



2011-2012 Hydrogen Student Design Contest:

Design a Combined Heat, Hydrogen and Power (CHHP) System for a University Campus Using Local Resources

Official Rules and Design Guidelines v 1.0

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Any revisions will be posted at www.hydrogencontest.org.

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The Hydrogen Student Design Contest is managed by the Hydrogen Education Foundation. For more information on the Hydrogen Education Foundation, go to www.hydrogeneducationfoundation.org



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At a Glance

Eligibility

The Contest is open to undergraduate and graduate students worldwide. Team members must be enrolled in a college or university by September 1, 2011 but do not have to be enrolled full-time.

Registration

Register via email by contacting Contest Coordinator Emanuel Wagner at ewagner@tcorp.com. Include a list of team members and faculty advisor by November 1, 2011, at which time your abstract is also due.

Important Dates

- November 1, 2011:** **Registration Deadline** (Abstracts are due)
- January 16, 2012:** **Submission Deadline for Phase I** (Feedstock Analysis)
- April 2, 2012:** **Submission Deadline for Phase II (Full Entry)**
- May 1, 2012:** Announcement of winners to winning teams
- May 15, 2012:** Grand Prize team presentation due for WHEC Conference to HEF Staff
- June 3-7, 2012:** First public announcement and presentation of all winning designs at World Hydrogen Energy Conference 2012 International Conference and Exhibition, Toronto, Canada.

1 Introduction

Each year, the [Hydrogen Education Foundation's](#) Hydrogen Student Design Contest (“the Contest”) challenges teams of university-level students from around the world to develop and design hydrogen applications for real-world use.

Established in 2004 by the Hydrogen Education Foundation, the Contest showcases the talents of students in many disciplines, including engineering, architecture, marketing, and entrepreneurship. Undergraduate and graduate students worldwide are eligible to participate.

1.1 The Challenge

The theme of the 2012 Contest is **“Design a Combined Heat, Hydrogen and Power (CHHP) System for a University Campus Using Local Resources”**.

The Contest will challenge university-level students to plan and design an innovative CHHP system for their university campus. As a part of their entry, teams will develop a feedstock analysis, technical design, address safety and code compliance, identify end-uses on campus, conduct an economic and environmental analysis, and develop business, marketing, and public education plans for their systems.

The system should be able to be integrated into the students’ university campus, either by designing a system for an existing facility on campus or by proposing new construction.

Students must determine the specific characteristics of the resources available on-site, the fuel conversion system, the CHHP system, and uses for the three outputs: heat, hydrogen and power. The majority of the fuel for the system must be made up by renewable resources. Students must also consider all relevant codes and standards when siting the system at their campus.

1.2 Background

Global demand for energy continues to grow while countries around the globe race to reduce their reliance on fossil fuels and GHG emissions by implementing policy measures and advancing technology.

Clean and renewable energy can be produced from many sources, and even use existing materials for energy generation. One such pathway is using wastewater, animal and organic waste, or landfills to create biogas for energy production. Biogas is a product of anaerobic digestion of any organic material, and yields 60% methane and 40% carbon dioxide. Methane is a potent greenhouse gas if vented into the atmosphere, but can also be used to substitute fossil fuels to produce energy. The cleanest way to generate energy from methane is by utilizing a fuel cell, which does not cause significant emissions or noise, unlike combustion systems.

Furthermore, modern carbonate fuel cells can produce not only electricity, but also heat and hydrogen.¹

Hydrogen-powered technologies are a very promising alternative to weaning supplies of fossil energy and are becoming more common. Hydrogen, when produced from renewable resources, provides a clean, emission-free and environmentally friendly fuel.

The transition to hydrogen as a fuel is advancing, but a number of key questions are still unsolved, including the well-known challenge of infrastructure development. According to the Electric Power Research Institute, “the primary obstacle to [hydrogen vehicle] implementation is the perceived infrastructure investment cost associated with building and operating hydrogen fueling stations during the early market penetration years of hydrogen vehicles.”² In other words, which should come first—the hydrogen vehicles or the stations to fuel them?

