Distributed Hydrogen Production

Lowering the cost and carbon footprint of hydrogen production globally

March, 2017

BENEFITS OF DISTRIBUTED HYDROGEN CO-PRODUCTION

A new approach to generating hydrogen is emerging which can serve existing and developing markets at lower cost and with lower environmental impact than existing alternatives. Hydrogen can be provided at smaller scale, local to users, while providing additional high value power and heat products. The technology uses an ultra-clean SureSource fuel cell which converts hydrocarbon fuel to hydrogen as part of the power generation process, and which can produce extra hydrogen for purification and export to local users at lower cost and with much lower emissions. Because hydrogen production is driven by waste energy from the fuel cell process (vs burning fuel in conventional methods), the carbon footprint for hydrogen production is much less than conventional methods. The hydrogen production rate is about 1200 kg/day, so these smaller-scale systems can be sited near industrial hydrogen users and fuel cell vehicle filling stations, eliminating the need to truck hydrogen long distances in polluting vehicles. The systems can also be sited near renewable fuel sources, such as wastewater treatment plants, to produce renewable hydrogen. Small scale hydrogen production has been attempted before, but high cost due to economies of scale has limited the commercial impact. By co-producing hydrogen with two other value streams (power and heat), this approach solves the scale problem. The fuel cell plant modified for hydrogen production is called a Trigeneration system because it produces power, heat, and hydrogen.

Source: NREL, Chris Ainscough

Industrial Hydrogen Use
Existing market

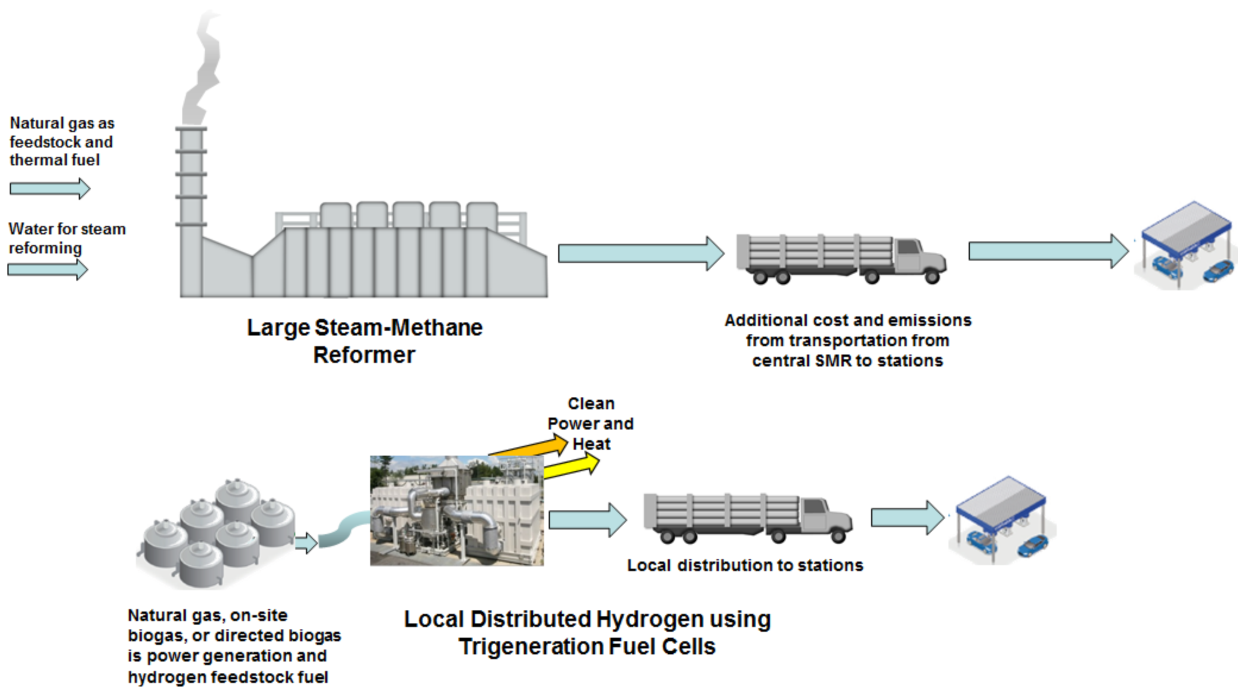
Vehicle Fueling
Emerging market

Applications for Distributed Hydrogen Production

Significant near term and emerging markets exist for Distributed Hydrogen Production

Hydrogen is typically produced from natural gas (which is mostly methane) in large plants that produce hydrogen from a reaction of steam and methane called reforming. These plants, called Steam-Methane Reformers (SMR), burn additional fuel to produce heat for the reforming reaction and steam production. Hydrogen produced in these large plants is distributed to users in trucks as liquid or pressurized gas. Fuel cell vehicles using this fuel emit much less greenhouse gas and NOX than a conventionally fueled vehicle. Additional emissions reductions are possible using locally produced hydrogen in Trigeneration fuel cell systems, which are inherently lower in emissions than conventional hydrogen production methods.

