by DOE in July, which sketches the agency's implementation plans, suggests quite strongly that DOE will focus funding on the hydrogen production facility (which we refer to as the "core plant"), rather than the broader ecosystem around it. In particular, the NOI offers specific targets for hydrogen production scale (a minimum of 50 metric tonnes [MT] daily), along with alignment with key metrics embedded in the ambitious agency-wide "Hydrogen Shot" initiative: production costs of less than $2 per H_2 kg, falling over time to $1; and less than 2 kg of lifecycle CO_2 emissions per kg of H_2 of produced.[4] All these targets are directly relevant for a core plant, and difficult to apply to the wider ecosystem.

The NOI thus suggests a strategic challenge for DOE. On the one hand, it appears to be seeking accountability and simplicity by focusing its funding on the core plant. On the other, it has an obligation to fulfill the congressional mandate to help build a hydrogen-driven ecosystem, which will depend on a flourishing ecology of end users and an effective infrastructure that links them to the core plant.

This report argues that DOE should resolve the challenge by making good on the NOI, *primarily* funding the core plant at the center of the hubs, as such a plant provides the most direct means of providing long-term benefits to the regional hydrogen ecosystem. But DOE should *also* fund critical infrastructure improvements on a case-by-case basis, removing important roadblocks to the adoption of hydrogen. The core plant will inevitably soak up a large percentage of the available funds, but it's important to ensure that other critical pieces are supported as needed.

Once this broad strategy is approved, DOE will have two further issues to resolve. First, there is the question of who selects and funds specific projects. The NOI states DOE's plans to fund a single entity in each region. Presumably, those entities would then fund projects (possibly even the core plant, although DOE could also fund that directly). We believe this delegated approach to be risky for both DOE and the hub entity. We recommend a hybrid approach in which all fundable projects are included in the hub proposal, but with DOE making the formal selection and directly funding selected projects. The process would then be supported by DOE's project selection expertise (which the hubs don't have) and by federal acquisition regulations (which hubs don't use).

Second, there is the question of identifying the projects to support beyond the core plant. We anticipate that construction of the core plant will utilize on the order of $250 million to $500 million in DOE funding for each hub.[5] This leaves a pool of funding that could reach hundreds of millions of dollars for each hub, depending on the eventual number of hubs. Those dollars could be spent on three areas: 1) ongoing operational funding for the core plant, 2) infrastructure (primarily for delivering hydrogen to end users), and 3) supporting end users of hydrogen, such as industrial plants or transportation systems. We accept that operational funding would be

appropriate for the core plant until they reach full operating capacity, but at that point, subsidies must taper off. We also strongly believe that DOE funding should support capital expenditure on selected infrastructure projects, especially those that connect the core plant to anchor end users. However, in principle, DOE should not be using demonstration project funds to subsidize end users directly, and it should not subsidize the ongoing operations of infrastructure providers.

THE STRATEGIC CHALLENGE FOR DOE: FUND A SINGLE PROJECT OR A MULTIPROJECT ECOSYSTEM?

The Core Plant Focus

Focusing funding on a single core plant within each hub has significant advantages for DOE. The hard metrics described earlier can be applied directly during the selection process. DOE is also more experienced in managing individual large projects—which it has done before—than multiproject ecosystems. Further, single projects align better with other DOE programs, such as those administered by the Loan Program Office, that might also be engaged in creating the hydrogen economy. Milestones for the core plant will be much easier to design, and progress against them will be more easily measured. This in turn means that go/no-go decisions for further funding, while still potentially difficult, will be more transparent and easier to defend.

But the core plant focus carries potential downsides for DOE as well. Notably, it makes a portfolio approach effectively impossible: The sheer scale of the funding and limited number of investments (four to eight) mean that nearly every project will be "too big to fail." The core plant focus could also undervalue downstream development, specifically the end users that are critical to the eventual emergence of the hydrogen economy, as well as the infrastructure needed to deliver hydrogen to them. Investments in hydrogen transport infrastructure, for example, may be critical for projects' success but would need funding from elsewhere. This approach might also require DOE to ignore many relevant criteria for ecosystem success, leaving it with overly narrow project objectives. For example, Congress explicitly included well-paying jobs as a program objective. But what matters here is not just jobs within the core plant, but well-paying jobs across the entire hydrogen economy in the region.

The core plant approach implies that all the ancillary work of building a regional hydrogen economy—and funding it—will fall on the hubs themselves. Key pieces of the infrastructure might therefore be left unfunded, while better funded or more influential local players can tilt regional development toward their strategic needs. This approach also denies the hubs a key lever in building out the ecosystem: control over the flow of funding.

