DOE Hydrogen Program Record	
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Title: Revised APU Targets	
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Item:

DOE targets for auxiliary power units (APUs) for heavy duty trucks have been updated to the values listed in Table 1.

Table 1. Technical Targets: 1 to 10 kW_e Fuel Cell Auxiliary Power Units Operating on Standard Ultra-low Sulfur Diesel Fuel.

	2010 Status	2013	2015	2020
Electrical efficiency at rated power[1]	25%	30%	35%	40%
Power density	17 W/L	30 W/L	35 W/L	40 W/L
Specific power	20 W/kg	35 W/kg	40 W/kg	45 W/kg
Factory cost, stack plus required BOP[2]	$750/kW[3]	$700/kW	$600/kW	$500/kW
Factory cost, system[4]	$2000/kW	$1400/kW	$1200/kW	$1000/kW
Transient response (10 to 90% rated power)	5 min	4 min	3 min	2 min
Start-up time from:				
20 °C	50 min	45 min	45 min	30 min
Standby conditions[5]	50 min	20 min	10 min	5 min
Degradation with cycling[6]	2.6%/1000 h	2%/1000 h	1.3%/1000 h	1%/1000 h
Operating lifetime[6,7]	3000 h	10,000 h	15,000 h	20,000 h
System availability	97%	97.5%	98%	99%

[1] Regulated DC net/LHV of fuel.

[2] Cost in 2010 dollars includes materials and labor costs to produce stack, plus any balance of plant necessary for stack operation. Cost defined at 50,000 unit/year production of a 5 kW system. Today's low-volume cost is expected to be higher than quoted status. Allowable cost is expected to be higher than the target for systems with rated power below 5 kW, and lower than the target for systems with rated power above 5 kW.

[3] Available cost status is that of a fuel cell stack only.

[4] Cost in 2010 dollars includes materials and labor costs to produce system. Cost defined at 50,000 unit/year production of a 5 kW system. Today's low-volume cost is expected to be higher than quoted status. Allowable cost is expected to be higher than the target for systems with rated power below 5 kW, and lower than the target for systems with rated power above 5 kW.

[5] Standby conditions may be at or above ambient temperature depending on operating protocol.

[6] Durability testing should include, at minimum, daily cycles to stand-by condition, and weekly cycles to full off condition (ambient temperature). The system should be able to meet durability criteria during and after exposure to vibration associated with transportation and highway operation, and during operation in a range of ambient temperature from -40 to 50 °C, a range of ambient relative humidity from 5% to 100%, and in dust levels up to 2 mg/m^3.

[7] Time until >20% net power degradation.

Supporting Information:

On May 28, 2009, DOE issued a request for information (RFI), DE-FOA-0000111, soliciting comments from stakeholders and the research community on proposed technical targets for combined heat and power fuel cells systems and APU fuel cell systems. The targets proposed in the RFI, as detailed in Table 2, were generated at a pre-RFI workshop organized by DOE on June 12, 2008 in Arlington, Virginia, and were further revised through interactions with the research community prior to release of the RFI.

Table 2. Proposed performance, durability, and cost targets for fuel cell systems for APUs using diesel fuel.

	Estimated 2008 Status	2012	2015	2020
Power output	1 - 10 kW	1 - 10 kW	1 - 10 kW	1 - 10 kW
Energy efficiency at rated power[1]	~16% DC	25% DC	30% DC	37.5% DC
Power density	17 W/L	25 W/L	30 W/L	35 W/L
Specific power	12 W/kg	15 W/kg	25 W/kg	35 W/kg
Factory Cost[2]	~ $750/kW	$550/kW	$450/kW	$300/kW
Transient response (10 - 90% rated power)		< 1 min	20 s	5 s
Start-up time from 20°C ambient	720 min	90 min	45 min	10 min
Average steady-state degradation	2.6%/1000 h	1.5%/1000 h	1%/1000 h	0.5%/1000 h
Transient power degradation	~ 1%	0.75%	0.5%	0.25%
Operating lifetime	~3000 h	12,480 h[3]	18,720 h[4]	31,200 h[5]
System availability	97%	97.5%	> 97.5%	> 97.5%

[1] DC net / LHV.
[2] Factory cost defined at 50,000 unit production (250 MW in 5-kW modules).
[3] Approximate hours in 2 yrs of operation at a weekly cycle of 5 days on and 2 days off.
[4] Approximate hours in 3 yrs of operation at a weekly cycle of 5 days on and 2 days off.
[5] Approximate hours in 5 yrs of operation at a weekly cycle of 5 days on and 2 days off.

Stakeholders submitted recommendations to DOE in response to the RFI. Revisions to the proposed targets were made using information provided in the RFI responses, as well as information obtained in subsequent discussions with stakeholders. Where target values were changed from those proposed in the RFI, explanation of the basis for the change is included below. The targets were designed with the intention that 2020 target values represent levels at which fuel cell APUs would be widely competitive with APUs based on internal combustion engines (conventional APUs), while initial commercialization may be possible at 2015 target values. Commercialization may not be possible at 2013 target values, but achievement of these targets would indicate a good progression from current status toward 2015 targets.