Hydrogen has also the potential to serve as a storage medium for the power grid and be utilized when demand is highest, reducing strain and thus a more stable electric grid.

A solution may present itself in the broader distribution of CHHP plants at viable sites that have a significant organic waste and wastewater production, such as commercial-scale sites such as hospitals, college and university campuses, reducing energy and organic waste disposal costs or providing additional revenue through the sale of the products. Using locally sourced, already available resources, CHHP plants can provide three important products: electricity to power the campus, a thermal energy for heating/ cooling purposes and hydrogen for transportation, back-up power or other needs. This on-site approach to hydrogen production advances hydrogen infrastructure technologies that will accelerate the use of this renewable fuel.

This type of tri-generation is in the beginning stages but shows great promise. At least two companies are currently manufacturing CHHP plants. For this Contest, we are inviting students to get involved in this exciting new frontier of hydrogen technology development.³

1.3 About the Contest

Since 2004, the HEF Hydrogen Student Design Contest has challenged multi-disciplinary teams of university students to apply their creativity and academic skills in the areas of design, engineering, economics, environmental science, business and marketing to the hydrogen and fuel cell industries.

The Contest is open to undergraduate and graduate students worldwide. Multiple teams from one institution are permitted, but students may not belong to more than one team and teams must be working independently.

¹ Jung, Darren, Flexible Co-Production of Renewable Electricity, Heat and Hydrogen using Biogas. Quadrogen Power Systems, 2010

² Rastler, Dan. Feasibility of Electrolyzer Based Home Refueling System for Advanced Plug-In Hydrogen Vehicle Applications. Electric Power Research Institute, April 2008.

³ Recent example is the Fountain Valley Fueling Station operated by the Orange County Sanitation District: http://news.cnet.com/8301-11128_3-20097576-54/sewage-powered-hydrogen-fueling-station-opens-in-ca/

Although the Contest designs are concepts when submitted, the Grand Prize winning teams from 2004 and 2005 each attracted the funding necessary for actual development and implementation: a new hydrogen fueling station and power park, respectively. The station designed in 2004 had its grand opening at Humboldt State University on September 9, 2008. The winning design in 2008, which included a back-up and portable power system powered by hydrogen for airports, has generated a great deal of interest for implementation at the Columbia International Airport in Columbia, South Carolina.

1.4 Judging

Submissions will be evaluated by a diverse panel of judges that include industry representatives and officials at U.S. Department of Energy.

1.5 Prize Summary

For this Contest, the Grand Prize winning team will receive a \$5,000 travel stipend to attend the World Hydrogen Energy Conference 2012 International Conference and Exhibition (WHEC 2012), June 3 – 7, 2012 in Toronto, Canada to present their design in a session. The design will also be published in an industry publication. Students may also be considered for summer internships with participating sponsors.

Honorable mentions (up to four teams) receive waved conference registration and accommodations for WHEC 2012 (up to 8 students per team), and an invitation to present the design in a poster presentation component of WHEC 2012. The designs will also be published in an industry publication. Students may also be considered for summer internships with participating sponsors.

For more details on contest prizes, please see Section 2.4.

2 Rules

2.1 Eligibility and Team Structure

- The Contest is open to undergraduate and graduate students worldwide. Team members must be enrolled in a college or university by September 1, 2011 but do not have to be enrolled full-time.
- Given the multi-disciplinary nature of this competition, teams are encouraged to include members with various expertises, including: architecture/planning, industrial design, engineering (all types), economics, business, environmental science, policy, chemistry, marketing, education, or any other field of study relevant to the team's design.
- Each team must have a faculty advisor. The faculty advisor must be a faculty member of a college or university with at least three students on the team. Adjunct and emeritus faculty are welcome to serve in this capacity. Faculty advisors may give guidance and suggestions but cannot perform actual design work. Faculty advisors can advise more than one team, but they must assist in making sure the teams work independently to keep competition fair to other schools with one team.
- Multiple teams from one institution are permitted. However, each team must work independently to keep the competition fair for other teams.
- Teams are encouraged to include members from only one school. If collaboration between different schools is desired, the team leader and designated faculty advisor must request approval by submitting the team registration form with a cover letter to the address in Section 2.3 or by email to ewagner@ttcorp.com. Teams with students from more than three schools are not allowed.
- A team of about 10 students is recommended, although teams with fewer or more members are allowed.

