ENERGY INDEPENDENCE NOW

EIN Briefing Paper

Crediting Hydrogen

An assessment of fuel incentives and renewable hydrogen investment in California.

Remy Garderet
Brian Goldstein

November 2014

Summary

Energy Independence Now (EIN) has investigated the current state of hydrogen fueling incentives and the renewable hydrogen framework in California with the aim of assessing current opportunities and barriers facing hydrogen transportation fuel investments. The following summarizes our findings as of November 2014, based on a wide range of discussions with industry and government stakeholders.

Summary findings on Hydrogen-related Environmental Credits

1. **LCFS credits for hydrogen can be valuable and could reduce the price at the pump.** Credits from a centralized steam methane reforming (SMR) system can be expected to fetch $0.87/kg, with LCFS trading at $50/ton, and all pathways have favorable GHG profiles.
2. **Renewable hydrogen gets more LCFS credits, and RINs in some cases.** LCFS credits for 100% renewable pathways can earn up to 50% more credits per kg than non-renewable paths. Biogas-based hydrogen can also earn RIN credits worth $0.75/kg at current prices.
3. **For biogas-based producers it is unclear if these credit premiums will pay for the additional cost of investment or biogas credits.** This issue is also tied to the competing uses of biogas, including CNG.
4. **Electrolysis is not well supported by credits.** No electrolysis pathway exists yet under LCFS and it is excluded from the RFS, a significant disadvantage relative to other production methods.
5. **LCFS and RIN prices are highly volatile, undermining their impact on investment.** The high volatility of LCFS and RIN prices makes it unlikely that they will drive capital investments in the early market, either for hydrogen in general or for renewable hydrogen specifically.
6. **At this early stage, credits may influence relative prices of hydrogen pathways but are likely not drivers of investment.**

Summary of Findings on Renewable Hydrogen Promotion

1. Renewable hydrogen, including both biogas-based SMR and electrolysis, is mandated by SB1505 but is closely linked to incentives, regulations and mandates of other sectors.
2. The CEC's ARFVTP program has been successful in soliciting a range of renewable hydrogen stations as part of the network investment.
3. Industry concerns remain regarding the impact of the ARFVTP renewable investments on the overall availability of funds for infrastructure, on the availability of biogas as the market grows and the missed opportunities for integration with the power and gas sectors.
4. EIN proposes 4 approaches to addressing some of these concerns:
   - Seek new approaches to funding, focusing directly on centralized biogas and electrolysis.
   - Focus on the Hydrogen/Electric Power intersect, engaging utilities and PUC.
   - Focus on the Hydrogen/Natural Gas intersect, engaging the growing biogas industry.
   - Review the broader policy framework and targets in which hydrogen now sits.

Hydrogen under the Low Carbon Fuel Standard

The California Low Carbon Fuel Standard (LCFS) allows hydrogen producers in California to collect LCFS credits from the sale of hydrogen for vehicles, which they can then sell on the open market to oil refiners and importers who need to meet their regulatory obligations to reduce carbon intensity.

1. **LCFS credits are potentially very valuable for hydrogen.** All of the current California hydrogen pathways have a favorable well to wheels GHG profile, generating sizable LCFS credits. For an onsite SMR pathway, each kg of hydrogen produced generates LCFS credits valued around $0.87/kg (assuming LCFS credits are trading at $50/ton of Co2 as they were earlier this year). If 33% renewable feedstock is used, the value increases by $0.14 to $1.01/kg. A fully renewable process could generate an additional $0.26/kg, based on EIN estimates, for a total of $1.27/kg (see appendix for details).

2. **Price volatility is high, and may limit the ability of these credits to catalyze investment.** LCFS prices reported by ARB ranged from $24 to $85 per ton of Co2 in August 2014, with the average having ranged from as high as $70 to as low as $28 this. This volatility may be problematic: investors valuing advanced biofuels companies reportedly value LCFS revenue at zero, given the high volatility, and there is no reason to believe that hydrogen LCFS revenues would be calculated differently. The impact of the LCFS as a driver of investment may therefore not be significant, even though it may serve to reduce the price of hydrogen at the pump once the infrastructure is in place.

Source: compiled by EIN from CARB data: http://www.arb.ca.gov/fuels/lcfs/lrtmonthlycreditreports.htm

3. **Trade sizes are large: aggregation might be needed.** The average size of trades could be a problem for hydrogen in the early years. As shown below, trades average at the CO2 equivalent of up to 700,000 kg of hydrogen (assumes a 33% renewable pathway), a number that corresponds to several large 1000+ kg/day stations in a mature market. In the future, producers may wish to pool their credits through brokerage services to sell them at a better price to participants.