Electrical Efficiency at Rated Power

Electrical efficiency status was changed from 16% to 25% based on RFI responses. Recommendations for a long-term target ranged from 35% to 45%. Given that high efficiency would be a principal selling point for fuel cell APUs, and given that some developers have stated that efficiencies as high as 45% are possible with some fuel cell technologies, DOE established a 2020 target value of 40% electrical efficiency. While an efficiency level this high may not be necessary for commercialization, it is a stretch target intended to maximize competitiveness with conventional APUs and maximize energy savings.

Power Density

Status numbers included in RFI responses generally supported the status included in the RFI document. Several RFI respondents indicated that power density levels higher than the target levels could be achievable, and that the targets should be increased to improve competitiveness of fuel cell APUs. Recommendations for a long-term target ranged from 20 to 55 W/L. Published values of power density for ten conventional APUs ranged from 11 to 33 W/L, with an average of 20 W/L. DOE increased the 2020 power density target to 40 W/L, an achievable value that would put fuel cell APUs ahead of conventional APUs.

Specific Power

Stakeholder input on specific power was similar to that received on power density, with long term target recommendations ranging from 23 to 55 W/kg. Published values of power density for ten conventional APUs ranged from 17 to 38 W/kg, with an average of 27 W/kg. Based on this input, DOE increased the 2020 target to 45 W/kg.

Factory Cost

Several RFI respondents noted that the cost target should not be normalized to rated power, given that neither fuel cell APUs nor competing technologies are expected to have a constant cost per kW over the specified 1 to 10 kW range. Noting that most competing conventional APUs have rated power close to 5 kW, DOE revised the target footnote to more clearly indicate that the cost target assumes a 5 kW APU, and that allowable costs will differ for APUs with rated power other than 5 kW.

Stakeholder input from the RFI indicated a need for a cost target more closely tied to the fuel cell stack. Following subsequent discussion with stakeholders and within DOE, a decision was made to split the cost target into two separate targets: one target for the fuel cell stack plus BOP required for stack operation, and a second target for the entire fuel cell APU system. Input obtained at the pre-RFI workshop indicated a stack cost status of approximately $750/kW. The system cost status was based on the estimate that current system cost (2010) would be 2.5 to 3.5 times higher than the stack cost, as well as information from developers indicating that 2012 system cost would likely be 2 to 3 times higher than the current stack cost status.

All RFI respondents indicated that the proposed factory cost targets were too aggressive. Noting that conventional APUs sell for around $7000 per unit, that this value represents a retail price, not a factory cost, and that increasingly stringent emissions regulations may lead to higher costs for combustion-based systems, DOE determined that a system-level factory cost of $1000/kW for a 5 kW APU ($5000 total) would make fuel cell APUs competitive with conventional APUs. Based on RFI input from stakeholders, as well as considerations of reasonable apportionment of cost between the fuel cell stack and the rest of the fuel cell APU system, DOE established a 2020 target for the fuel cell stack plus BOP required for stack operation of $500/kW for a 5 kW APU.

Transient Response
Most input from the RFI indicated that transient response time is not a major concern with fuel cell APUs, given that a truck battery can handle transient power requirements. Furthermore, setting an aggressive transient response target would encourage developers to divert resources from more pressing areas, such as cost reduction, decreasing the competitiveness of fuel cell APUs. Therefore, the 2020 transient response target was increased to 2 minutes, a value deemed attainable without excessive investment of R&D resources.

Start-up Time
Stakeholder input indicated that customers expect APUs to start up in less than one hour, and that to compete with conventional APUs, start-up times well under an hour will be required. Some RFI respondents indicated that start-up from ambient temperature is a low-priority target, given that high-temperature systems such as those based on solid oxide fuel cells would normally be maintained in an elevated temperature stand-by state when not in use, and would be required to start from ambient temperature only once per week. Therefore, the 2020 start-up time from ambient temperature target was relaxed to 30 minutes. An additional target for start-up from stand-by conditions was added, with the stand-by conditions undefined, since they will be different for different fuel cell technologies. The 2020 start-up time from standby target was set at 5 minutes, a value that RFI respondents indicated would satisfy consumer expectations.

Degradation with Cycling
Following RFI input, the transient degradation and steady-state degradation targets were combined into a single degradation with cycling target. The combined target represents degradation during a typical operating cycle. The 2020 degradation rate target of 1% per 1000 h was selected as a less aggressive target than the originally proposed steady-state degradation target, reflecting the inclusion of transient degradation in the target, as well as stakeholder input indicating that achievement of degradation targets as stringent as those proposed in the RFI is not required to be competitive with conventional APUs.

Operating Lifetime
Similar to the degradation with cycling target, stakeholders indicated that fuel cell APU systems could be competitive with conventional APUs without achieving lifetimes as long as the values targeted in the RFI. Suggested operating lifetime targets for 2020 ranged from 10,000 to 30,000 hours. DOE selected a 2020 operating lifetime target of 20,000 hours, a value roughly equivalent to the expected lifetime of the tractor and similar to or greater than conventional APU lifetimes. While maintenance would be required to achieve this lifetime target, service intervals for fuel cell APUs are expected to be longer than those of conventional APUs.

System Availability
Stakeholder input from the RFI indicated that customers expect APUs to operate every time they are turned on, with minimal servicing requirements and downtime. Furthermore, achievement of system availability as high as 99% has been demonstrated in fuel cell APU systems operating on natural gas. Therefore, the system availability target was increased to 99%.