2.2 Citations and Questions

- Teams may use any source of data or materials: journals, computers, software, references, web sites, books, etc. All sources used **MUST** be cited.
- Teams may contact professionals in the hydrogen and fuel cell industry, as desired, and are encouraged to do so. If information from them is used to develop the design, teams **MUST** cite all sources. Only open source data are allowed. No proprietary or confidential information should be included in any design or presentation.
- Teams may submit any questions about the contest by email (ewagner@ttcorp.com).

2.3 Report Format Submission and Scoring

- All submissions must be in English.
- Each team must register and submit an abstract of less than 300 words to ewagner@ttcorp.com by **November 1st, 2011**. Please include “**Hydrogen Contest Abstract – [Your school name]**” in the subject line of the email. The abstract should provide a basic overview of the team's project, highlighting the main features and goals

of its design. The abstract does not need to be included in the final submission. This information will assist the contest organizers in planning for the rest of the contest.

- Phase I: A 2-page resource assessment (see Section 3.1) must be submitted **by 11:59 PM ET January 16, 2012**, evaluations will be published and added to the final score.
- Phase II: Your team’s final entries must arrive at the location below **by 11:59 PM (ET), April 2, 2012**. Late entries will not be considered.
- Entries may be submitted in electronic form. If you would like to send a data storage medium, please send a CD/DVD/Thumbdrive with the electronic files to:

Hydrogen Student Design Contest
ATTN: Emanuel Wagner
Hydrogen Education Foundation
1211 Connecticut Ave. NW
Suite 600
Washington, DC 20036
United States of America

- **Electronic copy:** The entire report, including graphics and citations, should appear as a single PDF file. Electronic entries should be emailed to ewagner@ttcorp.com. Please include “**Hydrogen Contest Entry – [Your school name]**” in the subject line of the email. Please be cautious about the file size of the document.
- The following page limits have been recommended for the following sections. You may distribute the pages as you see fit provided that the final report does not exceed 36 pages + references and citations. Report pages must include 1 inch margins and be written in no less than 11 point font.

<u>Section</u>	<u>Page Max (Recommended)</u>
Cover Page	1
Executive Summary	1
Resource Assessment	2
CHHP System Technical Designs	10 (including drawings)
End Uses	5 (including drawings)
Safety Analysis	2
Economic/Business Plan Analysis	4
Environmental Analysis	3
Marketing and Education Plan	3 (2+1 for the advertisement)
Appendix	5
References/citations	as necessary (not inc. in page count)

Max. No. Pages	36 + references/citations

- Entries that exceed the maximum total page limit will be deducted **5 POINTS** for each page that exceeds the limit.
- The final submission must include an executive summary that reviews the main features of the project in language that a general audience can understand. For the other sections,

as you describe your design, keep in mind that the judging panel will include both technical and non-technical experts.

- Each section of the final project plan should concisely and completely fulfill the specific requirements in the design guidelines (Section 3) and provide any other relevant information.
- Judging criteria:

Points

30	Technical accuracy
20	Realism, ability to be effectively implemented and/or installed
20	Effective uses of renewable resources/energy efficiency
20	Practicality/usefulness
20	Value per dollar spent
20	Originality/Creativity
20	Safety and code compliance
20	Comprehensive nature of the design
20	Clarity of writing
10	Overall impact on community
200	TOTAL

- Teams are encouraged to copyright their designs. By submitting a design in this contest, however, teams agree to have their papers professionally published in the proceedings for the World Hydrogen Energy Conference 2012 and any participating media partners’ publications. The Hydrogen Education Foundation and Contest sponsors assert the right to publicize the design concepts for their own purposes. All work will be given due credit to its authors.