Source: EIN calculations based on ARB credit

Key actions needed for LCFS:

The California Fuel Cell Partnership, in its 2014 Hydrogen Progress, Priorities and Opportunities (HyPPO) report[1], identifies 2 key actions for 2014 that relate to some of these LCFS findings:

(22) Work with hydrogen fuel providers to begin participating in the LCFS market Participants

(23) Expand hydrogen transportation pathways

We support these priority action items, specifically highlighting the following actions:

1. **New pathways for SMR are needed**. Although five SMR-based hydrogen pathways have been defined by ARB, one of the main methods used by current station developers, involving centralized SMR with 33% biogas credits is not yet defined by ARB as a pathway. The calculations for this missing pathway should be relatively easy to produce based on information and precedents from the other pathways. Authorizing the new pathway requires a formal request by a hydrogen producer to begin the process, and we urge those producers to begin this early so they can begin to bank credits as soon as possible.

2. **An electrolysis pathway is missing, and may be more complicated to develop**. There is currently no electrolysis pathway even as several stations that are slated to open in 2015 will be using electrolysis. Although an electrolysis pathway based on California grid electricity carbon intensity would be easy to define, one that uses 100% renewable electricity may be more complicated. The LCFS does not allow the use of renewable electricity credits (RECs) to demonstrate renewable electricity input for any of the pathways. This means that a producer using renewable electricity will need to work with ARB to find alternative ways to verify they are using renewable power. In locations of the State where there is "Community Choice", the station developer can obtain a contractual agreement directly with a renewable power generator that could serve this function. EIN is concerned however, that in most areas where regulated utilities are the intermediary, there is no mechanism in place other than RECs to show use of renewables. *We would place this high on the ARB priority list as an issue to address to promote electrolysis.*

3. **LCFS should be expanded to "Materials Handling" (forklifts).** ARB has recently been considering whether and how to extend the LCFS to cover fuel sales to electric forklifts. EIN supports this effort, and suggests that it also include hydrogen-powered forklifts. We are confident that appropriate data can provide a basis for the energy efficiency ratio for these vehicles so that GHG displacement can be calculated by ARB. Expanding the LCFS to include forklifts will also help in harmonizing it with the Renewable Fuel Standard, which already counts fuel sales for forklifts. Such an expansion would create an additional market for renewable hydrogen, as some companies with large distribution centers promote fuel cell forklifts through corporate sustainability efforts.

[1] California Fuel Cell Partnership, *2014 Update: Hydrogen Progress, Priorities and Opportunities (HyPPO) Report*. http://cafcp.org/sites/files/Roadmap-Progress-Report2014-FINAL.pdf

The Renewable Fuel Standard & RIN credits for hydrogen

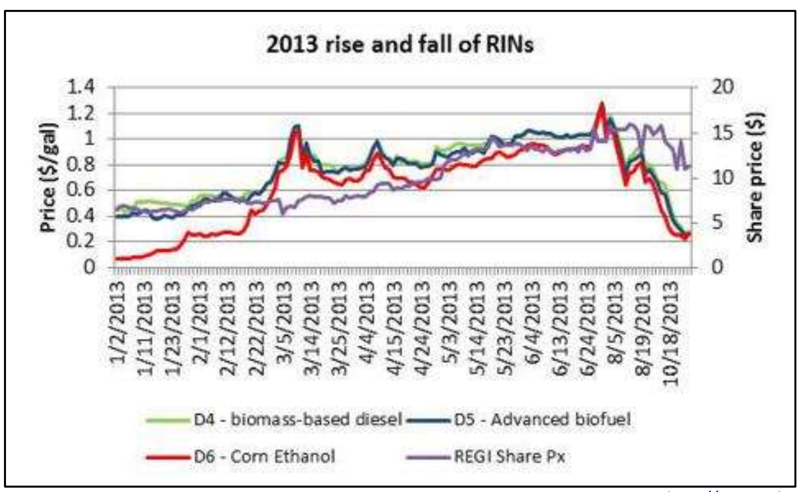
The RFS is the federal program administered by the EPA to promote the use of biomass-based alternative fuels, originally geared towards improving ethanol. Under the program, producers of alternative fuels generate RIN credits (renewable identification numbers), which they can sell to regulated parties who need to comply with renewable fuel volume EPA mandates.

1. **Hydrogen is now eligible to participate in the RFS program if it is made from biogas**. In July 2014, the EPA categorized biogas as a feedstock, opening the possibility for a producer of hydrogen from biogas to generate RINs if that hydrogen is sold for motor vehicles. An industry applicant needs to first petition for hydrogen to be added to the list of fuels and then submit documentation to get their actual pathway and facility authorized to generate RN credits, including demonstrating the chain of custody.

2. **Under RFS, hydrogen will generate the most favorable type of RIN credits**. The EPA has determined that hydrogen pathways that use biogas reduce GHG emissions by over 60%, thereby allowing it to collect "cellulosic" RINs of a category known as D3. These are generally the most valuable RINs, with prices expected above the "Advanced biofuel." Although cellulosic RINs are supposed to be more valuable, they are also subject to strong political pressure, evident as the EPA regularly recalibrates the total cellulosic targets.