Finally, the core plant focus means that go/no-go decisions will be harder to make. It is very difficult to imagine DOE accepting the fallout from ending a huge project in New York that is supported by Senator Schumer or an enormous project in California backed by Governor Newsom. Those are the political realities.

The Distributed Funding Model

Alternatively. DOE could distribute its funding across the regional ecosystem rather than focusing only on the core plant. For DOE, a distributed approach means the very high stakes of funding a few huge projects would be reduced, and the portfolio management approach recommended by the Information Technology and Innovation Foundation (ITIF) and other nongovernmental

organizations (NGOs) would be feasible to implement [ref].[6] Under this model, DOE would be able to fund many projects that carry different risk profiles, and it could assess their success over a much broader range of outcomes. A distributed model would also allow DOE to develop milestones and metrics that are simpler and easier to implement, again being focused around many smaller and simpler projects. For the hubs, a multiproject approach would help direct DOE resources into segments of the downstream infrastructure that could be hard to fund otherwise, and where lack of investment could badly damage the ecosystem itself.

However, the distributed funding model also carries significant risks for DOE. Breaking up the funding into multiple projects could mean the core plant doesn't get enough funding to reach scale, while—depending on who makes funding decisions—increasingly the potential for internal conflicts of interest at the hubs. Funding multiple projects could make it hard to determine whether the overall hub ecosystem was achieving its objectives, and would make go/no-go decisions at the hub level almost impossible (although, as noted earlier, such a decision would effectively be impossible anyway). Multiple projects would also risk diluting DOE's tracking and assessment capability.

WHAT SHOULD DOE FUND?

Aside from initial funds for planning and community outreach, there are, broadly speaking, five elements of the proposed regional hydrogen ecosystem DOE could fund:

1. The core plant buildout and closely related initiatives
2. Core plant operations
3. Infrastructure (including, for example, related long-duration storage, pipelines)
4. End users
5. De-risking

We believe that DOE should fund numbers 1 and 3, and be prepared to subsidize core plant operations until it reaches full production. Number 5 should be explored, as DOE may be better positioned than individual hubs are to address certain risks. Pump priming for end users should be avoided wherever possible.

Core Plant Capital Expenditures

Whatever DOE decides about funding additional elements of the ecosystem, it will fund the core plant and most of the program's funding will support core plant capital expenditures (CAPEX). How much will that cost? A useful reference can be drawn from the world's largest alkaline electrolyzer (AE) plant in China, which came online in late December. Baofeng claims that its 150 megawatt (MW) project can produce 27,000 tons of hydrogen per year.[7]

At current costs, then, production of 50 MT of hydrogen will therefore require about 278 MW of capacity. AE CAPEX is currently estimated at ~$1,000 per kilowatt (kW).[8] The CAPEX required to produce at that scale can be currently estimated at about $278 million. Building for 100 MT would cost on the order of $500 million. These figures roughly approximate the announced $250 million cost of Air Liquide's 30 MT green hydrogen plant in Nevada.[9]

These costs will fall over time, as supported by Glenk et al., the most comprehensive estimate of cost decline trajectories to date.[10] Drawing on a wide range of sources, Glenk argues that AE catalyzer costs are expected to fall at a rate of 2.96 percent (+/- 1.23 percent) annually; the cost of proton exchange membrane (PEM) catalyzers is expected to fall faster, at 4.77 percent (+/- 1.88 percent) annually. Catalyzers are a major cost element for CAPEX for electrolysis-based hydrogen production plants.

This admittedly inexact analysis suggests that the CAPEX for the core plant on the scale required by DOE will be on the order of $250 million to $500 million.

Facility Operations

DOE suggests in the NOI that the hubs should become self-sustaining, and that any operating subsidies will therefore be tapered off. However, a firmer limit may be needed, as the core plant will likely seek further subsidies to reduce costs and hence improve their competitive position downstream—and DOE will be poorly placed to resist these demands once it has sunk large sums into a given project.

The H2Hubs are supposed to demonstrate the commercial readiness of existing technology via a scale-up jump heavily funded by DOE. That readiness needs to be demonstrated by the successful rollout of a self-sustaining business when the plant reach full operation. At that point, no further economies of scale can be derived *from that plant,* so there is no point in subsidizing operations in the hope that costs will fall further. Markets for hydrogen are regional—these are "regional hubs"—and hence they need to become self-sustaining on a regional basis. The actual market test begins when the plant reach full-scale operations.

In rare circumstances, a core plant may be waiting for the final deployment of an important off-taker (e.g., completion of a power plant that utilizes the plant's H_2 production). DOE may find it prudent to provide some additional support in those circumstances. But in general, *DOE subsidies for facility operations should end at the point a facility becomes fully operational*.