2.4 Prizes

General Information

- One grand prize winning team and up to four honorable mention teams are expected to be selected.
- On **May 1, 2012** the Hydrogen Education Foundation will notify winning teams. **Teams are required to refrain from publicly announcing their achievements until the public announcement date at the World Hydrogen Energy Conference 2012 International Conference and Exhibition [WHEC 2012] in June 2012.**
- Contest winners will be announced publicly at WHEC 2012 (for more information on the conference, visit: www.whec2012.com). All winning teams will receive awards at the conference.
- Winning designs will be published in the proceedings of the WHEC 2012 and also online at www.HydrogenContest.org.
- For teams outside of Canada, passport and visa arrangements must be made by the individual team members.

Grand Prize

The grand prize winning team will receive:

- Invitation to present design to thousands of industry leaders in a session of the World Hydrogen Energy Conference 2012 International Conference and Exhibition (WHEC 2012) in June 2012 in Toronto, ON.
- A stipend of up to \$5,000 to cover airfare, meals, and incidental trip expenses (must be documented), as well as complimentary hotel rooms (double occupancy) and World Hydrogen Energy Conference 2012 International Conference and Exhibition conference registration for up to eight team members and their faculty representative.
- Priority consideration for summer internships at participating sponsor organizations

Important Information:

1. Team must send at least 1 representative to present the team’s design at WHEC 2012. However, the team is **strongly** encouraged to use the stipend to allow the maximum number of team members to attend and participate in the conference.
2. Team must send a 20-minute PowerPoint presentation (maximum of 20 slides) with highlights of the project plan (presentation will be given by the team representative(s) referenced above during a session of WHEC 2012. Presentations are due via email to ewagner@ttcorp.com by **May 15, 2012**.

Honorable Mentions

The honorable mention teams will receive:

- An invitation to give a poster presentation at the World Hydrogen Energy Conference 2012 International Conference and Exhibition.
- Complimentary hotel rooms (double occupancy) and conference registration for up to four team members and their faculty representative.
- Priority considerations for summer internships at participating sponsor organizations.

2.5 Contest Schedule

<u>DUE:</u> Registration Ends/ Abstracts due (see Section 2.3)	November 1, 2011
<u>DUE:</u> Phase I (Feedstock Analysis (see Section 2.3)	January 16, 2012
<u>DUE:</u> Entries due (see Section 2.3)	April 2, 2012
Announcement of winners to winning teams	May 1, 2012
<u>DUE:</u> Grand Prize team presentation due for WHEC Conference to HEF Staff	May 15, 2012
First public announcement and presentation of all winning designs at World Hydrogen Energy Conference 2012 International Conference and Exhibition, Toronto, ON.	June 3-7, 2012

3 Guidelines

For this Contest, student teams are challenged to plan and design the elements of a combined heat, hydrogen and power (CHHP) system and installation for their university campus. For your entry, your team will develop a feedstock analysis, technical design, address safety and code compliance, identify end-uses on campus, conduct an economic and environmental analysis, and develop business, marketing, and public education plans for their systems.

The technologies and systems participating teams select for their project plan must be commercially available and possible to implement for practical, real-world use by June 2012. Participants should clearly state any assumptions used in their entries.

3.1 Energy Flows and Resource Availability Study

In order for the CHHP system to be run at peak capacity, an assessment of available feedstock and energy flows needs to be performed. In this task, teams need to identify the type and source of the feedstock to continuously run the CHHP plant, and the energy conversions that take place.

The feedstock analysis should include the amount of locally available feedstock, e.g. wastewater, landfill gas or organic matter for the production of biogas. A graphical representation of the sourcing of the feedstock and conversion processes is encouraged.

Using as many available renewable sources as possible is highly encouraged. However, different renewable sources require different treatment/clean-up methods to be viable for use in the CHHP system. It is recognized that to provide a reliable supply of fuel for the system throughout the year, non-renewable feedstocks may be used when needed.

3.2 Combined Heat, Hydrogen and Power Facility Technical Design

There are many elements to consider when designing a CHHP system for a college or university campus. Key elements include the feedstock-fuel conversion, treatment, fuel cell power plant, and end-product use design.