3. **RFS does not reward for better drivetrain efficiency of fuel cells.** Although the type of RINs recognizes that a biogas-to-hydrogen path has a low GHG profile, the number of RINs generated under the RFS is based only on the energy content of the renewable fuel used rather than the well to wheels profile. Hydrogen vendors therefore are not rewarded for the greater drivetrain efficiency of fuel cells.

4. **RINs are valuable but volatile**. RINs are quite valuable to fuel producers, but prices have been extremely volatile. Recent prices show Advanced Biofuel RINs trading in the $0.50 range each. A year ago, they were double that. EIN estimates that a hydrogen pathway would generate 1.5 RINs per kg, based on the energy content. The value of the RFS could therefore easily represent $0.75 - $1.50 per kg, possibly more depending on the premium paid for Cellulosic RINs over Advanced RINs. For any biogas-based renewable producers, this would be in addition to any LCFS credits.



Source: http://static.cdn-

5. **Hydrogen pathways compete with other consumers of Biogas**. A biogas developer has several options for what to do with their biogas: They can either:
   a. Clean up the biogas and inject it into a natural gas pipeline, then sell a biogas credit to:
      i. A utility that may use it to meet its RPS requirements,
      ii. A CNG operator, who will then claim LCFS and RIN credits,
      iii. A hydrogen producer, who will reform gas and claim hydrogen LCFS credits (higher than the CNG pathway) and Cellulosic RINs (possibly more valuable than the CNG pathway as well).

   b. Reform it into hydrogen onsite. Here developers will fetch a slightly different hydrogen LCFS value (since the GHG profile is different), but the same number of RIN credits as if they injected it into the pipeline. They can then distribute renewable hydrogen to stations.

6. **Given the cross-sector links, the net effect of adding hydrogen to the RFS remains to be seen**. Adding hydrogen to the RFS has helped improve competitiveness relative to CNG, but whether and how it stimulates renewable hydrogen production depends on a multitude of factors. These may include: i) The relative market prices of non-renewable hydrogen, natural gas and CNG; ii) the extra LCFS value for renewable hydrogen and renewable CNG; iii) the relative value of RIN credits for renewable hydrogen and renewable CNG; and/or iv) the price of biogas credits. Although including hydrogen in the RFS has plugged a gap in terms of which fuels were covered, the net effect on biogas-based renewable hydrogen clearly depends on a broad array of variables.

   The recent change in the RFS seems to have created a surge of D3 RINs as CNG producers cash in. In September 2014, a report from OPIS states:

   > *"D3 cellulosic biofuel RINs surged to more than 3.492 million gallons. That is up from just 4,156 gal of the cellulosic biofuels recorded the month before in July. "The D3 [gallons] appear to be entirely from cellulosic compressed/liquefied natural gas producers," explained an industry source familiar with the issue.*
   > OPIS – Ethanol and Biodiesel Sample e newsletter.

7. **As use of hydrogen increases, the 33% renewable requirement is likely to play an increasing role in setting the price for biogas credits**. Since CNG has no renewable requirement, CNG retailers' willingness to pay for biogas will be limited by the value of associated LCFS credits and RINs. However for hydrogen retailers, the willingness to pay for biogas credits will be influenced by the price of compliance-eligible alternatives, namely renewable electrolysis.

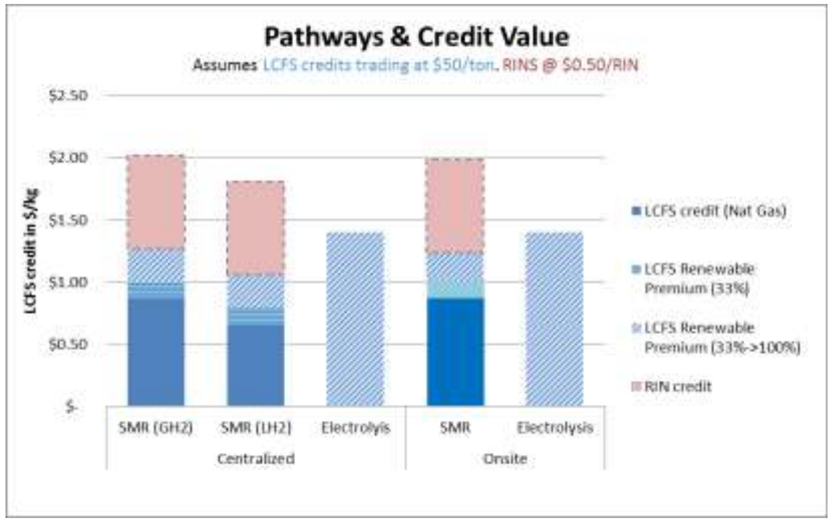
Key actions needed:

A biogas-to-hydrogen developer needs to take the lead to petition the EPA for a hydrogen pathway. Once that is done, they can apply for a formal pathway, building off the GREET analysis done by CARB for the LCFS.

Maximizing the value of LCFS and RFS credits

Together, LCFS and RFS provide significant value to hydrogen fuels for transport. However it is important to distinguish the effect of these programs is on both price setting and investment.