Infrastructure

Well-established economic arguments line up behind public funding for infrastructure. The likelihood that private entities cannot capture the full social benefit of infrastructure deployment underpins the conceptual framework that supports public investments in socially beneficial infrastructure.

However, DOE should be wary of over-committing here. Its infrastructure funds will be limited because most funding will be committed to core plant CAPEX. In addition, many infrastructure projects will be commercially feasible, so there are risks that DOE funding could be used to de-risk projects that would be built anyway, thereby artificially improving returns for private investors.

DOE should, therefore, develop a methodology that meets two core requirements: First, it should identify infrastructure projects that are systemically important for a given regional hydrogen hub that are in particular necessary for connecting the core plant to important end-user markets. Second, it should evaluate proposals tightly with a view toward screening out projects that do not require a DOE contribution. The latter is not a simple task, though it would become easier over time as similar projects are deployed at different hubs.

However, DOE should in principle avoid subsidies for ongoing operations for infrastructure once the it is fully operational. While start-up support for infrastructure operations is appropriate as the plant and infrastructure ramp up to full capacity, ongoing support at that point should no longer be necessary. Sufficient ongoing funding should be available via subsidized CAPEX. Further subsidies would be an unwarranted blank check, and would in fact demonstrate that the regional hubs are not self-sustaining over time.

End-User Subsidies

DOE should in principle seek to avoid end-user subsidies. These have been defended in other circumstances as a way to "prime the demand pump," which can lead to further supply and hence a virtuous circle of growing scale, declining costs, and increasing demand.

But that is not the purpose of the H2Hubs demonstration program, which is primarily designed to demonstrate that a regional hub can be self-sustaining once a scale of 50–100 MT daily in H_2 production has been achieved. That scale should cut the resulting price of H_2 substantially, and DOE CAPEX subsidies will cut them further. If that does build a sufficient volume of end user demand to demonstrate that the hub is self-sustaining, then the program would have succeeded in establishing that fact.

Note that end users will receive an indirect subsidy because half of the core plant's construction costs and some of the hubs' infrastructure costs will have been paid by DOE. That reduces the amount of capital expenditures that must be recovered from end users, which is an ongoing subsidy, even beyond the end of DOE's direct funding.

De-risking

One of the most important lessons from previous large-scale energy demonstration projects—such as the Synthetic Fuels Corporation of the late 1970s and early 1980s, for example—is that when markets turn against them, innovative projects may not be able to ride out the storm. While it is probably impossible to completely insulate demonstration projects from market forces, it is worth considering ways risks could be mitigated. There are three critical market risks:

- Essential inputs such as feedstocks or electricity could become much more expensive.
- Core plant components could become much more expensive (e.g., critical minerals and components).
- Downstream sales could be affected by significant cost declines in markets for substitutes (e.g., a breakthrough in electric-vehicle batteries could undercut the economics of hydrogen in the transportation sector).

While the last two risks are real enough, it is upstream in particular where DOE or the federal government more broadly could have a role to play. The shock caused by the Russian invasion of Ukraine has already rippled into natural gas (NG) markets, as EU countries seek to replace Russian gas with liquified natural gas from elsewhere, causing a sharp price surge globally.

Is this a permanent shift in the cost curve for gas? No one really knows. However, the NG shock already has clear implications for hubs that plan to use NG as a feedstock—and also for those with plans to deploy hydrogen mixed with NG for power generation or other downstream uses.

Because H_2 is an infant industry, it is poorly placed to ride out these shocks. Accordingly, DOE should consider how it can best protect the hubs. One way is simply to subsidize the cost of inputs once they move beyond a specified benchmark level. Alternatively, it may be possible to hedge against certain shifts (e.g., in the price of NG) using forward contracts. DOE could help by funding these prior to hub completion so the economics of the hubs can be defined for a significant period in the future. Finally, DOE could also either provide or perhaps organize insurance against shocks, as it is likely better positioned than any single hub to address these risks.

In all these cases, DOE should provide funding more as a loan—or even against equity—rather than as a simple grant, wherever possible. If investors are provided with shock insurance of some kind, funded by DOE, they should be prepared to pay for that insurance at some point to be determined.

WHO FUNDS WHAT?

In the NOI, DOE clearly states that it plans to fund hubs via a single entity. Any additional funding beyond the core plant would presumably come via subcontracts selected and managed by the hubs.

This approach has some obvious advantages, as the hubs are presumably best placed to understand which investments will provide the best bang for the buck. They will also be able to act more quickly than DOE, as they will not be constrained by cumbersome federal procurement rules. And DOE, of course, will not have the burden of selection or even close monitoring and subsequent go/no-go decisions.

