Bloomenergy®

TECHNICAL NOTE

Bloom Energy Server:

A guide to H_2 Blending with Natural Gas

Executive Summary

Many countries and countless companies have put together sustainability plans to tackle the problem of global warming and join the global effort to reach Net Zero emissions by 2050. This Global decarbonization campaign has started an energy transformation to change the way we produce energy which involves moving away from traditional combustion technologies toward cleaner energy sources like renewables and fuel cells that do not produce harmful greenhouse gases. This energy transition also includes moving toward cleaner energy fuel sources like natural gas, which produces 50% less $C0_2$/MMBtu than coal. Currently natural gas makes up more than 38% of fossil fuel usage today in the United States (24% Globally)[1]and serves as a great transition fuel, as the world transitions to carbon free fuel sources.

Bloom's entire portfolio of products were developed and designed around leading and complimenting the global energy transformation and reducing carbon emissions. One of Bloom's core products, the Energy Server, has the largest installed base of any solid oxide fuel cell (SOFC) manufacturer, and this installed base operates primarily on readily available natural gas. The engineers and product teams at Bloom Energy have developed the Energy Server to be fuel flexible and future proof to handle the needs of the energy sector as they transition to even cleaner fuels. The Energy Server was designed to integrate and operate alongside the energy transformation movement and not become a stranded asset for customers.

One of the fuels that will take a front seat in the next stage of the fuel transition strategy for the energy sector, is hydrogen gas (H_2). In recent years, the energy sector has been talking more about hydrogen, which has zero carbon content. H_2 comes with its own set of challenges for storage, transport and safe usage but it is naturally formed in many things, easily extracted with no negative impact on the atmosphere. As the energy sector evaluates H_2 as the next big move toward decarbonization, the industry will undertake a potential long and expensive upgrade process to change existing infrastructure and equipment to be able to safely make, store, distribute and use hydrogen.

Although Bloom Energy has Energy Servers installed today that were optimized to run on 100% H_2 gas, at the time of this Technical note, most of the installed base of Energy Servers were optimized for natural gas, since that is what is most commonly available. As the market for H_2 grows, customers often ask Bloom if they can blend H_2 gas with the incoming natural gas that is feeding Bloom's Energy Servers today. This technical note will address the question of H_2 blending in existing Energy Servers as well as provide customers with guidance, tradeoffs, recommendations, and upgrade information to get the most out of the Energy Server today as well as plan for the Energy Server of tomorrow. The good news is, Bloom Energy has a product roadmap that is built around the energy transformation. One that is fuel flexible and upgradable. As the planet's energy transformation matures, Bloom will be there to serve their installed base as well as offer the latest innovative Energy Servers for the future.

How do you know if your existing Bloom Energy Servers can accept and operate with blended H_2 and natural gas?

Bloom Energy has been manufacturing Energy Server's commercially since 2008. The earlier models were not designed to handle H_2 gas of any amount, so H_2 blending on the very early Energy Servers is not recommended by Bloom. If you are wanting to blend H_2 for an existing Energy Server, you need to read the product nameplate and make sure the Model number shows an "ES5" in the first position of the system model number, as shown in Figure 1. If the system model number starts with "ES5" this technical note for fuel blending can be used. If the system model number does not start with "ES5", blending H_2 is not allowed.