1. **The credit value of LCFS and RFS combined is significant, and will impact prices.** The chart below shows a combination of LCFS and RIN prices for several hydrogen pathways. This shows that total credits for a renewable SMR pathway, under current prices, might fetch around $2/kg. In the chart to the right, LCFS values (shown in solid blue for ARB published pathways, and striped for EIN) assume a $50/ton estimates. RIN values (shown in red) assume a $0.50 per RIN price and 1.5 RINs/kg. These only apply to the 100% renewable biogas-based SMR paths. Combined, these credits will undoubtedly affect the relative prices paid at the pump from different hydrogen pathways.



Source: EIN calculations. Striped bars represent EIN

2. **Credits have the potential to drive investment in a developed and stable market**. The value of both LCFS credits and RFS credits is large in relation to the variable costs and margins of the fuels themselves. They can therefore significantly impact the profitability of stations, which will eventually lead investors in this market to play close attention to credit prices.

3. **Currently, the high volatility of these markets combined with low hydrogen sales volumes limits the impact of these credits.** The volatility of both LCFS and RIN prices undermines the effect both these systems can have because current investors cannot count on revenues from credit sales. This price uncertainty, coupled with very small volumes of hydrogen sales, makes it highly unlikely that these credits will play a significant role in catalyzing investments at this early stage of the market. The fact that no producers have yet applied to opt-in to the LCFS or petitioned the EPA for the RFS pathway is an indicator that they the credits are playing a significant as economic incentives.

LCFS and RFS credits affect relative prices of hydrogen pathways but are unlikely to *drive* investment at this stage of the market's development.

Key actions needed to capture environmental credit value

To make LCFS and RFS credits drive investment in the early hydrogen market, some complementary credit-linked mechanism would be needed. Some ideas include the following:

1. **A revenue-assuring mechanism could be put in place to improve reliability of revenues**. Earlier this year, a bill sponsored by California legislator Muratsuchi (AB2390) proposed a *Green Credit Reserve* that would provide a guarantor to purchase LCFS and RFS credits at a minimum price. This type of mechanism would help make these credits more valuable as drivers of investment. We are not aware of the reasons for this bill's failure but endorse any future attempt to create such a mechanism.

2. **Credit sales could also be linked to State grant and loan programs**. Alternatives to the Green Credit Reserve could also be considered to help the credit market drive actual investment. One option would be to use a revolving loan fund linked to credit markets. For example, a State entity could use Greenhouse Gas Reduction Funds to establish a revolving loan fund that issues loans with repayment terms linked to credit prices. If credit prices were trading below a certain level, debt repayments and principle would be reduced accordingly. If credit prices were high, the loans would be fully repaid. In this way, the loans would ease capital injection into infrastructure development and support the functioning of the credit markets by limiting the risks that investors face in relying on those markets.

Renewable Hydrogen: Context, Concerns, Options

Context & Drivers

1. **The State's renewable hydrogen goal remains an important signal to all stakeholders.** The goal of promoting a renewable hydrogen portfolio is an important part of the State's investment in hydrogen infrastructure and FCEVs. Stakeholders regularly use the renewable hydrogen mandates and targets as a strong defense against skeptics and an indicator of the value of public investments and trajectory of the market. We therefore believe the appropriate question to ask in relation to renewable hydrogen is not *whether* to support that goal, but rather *how*.

2. **The Renewable Hydrogen Requirement, enacted by SB1505, sets a 33% renewable requirement for stations.** As described in the legislation, it goes into effect for all State-funded stations immediately and applies to all stations once a threshold of 3,500 metric tons of hydrogen per year are being dispensed. According to CARB, this "trigger" could occur as early as 2018.[2]

3. **Renewable Hydrogen relates to two very different types of technologies.** Discussions about renewable hydrogen generally refer two types of technologies: 1) Biogas-to-hydrogen technologies, using both centralized and onsite SMR, and 2) Electrolysis-based hydrogen using renewable power, also centralized and onsite. Although both yield a similar product from a hydrogen consumer perspective, they are technologies with vastly different cost profiles, maturities and optimal usages. A third source is waste hydrogen from such processes as the chloralkali process, used in the production of chlorine and sodium hydroxide. While not currently defined as one of the renewable resources under the PUC code that SB1505 refers to, it could be a significant source of hydrogen in some regions, and – like other waste streams - represents a valid displacement of fossil fuels.

4. **The feedstock can be physically co-located, or distant; both options are valid.** Renewable hydrogen can be made from biogas at the site of a waste facility, or from biogas that a producer injects into a natural gas pipeline, and is then drawn on elsewhere for the hydrogen production. Similarly, an electrolyzer can be physically co-located with the renewable source of power or grid-tied, with the renewable power coming from elsewhere in the system. Both the LCFS and the CEC require that applicants prove that the producer and user are physically connected (through a pipeline of grid), and that the resource is not double counted, but there are remaining questions around what the LCFS process will allow to demonstrate exclusive use of renewable power or biogas.