Based on the Resource Availability Study, teams will have defined the available feedstock, which will differ from university to university. The specific characteristics of the available feedstock require different treatments. Teams will need to design the fueling system that converts the feedstock to a useable biogas, including necessary treatments such as clean-up.

The design could, e.g. be using an anaerobic digestion system to convert organic feedstock, a wastewater system, landfill producing landfill gas, or something else. The system must be sized appropriately to fuel the CHHP system defined below.

However, biogas or landfill gas require a clean-up, or treatment, in order for the gas to be suitable for a fuel cell. As a rule of thumb, biogas treatment is 10x more difficult than natural gas, and landfill gas treatment is 10x more difficult than biogas. The appropriate treatment system needs to be designed using existing technologies.

In order to allow for a comparative assessment of each design, the CHHP plant is pre-defined.

All teams must use the specifications of the DFC 3000 system developed by FuelCell Energy. The technical specifications of this system are available at <http://www.fuelcellenergy.com/files/FCE3000%20Product%20Design-lo-rez%20FINAL.pdf>. Teams must consider that biogas and landfill gas have a lower heating value than natural gas.

Power and heat delivery and hydrogen production, compression, storage, and delivery elements of the system need to be carefully planned. All relevant local, national, and model codes and standards should be taken into account when siting the system. For information on standards, visit www.fuelcellstandards.com.

The technical design will include:

1. Site plan. The plan should include a detailed diagram of the entire system and the campus. Depending on the system design, plans shall include the feedstock storage, conversion systems, fuel cell power plant, power distribution, heat distribution system, hydrogen production equipment, dispenser(s), storage tanks, safety equipment, basic equipment installation plan and elevations, and any auxiliary equipment or other items the project team wishes to include.
2. Description of major system components with specifications and rationale for their choice. Major components may include:
 - a. Feedstock Delivery System and Storage
 - b. Feedstock-to-Fuel Conversion System
 - c. Gas Treatment System and Fuel Storage
 - d. DFC 3000 Fuel Cell Power Plant
 - e. Power Distribution
 - f. Heat Recovery and Distribution System
 - g. Hydrogen Recovery and Cleaning System
 - h. Hydrogen Compression
 - i. Hydrogen Storage
 - j. Hydrogen Dispensing / Distribution System
 - k. Mechanical Supply Systems
 - l. Electrical Supply Systems
 - m. Safety Equipment

3.3 Energy End-Uses on Campus from CHHP System

In this section, teams must specify the uses of the three end products power, heat, and hydrogen. All relevant local, national, and model codes and standards should be taken into account.

The DFC 3000 can be adjusted to produce either more or less hydrogen, resulting in an increase or decrease in electricity output. Teams have to identify the best hydrogen to electricity ratio, depending on economic grounds (see Section 3.5).

3.3.1 Electricity Use

The Power @ plant rating is 2.8 MW. In the design, the amount and use of the electrical output must be defined; on-site use and feeding back to the electric grid need to be quantified.

3.3.2 Thermal Use

The amount of thermal energy produced in a CHHP system is significant (7,460,000 Btu/h at 120°F). In order to create an economically feasible system, uses for the thermal load need to be proposed. In the design, the amount of thermal energy, the customers and the delivery system need to be described. Be cognizant that supplying heat to any new customer may require significant piping.

3.3.3 Hydrogen Use

The hydrogen produced needs to be compressed, stored and dispensed. For this section, include all details on your hydrogen equipment and the rationale for your choice. Quantify the amount and degree of purity of the dispensable hydrogen, and identify potential customers.

3.3.3.1 Hydrogen Compression

Hydrogen gas has much lower energy density by volume than fossil-fuel based sources of energy. As a result, compression of the gas to improve its energy density is a commonplace practice. For this section, include all details on your hydrogen compression equipment and rationale for your choice.

3.3.3.2 Hydrogen Storage

Depending on your system, you may decide to store hydrogen on-site instead of production on-demand. If you choose to incorporate hydrogen storage tanks into your design, be sure to explain in detail all major characteristics of the storage unit(s), and location relative to the residence.