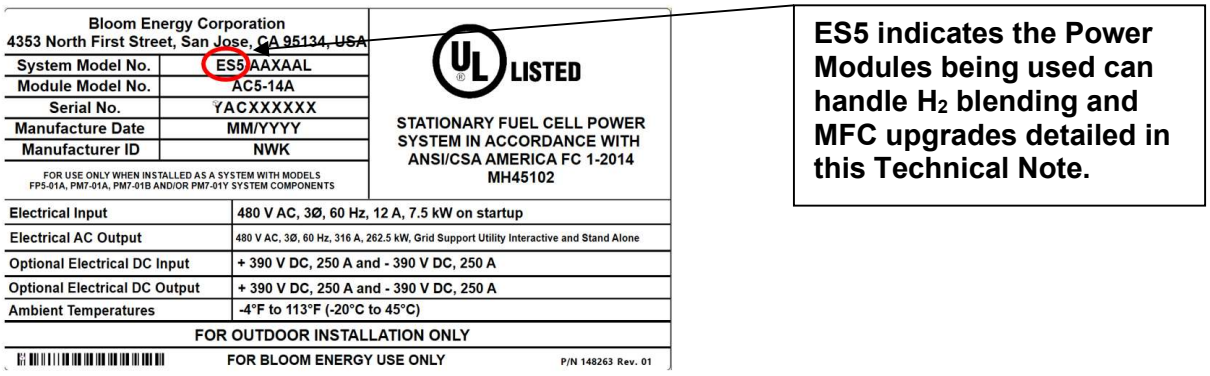

Figure 1: Energy Server Nameplate, showing model numbers that apply to this Technical Note for blending.

If you have an existing Energy Server 5 that you are considering blending H_2 gas with natural gas as feed fuel please use this technical note for guidance and always feel free to reach out to your Bloom Emergency Services Hotline - [408-543-1678].

If you are designing a new project in which you plan to use Bloom Energy Servers with blended H_2 and natural gas as feed fuel, the amount of H_2 blending must be indicated at the time of quotation and project planning so the Energy Server can be optimized for the intended feed fuel. This is important to ensure the Energy Server's power output and fuel efficiencies are maximized and the most economical solution is provided to the customer. The intended customer fuel source is also part of the managed service agreement contract and is used to define both warranty as well as the basis for any Bloom Energy performance guarantees.

Who is responsible for safely blending, storing, and transporting H_2 gas?

All blending of H_2 into natural gas feed fuel must happen outside the Energy Server and is the customer's responsibility to either produce or procure the proper fuel mix recommended in this technical note and that meets the Bloom managed service contract and fuel specifications.

Currently the Department of Energy (DOE) recommends no more than 15% of H_2 to be blended and passed thru existing natural gas pipelines and distribution equipment. The DOE's recommendation is to protect the existing natural gas pipelines from embrittlement and corrosion of steel and welds used to build the natural gas pipeline. In addition, the costs to control H_2 permeation and leaks under H_2 compression is high, so the system upgrades for high levels of H_2 can be costly and possibly prohibitive for companies to distribute natural gas with H_2 blending. Customer should ensure that if they are blending their own H_2 gas or procuring the gas from other sources, that the customer and supplier follows all the safety and design recommendations from experts in the industry including the recommendations from the DOE.

Bloom Energy Servers can handle more than the DOE recommended 15% H_2 blending and can go as high as 20% without the need for mechanical changes to the server. Table 1 indicates the different blending ranges and what Bloom Energy recommends for the ES5 model of Energy Servers:

% H2 by Volume		
5-20%	Contract Changes Only required	If blended feed fuel is mixed and transmitted safely to the Energy Server and the natural gas meets the Bloom Energy natural gas specification, the Energy Server can handle up to 20% of H_2 blending without the need to upgrade the equipment or the local piping installed by Bloom Energy Service teams during initial system commissioning. Bloom Energy performance guarantee's must be updated.
21-50%	MFC and Fuel Processing Module (FM) update and Contract Changes required	If the customer desires to purchase or blend between 21% volume and 50% of H_2 with natural gas, the customer should contact Bloom Energy and have an assessment done regarding the Mass Flow Control (MFC) and the gas pipes on the Energy Server pad. The MFC controls the volume of intake fuel to the fuel cells. Fuel Module (FM) will also need to be upgraded to a centralized desulfurization unit prior to blend Natural Gas with H_2. The Bloom Energy managed service agreement would also need to change slightly to adjust for expected efficiency losses.
>51%	Not Recommended*	Customer should contact Bloom Emergency Services Hotline - [408-543-1678] for complete system review and recommendations.