5. **The CEC has put SB1505 into action through the ARFVTP grant program, currently the main driver of renewable hydrogen investment.** The CEC, following the requirements of SB1505, has made renewable hydrogen an integral part of the grant program. This program, slated to spend approximately $20m per year until 100 stations are in place, includes both a general requirement that applicants demonstrate 33% or more renewable content as well as a specific "100% renewable" category, which is eligible for higher funding levels.

6. **The CEC program has been successful in supporting a variety of renewable hydrogen applications.** In the most recent solicitation, the CEC has been able to successfully attract developers of both SMR hydrogen using biogas-credits and onsite electrolysis using RECs or equivalents.[3]

---

[2] CARB. Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development, June 2014.
[3] California Energy Commission. See PON 13-607. http://www.energy.ca.gov/contracts/PON-13-607_NOPA.pdf

Industry Concerns

EIN's discussions with industry highlight the following broad concerns relative to renewable hydrogen.

1. **Scarcity of infrastructure funds**. Many stakeholders are concerned that the higher cost of renewable projects will divert resources from already scarce funds that have been allocated towards building the initial network of stations. They worry that the need for stations to support a successful launch is a standalone challenge without the additional renewable requirements.

2. **Cost of hydrogen.** Discussions with stakeholders regularly reflect the concern that the renewable requirements will raise the cost of hydrogen for consumers, adding an additional barrier to the early success of FCEVs. Stakeholders welcome any measures that ensure the renewable requirements do not generate extra costs for this alternative fuel.

3. **Biogas and future availability.** Fuel providers are concerned that biogas credits will become scarce, putting upward pressure on renewable hydrogen prices. The total amount of potential biogas resources in the State is limited and the increasing number of competing buyers will put pressure on the market, as described in the RFS section above.

4. **Missing an electrolysis niche.** Electrolyzers are capital intensive but can generate cost-effective hydrogen when the capacity factor is high (i.e. used most of the time) and when power costs are low (see appendix for an illustration of this). It can be challenging to make them profitable for the small scale, intermittent needs of a station in the early market. Electrolyzer technology development and cost reductions could be promoted as part of a "baseload" production of renewable hydrogen, but this would require a more centralized or mini-cluster approach, rather than individual station focus.

5. **Lack of integration with utilities.** Discussions with electrolyzer-based companies highlight how the value of electrolysis-generated hydrogen is tightly linked with utility and grid operations. Electrolyzer technologies provide their highest value as linkages between the electricity sector and the transport sector, yet there is a sense that the current policy and funding framework do not take advantage of this. Specifically, the lack of utility involvement in the renewable hydrogen discussion is a clear indicator of this missed opportunity

6. **An overall irregular policy landscape.** Stakeholders are highly aware that the renewable bar is set much higher for hydrogen than other fuels. While electricity has RPS requirements, the EV chargers and BEV buyers are not paying for the transition to renewables – the entire power sector is. Similarly, CNG has no renewable feedstock requirements and petroleum fuels face proportionately much smaller renewable requirements through the RFS and LCFS targets. This irregular policy landscape leads to a common sentiment among stakeholders that the renewable requirements need to be eased or delayed to allow hydrogen to reach a competitive scale or that much greater resources need to be directed toward the renewable hydrogen goal in order to avoid transferring the additional price burden to FCEV buyers.

Options to Consider for Renewable Hydrogen

The current question facing stakeholders is how to promote renewable hydrogen while simultaneously building a network of stations for FCEVs.

Promoting renewable hydrogen is a major, economy–wide project that requires far more than a grant program coupled with a mandate on stations. We believe it will require both long-term technology development incentives as well as broad policy adjustments that break silos between transport, electric power and the gas sector.

EIN proposes four broad approaches to help start this process. These tackle the challenge from both the bottom up, with funding and specific projects, and top down with a larger policy umbrella. These suggestions are intended to be complementary and are aimed at stimulating discussion within the stakeholder community.

1. NEW APPROACHES TO FUNDING

Seek new funding for renewable hydrogen supply to complement network development funds.
Focusing on the supply of renewable hydrogen, rather than depending on the demand for it by retail stations could help drive investment more directly.

In relation to biogas-based renewable hydrogen, most of the SMR-based stations rely on contracts with biogas producers to meet renewable targets. The renewable hydrogen requirement for stations is in many ways an indirect support for biogas development. State agencies could reduce the burden on hydrogen dispensers by increasing its *direct* support of biogas facilities and ensuring biogas credits are offered for sale to the hydrogen network first.

Likewise, funds targeting centralized electrolysis could reduce the burden on the station network to meet the renewable requirements. Centralized electrolyzers can provide cost-effective renewable hydrogen only at scale with high utilization. This does not fit within the economic parameters of the current station-oriented PONs. Separate funding to support electrolyzers, perhaps in conjunction with a small cluster of stations, could complement and support renewable network development while avoiding the financial risk associated with under-utilized, small electrolyzers during the early stages of the market.