3.3.3.3 Hydrogen Dispensing (if used for hydrogen vehicle fueling)

There are many factors to consider when optimizing the hydrogen dispensing system. Your system shall be designed to safely dispense gaseous hydrogen to a vehicle with SAE J2600 compliant connections and tank systems as described in Appendix A of SAE TIR J2601. In this section, detail all major characteristics of the dispensing system, including fill rate and pressure(s). Be sure to explain the rationale for your choices.

3.4 Safety Analysis

In this section, teams must show how their system design will operate safely and maintain the safety of the surrounding environment. Teams shall describe how safety concerns and applicable codes have been addressed for their CHHP system. Safety equipment and operational safety, as well as public perception of safety, are included.

Judges will score the design according to how well they think safety has been comprehensively addressed across all systems in the design. Teams must address the following minimum requirements:

- Identify the most significant safety risks in their design. In determining which failure modes should be addressed, teams should consider both the magnitude of potential damage and frequency.
- Describe how their design mitigates the risk of any identified issues.
- List applicable codes and standards, show how the design is compliant, and describe how code requirements were used to ensure safety (visit www.fuelcellstandards.com for information on different relevant codes)

Teams must document their sources as necessary.

3.5 Economic/Business Plan Analysis

The teams will complete an economic analysis of the system that includes capital costs, operating costs, and maintenance costs. The project team should determine the cost of electricity and heat produced, and dispensed hydrogen (\$/kg) based on the economic analysis. The team should also determine the market price of their CHHP system and develop projections for future market growth. For all costing analyses, teams must use documented sources.

The analysis should include:

- Capital costs for all equipment, including installation costs.
- Operating costs of all fuel, power, water or other resources necessary for operation (i.e., biogas or natural gas, if not produced on-site). Justify costs for water, biogas/natural gas and electricity (when needed) using relevant local utility prices.
- Costs per kWh of electricity and BTU of heat justified with a cost analysis of production and delivery
- Costs per kg of H₂ justified with a cost analysis of production and delivery systems.
- Maintenance requirements and costs.
- A comparison of annual fuel costs for the CHHP fueled campus compared to the current annual fuel costs.
- Determined market price
- Projections for market growth for CHHP systems

Teams are encouraged to address any other issues that may affect the economic viability of the project plan (within the page limitations of this section). For example, teams may examine

potential tax credits and other incentives that could help reduce the total cost of the project.

3.6 Energy Savings and Environmental Analysis

Teams should clearly explain the environmental impacts (positive and negative) of the design. For example, if biogas is used as a feedstock, the amount of organic waste reduced should be provided.

Think about how to minimize energy losses throughout the system. Innovative energy efficiency solutions will be rewarded.

- For the designed CHHP system, an analysis of amount of
 - organic waste displaced
 - fossil fuels displaced (for heating and electricity, and transportation, when applicable)
 - electricity from the grid reduced
 - GHG emissions avoidedmust be developed.
- For all emissions analyses, teams must use documented sources.

3.7 Marketing and Education Plan

To attract prospective customers, teams must create a realistic marketing plan and a one-page ad (scaled to fit on a standard letter (8.5” x 11”) or DIN A4 page) for inclusion in a local publication. The cost of implementing this plan must be included in the allowable overall project budget.

The plan should:

- build support for your design and understanding of the CHHP technology;
- allay public safety fears or reduce potential resistance; and
- raise local awareness of the benefits of hydrogen and fuel cell technologies so your designs can be built and installed with maximum acceptance.

Optional: We encourage teams to create a 30 second ad (video) for their design. The ad needs to feature the proposed system design in a recognizable manner. The video ad will not be part of the judging process, but will be published on the contest website and other social media outlets.

Note: Be creative with your marketing plan. Public acceptance is a key element in adopting hydrogen and fuel cell technologies.

4 Additional Resources

For links to informative websites, presentations, and publications that may help with your project, please visit our website, www.hydrogencontest.org/resources.asp. We will update this page throughout the course of the Contest.

Liability:

The Hydrogen Student Design Contest, the Hydrogen Education Foundation or any sponsoring or supporting organization assumes no liability or responsibility for accidents or injury related to the contest.

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