Table 1: Bloom Recommendations for Energy Server 5 H_2 blending

**Bloom Energy has an Energy Server optimized for 100% Hydrogen feed fuel. Consider converting existing server.*

How extensive is an Energy Server upgrade?

As seen in Table 1, the Energy Server is designed to handle up to a certain amount of H_2 blending without any system changes. Since H_2 takes up more volume per btu, at levels between 21 and 50%, changes must be made to the Power Modules (PM)'s to allow for this higher volume, and a second Mass Flow Control (MFC) device must be added. The number of PM's in an Energy Server varies based on the size of the system. Figure 2 is a typical 300 kW system which houses 6 PM's and an equipped space. This work can only be performed by a Bloom Certified Service member to maintain the warranty on the equipment and preserve any Bloom Energy performance guarantees.

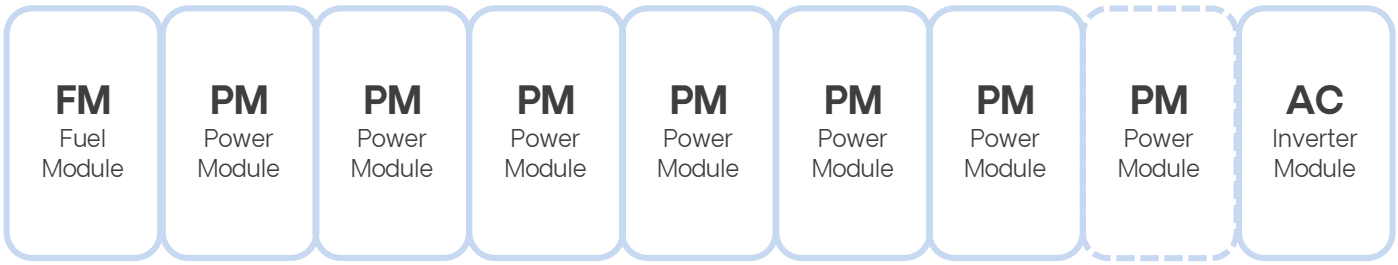

Figure 2: Typical Energy Server layout for 300 kW system

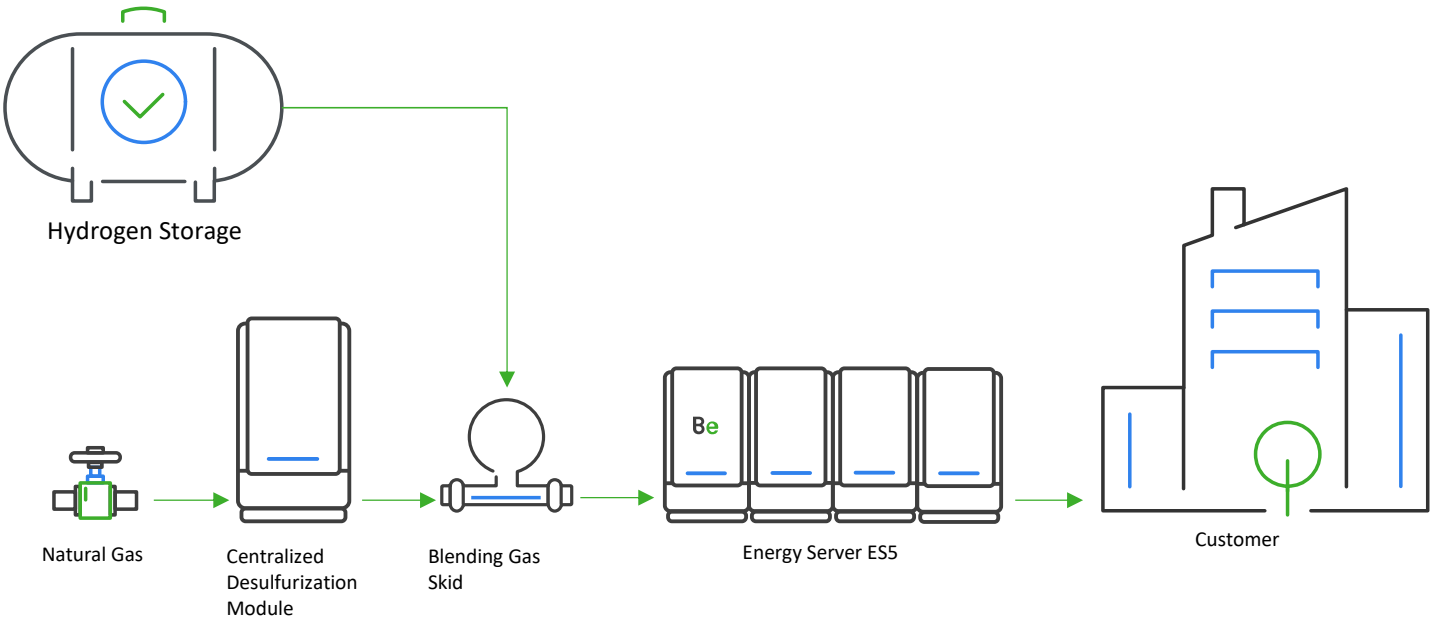

Figure 3: Simplified Diagram of an installation with blended H_2 on site

For high concentrations H_2, the Fuel Module (FM) will need to be upgraded to a centralized desulfurization module prior to blend Natural Gas with H_2. For a typical 300 kW system as shown in Figure 2, there is only one FM to be upgraded. Once the upgrade has been performed by Bloom Energy, the system contract would be adjusted to account for any expected efficiency losses described in the next section.

Energy Server Performance with H_2 blended natural gas.

Now that we talked about how much H_2 can be blended safely with natural gas and used to operate an Energy Server 5, and what upgrades may be required, let's talk about Energy Server system performance and trade-offs, when blending H_2 gas.

Since H_2 has a higher volume than natural gas and a third of the energy per m^3, the Low Heat Value (LHV) of the incoming fuel changes as more H_2 is introduced into the fuel stream. However, due to Bloom's design optimization, the efficiency impact is not

severe. The average lifetime electrical efficiency for a typical Energy Server installation is 51% for 20% H_2 and 48% for 50% H_2.

Customer benefits for blending H_2 and natural gas