In both cases, the focus of this effort should be on finding *new* sources of funds. The AB32 Greenhouse Gas Reduction Fund (GGRF) is conceptually well aligned to support these kinds of efforts. Promoting biogas use, whether it is used to make hydrogen or not, is a recognized GHG reduction strategy as is promoting electrolysis to drive development of stranded or underutilized renewables.

These efforts are also good candidates for support from the ARFVTP's separate "Alternative Fuels Production" funding category rather than the "Alternative Fuel Infrastructure" category because they directly drive new fuel for the transport sector. The intent would be to help drive larger scale applications of these technologies, thereby reducing costs while making biogas credits more available and helping meet the statewide 33% renewable goal without placing the burden solely on dispensers.

Explore new funding and mechanisms to offset the renewable hydrogen cost.
In the most recent CEC solicitations, 100% renewable hydrogen projects were able to apply for a separate "carve-out" within the solicitation. Some stakeholders have suggested that this adds a layer of

complexity to an already difficult balancing act between choosing appropriate coverage vs. capacity stations. The CEC could solicit input on alternative ways to promote renewables. One option would be to offer a fixed, incremental payment for stations that are already approved using the normal metrics but go beyond the 33% requirements. This payment could be simply linked to total capacity and percentage of renewable feedstock. This would in effect "decouple" the goal of choosing the best station for the network from the goal of promoting renewable hydrogen. This or any similar mechanism aimed at buying down the cost of the renewable target is worthy of support from other funding sources such as GGRF.

2. FOCUS ON THE HYDROGEN / ELECTRIC POWER INTERSECT

Target utilities and the Public Utilities Commission (PUC) to raise hydrogen-related issues.
From a utility perspective, hydrogen stations and centralized production facilities offer multiple opportunities that should be of interest. These include concentrated load growth (electrolyzers represent significant power use and revenues, an enabler of otherwise stranded or underused renewables either in converting it to hydrogen for delivery or as "round-trip" electricity storage), opportunities for demand side management and grid ancillary services.

There are a multitude of PUC and utility-related policies and incentives that need to be reviewed and adjusted to allow utilities to successfully promote the use of hydrogen. These include rate plans for electrolyzers, definitions of storage, integration into renewables planning, grid planning implications and payments for grid ancillary services. They also relate to whether utilities could count hydrogen production based on stranded renewables towards meeting their own RPS targets.

The California Fuel Cell Partnership HyPPO report identifies the link with PUC proceedings as "Priority #25. Explore how FCEV commercialization interacts with current and future PUC proceedings." [4]
EIN supports this finding and would expand it, based on the comments above, to include direct engagement with utilities. Our recommendation is to form a small working group that brings in relevant stakeholders to define the areas of interest from utility & PUC perspectives, and then to propose a process by which to address the barriers and incentives.

3. FOCUS ON THE HYDROGEN / BIOGAS INTERSECT

Target gas utilities. The gas-focused utilities are increasingly aware of the importance of renewable natural gas as a component of their portfolio and a bridge towards lower GHG targets. However the intersect with hydrogen and opportunities for investments are not always clear. A targeted engagement with gas utility leaders to lay out the opportunities and barriers relating to the intersect of natural gas infrastructure and hydrogen investments would be a good first step.

Engage biogas-related industry-groups. There are a large number of industries and associations interested in promoting the development of renewable natural gas from waste sources and biomass resources and for multiple uses included transport, direct heat and power. Many of these organizations are not fully aware of the opportunity associated with hydrogen, either as part of the energy transformation and storage in the system or as an emerging driver and demand for biogas as a feedstock. As with utilities, a direct engagement with these organizations would benefit the hydrogen industry.

[4] CaFCP, HyPPO. Page 25.

Support Renewable Gas Credits. Renewable Electricity Credits (RECs) have played an instrumental role in decoupling the physical generation of renewable power from the investor, while ensuring there is no double counting of that power. If centralized biogas production is to play a key role in the hydrogen sector, enabling hydrogen to meet its renewable targets, an equivalent formal biogas "credit" system will be necessary. Hydrogen advocates should support efforts to develop such credits

4. REVIEW BROADER POLICY FRAMEWORK AND TARGETS.

The policy landscape has evolved considerably since SB1505 was passed.

First, there has been a shift away from the focus on renewable vs. non-renewable resources to a clear goal of GHG reductions, as encapsulated both in AB32 and its programs such as the LCFS. All uses, whether they include renewables, some fossil or waste byproducts are evaluated relative to the GHG metric.

Second, passage of the LCFS creates a mechanism for <u>all</u> alternative fuels to promote lower GHG fuels, in effect superseding one of the original goals of SB1505. The LCFS design represents a shift away from fuel-specific goals such as SB1505, towards using the market to price the carbon within fuels and incentivizing continuous improvement.

