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PPI Resources for the 2020 DOE Solar Decathlon Design Challenge Competition

12-Nov-19

The following resources are intended for student design teams of the **2020 DOE Solar Decathlon - Design Challenge Competition**.

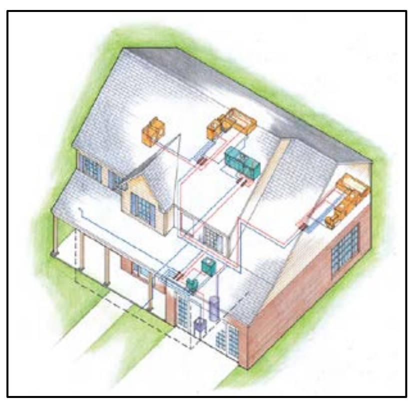
The Plastics Pipe Institute (PPI), based in Irving, TX, is a non-profit trade association which began in 1950. Our members are the firms that pioneer plastic piping technologies to deliver sustainable solutions for the built environment.

PPI members and staff engineers work together to research innovative plastic piping technologies from around the world and to share knoweldge about these products and their proper usage with engineers, designers, builders, architects, students and end-users.

Our **Building & Construction Division** focuses on plastic pressure pipe systems used for applications such as plumbing, fire protection, hydronic heating and cooling, and ground source geothermal piping systems.

We encourage design teams to incorporate innovative plumbing and mechanical systems to improve the health, safety and welfare of your buildings and their occupants.

These systems can assist designs in practically all categories, and, in particular, **Energy Performance, Engineering, Architecture, Market Appeal, Financial Affordability, Operation, Comfort & Environmental Quality,** and **Innovation.**



To provide inspiration and guidance, we are pleased to share the following information about the systems which are based on technologies supported by our organization and our members:

HOT- AND COLD-WATER PLUMBING

Plastic piping materials have been used for hot- and cold-water plumbing for decades and provide economical, safe, sustainable, and reliable plumbing systems without the cost, corrosion or environmental issues associated with metal piping. The pressure piping materials represented by PPI – CPVC, PEX, PE-RT, PP – are approved in model plumbing codes.

Plastic pipes don't corrode or suffer scale build-up which can reduce flows. Flexible plastic pipes such as PEX and PE-RT allow for bends and sweeps to be formed by hand, reducing installation time and pressure loss in the piping. And since these plastic materials are inherent insulators, thermal heat transfer through pipe walls is reduced.

The publication **"DESIGN GUIDE for Residential PEX Water Supply Plumbing Systems"** explains that by applying proper design techniques, PEX plumbing systems can deliver the optimum combination of performance, efficiency, cost and longevity. Other plastic materials can provide similar benefits.

PPI has also published an ASPE-accredited course called *Design of PEX Plumbing Systems to Optimize Performance and Efficiency.* This course teaches how to achieve these benefits.

Thoughtful design of hot-water plumbing systems using recirculation loops close to the plumbing outlets (i.e. fixtures) can reduce the wait time for hot water and the associated waste of water. Both the DESIGN GUIDE and the above-mentioned course help to explain how to achieve this.

How this can help your design

- Plumbing systems can contribute to **Operation, Comfort,** and **Environmental Quality**; don't overlook plumbing design
- Plastic plumbing pipes are quieter and transfer less heat than copper pipes
- Plastic plumbing pipes can reduce installation costs while improving long-term performance and reliability
- An optimized plumbing design (hot-water recirculation) can save water and energy
- The properties of plastic plumbing systems can improve the health, safety and welfare of building occupants through efficient and reliable delivery of clean water
- Just as teams will specify which appliances they'd use, teams should also specify the type of plumbing system materials

Helpful Webpages:

- https://plasticpipe.org/pdf/pex_designguide_residential_water_supply.pdf?pdf=PEXHandbook
- https://plasticpipe.org/pdf/designing-pex-plumbing.pdf
- https://plasticpipe.org/pdf/presentation-achieving-net-zero.pdf
- https://plasticpipe.org/building-construction/bcd-technical-literature.html

FIRE PROTECTION

Fire is the largest single cause of property loss in the United States. Building codes currently require fire protection systems, also known as fire sprinkler or fire suppression systems, for most commercial and multi-family buildings, where they have proven effective at reducing property damage and saving lives.