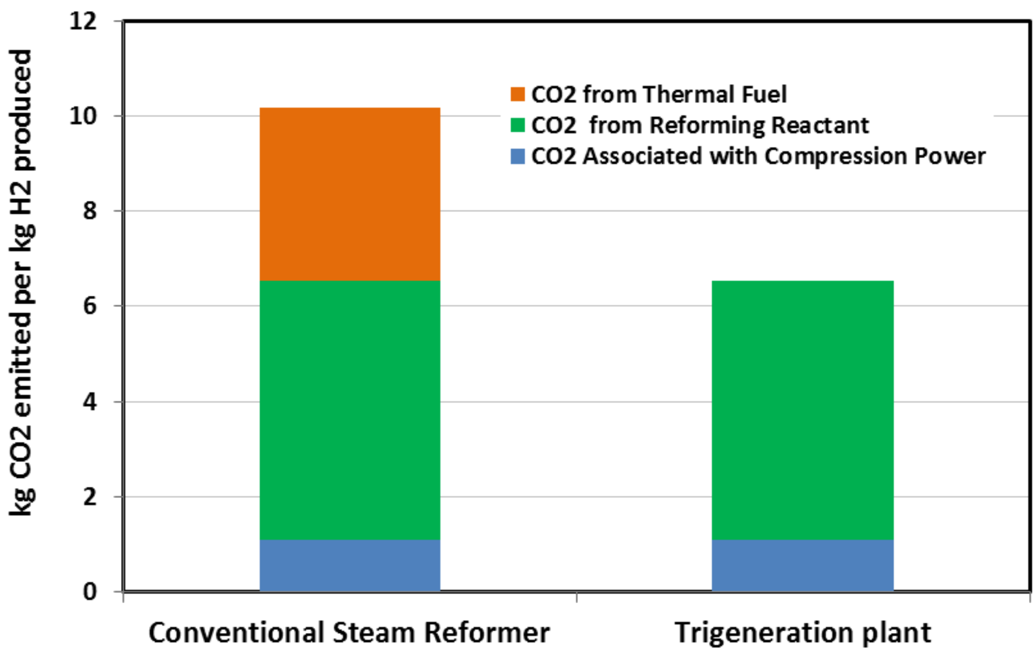
Trigeneration systems also produce hydrogen through a reforming reaction, but the heat and steam needed for the reforming process come from the fuel cell power generation reaction, so no additional fuel is burned and no water is consumed. NOX emissions are negligible, and GHG emissions per kg of hydrogen produced are about 40% less than conventional SMR production when using natural gas fuel. When using biogas fuel the hydrogen is carbon-free. The price of the hydrogen is reduced by the revenue coming from the co-production of power and heat from these fuel cell systems. While producing clean hydrogen, Trigeneration systems provide clean power and heat in projects that can provide power savings, improve grid reliability, and support microgrid systems.



Comparison of Central and Distributed Hydrogen Production

Trigeneration is inherently cleaner than conventional production, and production closer to point of use reduces emissions and cost associated with transportation

Carbon footprint is an area where the Trigeneration concept offers significant advantages over conventional reforming. In the natural gas reforming reaction, hydrogen is removed from methane (CH_4) in the fuel, and the carbon component of the methane combines with oxygen to produce CO_2. In the theoretical complete reforming reaction 5.4 kg of CO_2 are emitted for every kg of hydrogen produced. But in addition to providing the reaction feedstock, extra natural gas is also burned to provide the thermal energy required by the reforming reaction. Considering the extra fuel that is burned in a typical large scale reformer, about 9 kg of CO_2 are emitted for every kg of hydrogen produced. In the Trigeneration system the thermal energy required to drive the reforming reaction is provided entirely by fuel cell waste heat, so the carbon footprint of hydrogen production is driven down to the theoretical 5.4 kg CO_2 per kg of hydrogen. In addition, since these systems can be deployed near renewable fuel sources, such as wastewater treatment digesters, they can be fueled with biogas, essentially driving the carbon footprint to zero. Many of the SureSource fuel cell plants deployed in the US are operating on renewable fuels at wastewater treatment plants, and in fact the first Trigeneration system provided zero carbon hydrogen from renewable fuel at a wastewater treatment plant. The California Air Resources Board (CARB) has established a Low Carbon Fuel Standard (LCFS), and conducts comprehensive lifecycle analyses of alternative fuel pathways to determine carbon intensity. Trigeneration from biogas has a negative carbon intensity rating in the program, meaning that vehicles operating on Trigeneration derived fuels avoid the emissions of conventional vehicles entirely, plus they avoid additional emissions because of other offsets from power generation.