Third, other regulations that break down sector silos have been put into place. The recent opening of natural gas pipelines to biogas begins to connect the waste and gas sectors. The rise of battery electric vehicles now links the transport and power sector. Many of these traditionally separate sectors now find themselves competing for either physical access to resources (such as biomass, waste gas, or renewable power) or for the credit systems that link them, such as RECs.

The California Fuel Cell Partnership HyPPO report identifies a need for a policy review in its Priority Action #24, which recommends "Ensure the benefits of all hydrogen production pathways are supported in California Policies."[5] EIN agrees that there is a strong case to be made for a formal review of the policy framework that drives hydrogen. We argue that it is essential that this be done within the context of the State's overall GHG goals and targets, and across the multiple sectors that are affected.

[5] CaFCP, HyPPO, page 25

Appendices

The Low Carbon Fuel Standard

The Low Carbon Fuel Standard applies to California sales of fuels for motor vehicles. Oil companies (imports & refiners) are the regulated parties, who must report all fuel sales and corresponding carbon intensity every quarter. The average carbon intensity of these sales must meet a steadily declining target and, if they cannot meet it, they need to buy LCFS credits for any shortfall in reaching that target. These purchases are private transactions but the price and volumes are reported to CARB.

Hydrogen producers can “opt-in” to the program to generate LCFS credits. They will report hydrogen sales to ARB and generate credits depending on the carbon intensity of the hydrogen pathway used. They can then either bank or sell those credits to the regulated parties. By default, the owner of the hydrogen at the point of dispensing owns the credit but this can be transferred by contract to others in the supply chain. There are currently 5 default hydrogen pathways defined by ARB and a producer can propose a new one if it is different and/or better than the existing one.

LCFS Credits Value

The table below highlights the potential value of LCFS credits for hydrogen pathways.

This shows the value of credits for the SB1505 ‘compliance’ pathway, which is based on onsite reforming of gas, of which 33% is of renewable feedstock. That pathway has a carbon intensity (CI) value of 76.1, which is adjusted by the Energy Efficiency Ratio of 2.5 for the drivetrain efficiency of vehicles.

The table shows that:

- The value of an LCFS credit would be around $1/kg for this pathway, assuming LCFS credits are trading at $50/ton.
- The value to a station is highlighted, showing the significance of this revenue stream.
- It is worth noting that revenues for the 500kg station running at 70% are about equivalent to payments on a $1m loan (10yr term, 4.5% rate).

VALUE OF LCFS CREDIT	Pathway, in year 2014: *76.1: Compressed H2 from on-site reforming with 33% renewable feedstocks*					
			Per Station			
LCFS Trading Price	Per kg	Per Vehicle / yr	250 kg station		500 kg Station	
$/ton Co2			@ 25%	@70%	@ 25%	@70%
$20	$0.40	$83	$9,175	$25,689	$18,349	$51,378
$30	$0.60	$124	$13,762	$38,534	$27,524	$77,068
$40	$0.80	$166	$18,349	$51,378	$36,699	$102,757
$50	**$1.01**	**$207**	**$22,937**	**$64,223**	**$45,874**	**$128,446**
$60	$1.21	$249	$27,524	$77,068	$55,048	$154,135
$70	$1.41	$290	$32,112	$89,912	$64,223	$179,825
$80	$1.61	$332	$36,699	$102,757	$73,398	$205,514

Source: EIN calculations. See LCFS factsheet for guidance on replicating these.

Electrolysis-Based Hydrogen

The cost of hydrogen made from an electrolyzer is highly dependent on two factors: the price of electricity and the utilization factor (i.e. how much is it being produced relative to the capacity of the machine). The chart illustrates the cost of hydrogen from an onsite electrolysis station with the following profile:

Size of station: 400 kg/day of hydrogen (a 1MW electrolyzer)
Energy use: 72 kwh/kg of hydrogen
Capex: $4m
Annual O&M costs: $40,000/ yr.
Lifetime: 20 years.[6]

Actual station costs will vary, but this simple table illustrates a few key takeaways:

- **Electrolysis can provide cost-effective hydrogen, under the right circumstances**. The green areas represent costs of under $9/kg, which would be competitive with many of the current generation methods for delivered hydrogen stations. This is without any capital cost share. It is also for a 400kg station - larger stations would be more cost-effective for similar utilization rates and power, while smaller ones would have higher costs.
- **Continuous utilization is critical**. If a station is only expected to run at night, the capacity factor is already below 50%. This illustrates why these units are ideally best suited for "baseload" type applications and will struggle to be profitable with low or intermittent use.
- **Price of power is also key**. This electrolyzer uses a lot of power, so the price of that power is critical. With "time of use" pricing, an electrolyzer operator will need to optimize when it runs to maximize its utilization while avoiding the highest peak prices.
- **This profile can be useful to utilities and grid operators.** Electrolyzers offer the electric power sector value in many different ways to help manage grid loads and bottlenecks. They are also concentrated, unlike hundreds of home BEV chargers, and so easier to manage. Utilities however, will need to be allowed to sell that hydrogen to capture this value.