The main reason why a customer would choose to blend H_2 gas with natural gas would be to decrease their carbon intensity scores, and lower emissions. Since H_2 has no carbon molecules, the blended gas is greener, and the customer is less reliant on buying carbon-based fuels. At the time of this Technical note, the availability and cost of H_2 is not where it needs to be to make the business case to blend H_2 today for any fuel cost savings, but all of that could change over time with regulation, incentives or changes in gas prices, so today, the clear benefit to the customer to blend is lowering emissions.

The expected amount of CO_2 emissions averted with the various amounts of H_2 blending can be up to 23% CO_2 reduction when 50% H_2 is used in the mix. Exact emissions savings would vary by location and application and customers are encouraged to work with your local Bloom Energy Services team to evaluate site specific emissions savings.

Today, our ability to predict the emissions benefits to the customer for H_2 blending in this technical note is theoretical and based on measurements and extrapolation and models built with extensive field data we have collected over the past decade. Exact emissions based on the customer installation, gas quality, gas production and local emissions tracking, can only be evaluated accurately with exact site data.

Summary and Conclusions

Bloom Energy has been installing and operating Energy Servers since 2008 and utilizing the latest Energy Server Model 5 since 2015. For those customers with an existing Energy Server model 5 who are looking to blend H_2 gas with natural gas as feed fuel, can do so safely with no system changes up to 20% H_2 blending, with an upgrade path to easily blend up to 50% H_2 gas. Customers also have the option to convert the entire server to a hydrogen optimized Energy Server by contacting Bloom Energy Service teams.

As the Energy Transformation continues, remember that Bloom's Energy Server produces energy without combustion, is fuel flexible and future proof. Please contact Bloom Energy services to help you plan your energy transformation and decarbonization efforts and learn about other system upgrades that are available as well as new solutions that are under development.

References:

1. Per the US Energy Information Administration 2021