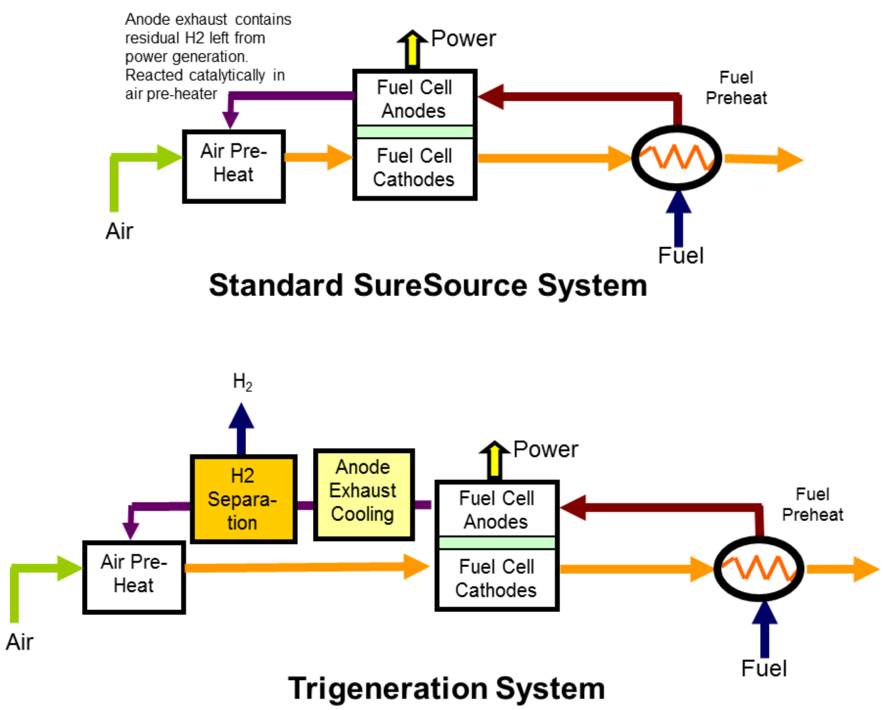


Comparison of Carbon Footprint for Hydrogen Production

Thermal energy required for reforming process is produced by burning fuel in conventional reforming, but driven by fuel cell waste heat in SureSource Trigeneration systems.

The Technology

The Trigeneration system is based on FuelCell Energy's proven SureSource fuel cell products. A major advantage of these products is internal reforming. Hydrocarbon fuels such as natural gas or biogas can be sent directly to the fuel cell stacks, where they will be reformed to hydrogen before reacting electrochemically to make power. The thermal energy required by the reforming process is provided by fuel cell waste heat, eliminating the need to burn additional fuel. This makes internal reforming a low-cost and extremely efficient way to produce hydrogen. The Trigeneration system concept is an extension of the standard SureSource system design, and Trigeneration systems are a modification of FuelCell Energy's SureSource 3000 product. In standard SureSource powerplants the power generation reactions consume about 70% of the internally reformed hydrogen. The remaining 30% is used in a catalytic reactor to pre-heat incoming process air. In the Trigeneration system, excess hydrogen produced by the internal reforming reactions is separated from the system and the air pre-heat energy is provided by heat exchange with other process streams. The additional equipment which separates and purifies the hydrogen relies on conventional process engineering technology for hydrogen purification.



Trigeneration Simplified System Schematic

Standard SureSource power plant is modified to include equipment to extract residual hydrogen from stack anode exhaust stream

The power output and hydrogen generation profile for SureSource3000-based Trigeneration systems are shown in the following table. Power output levels in Trigeneration mode reflect the additional parasitic power needed for hydrogen separation and compression.

Standard Configuration Output, kW	2,800
Trigeneration Configuration Output, kW	2,350
Hydrogen Production, kg/day	1,270

SureSource Trigeneration Hydrogen Production

Hydrogen production rates are a good fit for industrial hydrogen users and several vehicle filling stations

SureSource3000 2.8MW Powerplant