Cost of Hydrogen, from a 400kg/day electrolyzer station

Cost of Power ($/kwh)	Capacity Factor (Utilization)									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
$0.02	$17.88	$9.66	$6.92	$5.55	$4.73	$4.18	$3.79	$3.49	$3.27	$3.08
$0.03	$18.60	$10.38	$7.64	$6.27	$5.45	$4.90	$4.51	$4.21	$3.99	$3.80
$0.04	$19.32	$11.10	$8.36	$6.99	$6.17	$5.62	$5.23	$4.93	$4.71	$4.52
$0.05	$20.04	$11.82	$9.08	$7.71	$6.89	$6.34	$5.95	$5.65	$5.43	$5.24
$0.06	$20.76	$12.54	$9.80	$8.43	$7.61	$7.06	$6.67	$6.37	$6.15	$5.96
$0.07	$21.48	$13.26	$10.52	$9.15	$8.33	$7.78	$7.39	$7.09	$6.87	$6.68
$0.08	$22.20	$13.98	$11.24	$9.87	$9.05	$8.50	$8.11	$7.81	$7.59	$7.40
$0.09	$22.92	$14.70	$11.96	$10.59	$9.77	$9.22	$8.83	$8.53	$8.31	$8.12
$0.10	$23.64	$15.42	$12.68	$11.31	$10.49	$9.94	$9.55	$9.25	$9.03	$8.84
$0.11	$24.36	$16.14	$13.40	$12.03	$11.21	$10.66	$10.27	$9.97	$9.75	$9.56
$0.12	$25.08	$16.86	$14.12	$12.75	$11.93	$11.38	$10.99	$10.69	$10.47	$10.28
$0.13	$25.80	$17.58	$14.84	$13.47	$12.65	$12.10	$11.71	$11.41	$11.19	$11.00
$0.14	$26.52	$18.30	$15.56	$14.19	$13.37	$12.82	$12.43	$12.13	$11.91	$11.72

Green if < $9

[6] This station profile is extrapolated from data presented by Proton Onsite to the California Hydrogen Business Council, May 5, 2014.

LCFS FACTSHEET

This information was compiled by Remy Garderet of Energy Independence Now and any inaccuracies are the sole responsibility of the author. Please report any errors or omissions to Remy at remy.garderet@einow.org.

1. **All sales of hydrogen for transport use in California are eligible to generate LCFS credits.**
   They do not have to be renewable hydrogen, and do not have to be produced in California.
2. **The "owner of the hydrogen at the time the finished fuel is created" earns the credit**
   This can be changed by contract. See page 38 of the LCFS regulation
3. **The hydrogen producer (or other owner of fuel) must opt in to the program to start generating credits**
   They will have to report kg sales on a quarterly basis for light duty and heavy duty vehicles separately into the online system known as the LRT.
4. **Pathways:** One of the 5 published hydrogen pathways can be used.
   The pathways and their corresponding Carbon Intensity (CI) value in grams of Co2/MJ are:
   - *Compressed H2 from central reforming of NG (includes liquefaction and re-gasification steps)..... 142.2*
   - *Liquid H2 from central reforming of NG: 133*
   - *Compressed H2 from central reforming of NG (no liquefaction and re-gasification steps) 98.8*
   - *Compressed H2 from on-site reforming of NG.. 98.3*
   - *Compressed H2 from on-site reforming with 33% renewable feedstocks 76.1*
5. **New Pathways.** ARB will consider applications for new pathways, as well as pathway modifications, based on the GREET model. There is new proposed regulation language on exactly how to do this.
6. **Earning**: To calculate the number of credits earned per kg of H2, use the following calculation
   Energy Efficiency Ratio (EER) is 2.5 for light duty vehicles; the 2014 GasolineCI is 97.47; HydrogenCI is the number from your pathway above; H2Density is 120 MJ/kg.
   *Credit (in tons of Co2 displaced per kg of H2) = (Gasoline Baseline- (HydrogenCI/EER))*H2Density*EER*10*$^{-6}$
7. **Trading:** Credit can be sold (to an oil importer/refiner who is an LCFS regulated party) in private transactions. The price, and volume must be reported to ARB for the credit transfer to materialize.
8. **Reporting.** Sales of hydrogen are reported quarterly as well as annually. ARB publishes public reports showing aggregate prices and activity.

The right ARB contacts for specific questions are detailed on : http://www.arb.ca.gov/fuels/contact.htm
All documents are on the LCFS site: www.arb.ca.gov/fuels/lcfs/lcfs.htm

Answers to some FAQs

- You can generate and sell credits, even if you received grant funding from the CEC
- Electricity credits (RECs) cannot be used to lower the CI value of a fuel.
- Biogas as feedstock, demonstrated through a contract, can be used for a lower CI value.
- Sales of hydrogen to buses also count, but use the heavy duty EER (1.9) and diesel CI baseline.
- There is no time limit to banking the credits.
- You can only start earning credits once you opt-in. There is not retroactive crediting.