But there may be substantial downsides for the hubs as well. They would be left with the challenging task of picking which downstream projects to fund. That could be problematic for coalitions that are only now emerging and have no institutional history on which to rely, and also have no technical capacity to make funding decisions. And those decisions would be made outside the procedural protections of Federal procurement rules. Hubs would likely also have a hard time enforcing go/no-go milestones for subcontracts. Regional hub staffers have observed in interviews that hubs could even be split up by internal conflicts if forced to make these decisions.

Given these competing costs and benefits, it makes most sense for subproject funding decisions to be made jointly by DOE and the hubs. Rather than making a single grant to hubs that then select subcontractors, the hubs should define subprojects of value to the regional ecosystem, and DOE should then make final funding decisions within a budget shaped by the overall amount awarded to the original hub proposal minus DOE funds committed to the core plant. That would ensure that all subprojects nationwide are covered by a unified system of tracking and evaluation, real go/no-go milestones are in place, and appropriate decisions will subsequently be implemented.

One way to implement shared decisions would be for the hubs to include in their proposals infrastructure projects that are important for the regional ecosystem and meet the DOE fiscal test for subsidy. This would help DOE choose between competing hub proposals and set the stage for a subsequent phase wherein those infrastructure projects would compete for funds within each

hub's overall budget, using normal DOE funding procedures. These projects would be subject to DOE monitoring and evaluation, and DOE go/no-go decisions.

HOW TO FUND AN ECOSYSTEM

What Congress wants from the hydrogen hubs program is clear enough: a thriving regional hydrogen economy that cuts emissions, creates jobs, and opens a pathway into a bigger hydrogen sector. The question is how to get there, and specifically the role of DOE and OCED hydrogen hubs program. Our conclusions are as follows:

1. Focusing solely on a single production facility is too narrow and disregards congressional intent. It places too much emphasis on the core and not enough on the spokes and network. It makes a portfolio approach to DOE investment impossible, and over-emphasizes production at the expense of distribution and market demand.
2. Demonstrating H_2 production at scale is expensive. A significant percentage of hub funding will still need to go to the central production entity. That entity is also the focus for hard targets for H_2 production, costs, and CO_2 emissions.
3. A hybrid model could work best. DOE should consider determining the funding needed for core plant CAPEX and an operating expense (OPEX) subsidy up to maximum production capacity and then allocate the remainder of the hubs' proposed budget to address specific key roadblocks facing the regional networks and possible actions to reduce systemic risk. The amount available would depend on the residual funds remaining after DOE pays its share for the core plant.
4. Residual funding could at least in principle also require a different match: As infrastructure is further downstream than hydrogen production, and hence closer to the market, DOE could seek a non-DOE match higher than the proposed 50 percent, thereby stretching DOE dollars further.
5. Preliminary identification of residual funding projects should be included in the hub selection process. That would ensure that DOE runs all selection competitions, while the hubs retain an important voice in funding decisions.
6. DOE funding should focus primarily on CAPEX for both the core plant and infrastructure-related projects. OPEX funding should be limited in principle to the period before the plant and infrastructure reach full operating capacity (DOE should be able to waive this in exceptional cases).
7. End-user subsidies should in principle be avoided. They will be expensive over even the medium term, and once started, will be difficult to end.
8. DOE should explore options for insulating hubs against volatile energy prices.

Under this hybrid model, DOE would seek hub proposals that explicitly allocate funding to both the core plant and regional infrastructure. The core plant would need to meet the hard targets, while the residual funding elements could ensure that the hydrogen ecosystem as a whole is viable.

NEXT STEP: THE SELECTION PROCESS

Once these strategic choices have been made, DOE will need to develop an appropriate selection process. The numerous detailed requirements outlined in the NOI make this especially challenging: There are 24 different potential selection criteria mentioned in the paper. Bluntly, a selection process with that many criteria offers no objective criteria at all; it will always be possible to select any given project. The next report in this series will argue that DOE must create a selection process that is fair, effective, timely, and highly transparent.

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ENDNOTES

1. Infrastructure Investment and Jobs Act, 42 U.S.C. § 18861.
2. Infrastructure Investment and Jobs Act, 42 U.S.C. § 16161a(a).
3. Infrastructure Investment and Jobs Act, 42 U.S.C. § 16298d(j); "Regional direct air capture hub means a network of projects, potential CO_2 utilization off-takers, connective carbon dioxide transport infrastructure, subsurface resources, and sequestration infrastructure located within a region."
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5. Air Liquide recently commissioned a green hydrogen plant in Nevada that will cost $250 million and produce 30 MT of hydrogen daily. DOE requires hubs to produce at least 50 MT to 100 MT, so this plant will be two to three times as expensive, the cost of which DOE will provide no more than 50 percent.
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