Fire protection systems using automatic sprinkler heads deliver significant savings in lives, development costs, and water conservation. Fire sprinklers make it possible to immediately halt raging fire events, save lives, diminish destruction, reduce demands on responders, and conserve water by extinguishing flames at onset.

More than half of residential fires take place in one- or two-family dwellings. Having a residential fire sprinkler system installed in homes like these is like having a firefighter on-site and on-duty 24 hours a day.

Guidelines from the organization NFPA describe how to design and build such systems.

Several types of plastic pipes are approved for fire protection systems. In fact, many residential buildings utilize multi-purpose fire protection systems whereby the cold-water plumbing pipe also supplies the sprinkler heads in each room, eliminating a redundant piping system. These systems are easy to install and provide peace of mind.

How this can help your design

- Fire protection systems can contribute to **Operation, Engineering, Innovation,** and **Market Appeal**
- While it might not be mandatory to include such a system in your location, it is certainly a nice feature to include these low-cost systems to help save lives, especially if your design is targeting student housing or families with children, or is a multi-family unit
- Fire protection systems are often constructed for less than $2/ft^2 and even lower with combined multi-purpose systems

Helpful Webpages:

- https://plasticpipe.org/building-construction/bcd-fire-protection.html
- https://plasticpipe.org/pdf/spot-light-on-fire-sprinklers-032612.pdf
- https://www.awwa.org/Portals/0/files/resources/water%20knowledge/Residential%20Fire%20Sprinkler%20Systems%20Report.pdf
- https://www.firesprinkler.org/
- https://www.nfpa.org/
- https://nfsa.org/

GROUND-SOURCE GEOTHERMAL

An ideal source of thermal energy for heating and cooling any building is a ground-source geothermal or geoexchange system, which relies on solar energy delivered to the earth as a source for heat energy, as well as heat rejected from the building during cooling operations. These systems are reversible, switching from heating to cooling as needed.

Geothermal heating and cooling systems, also referred to as *ground-source*, *ground-coupled*, or *earth energy* heat pump systems, are "...self-contained, electrically-powered systems that take advantage of the Earth's relatively constant, moderate ground temperature to provide heating, cooling, and domestic hot water more efficiently and less expensively than would be possible through other conventional heating and cooling technologies", according to IGSHPA, the International Ground Source Heat Pump Association.

Closed-loop geothermal systems utilize plastic pipes which are buried in the ground in a variety of configurations, or submerged in water. The network of pipe and fittings, sometimes referred to as the *ground-coupled heat exchanger*, or simply the *ground loop*, is typically connected to a mechanical fluid-source heat pump unit. The ground loop and the earth or water surrounding it is the thermal energy source during heating cycles and the thermal sink during cooling cycles.

The heat pump transfers thermal energy to or from the fluid in the ground loop to the building's heating and cooling distribution system, which could be air-based (through a coil) or hydronic, using water to transfer energy to and from heat exchangers such as fan coils, chilled beams, radiators or radiant systems (see below).

The design of ground-source geothermal systems is well understood and can be modelled for long-term operation using various software programs. The design of a system for a specific application, including selection of the proper piping materials and ground loop installation method, is an important part of installing a successful system.

Site-specific considerations such as soil material, distance to bedrock, water table level, availability of a pond or water retention feature, can be the dominant factor in system design.

Although there is a higher up-front capital cost investment to install the outdoor ground loops, geothermal systems are cost-competitive with financial paybacks in the 5 - 7 year range for many systems. At the moment, 30% federal tax credits are available for residential systems, and many other state and local incentives are available around the country.

Many homeowners and building owners select geothermal heating and cooling systems for reasons beyond the payback, such as reduced CO_2 emissions, elimination of high GWP gases found in VRF systems, significantly reduced operating costs, and long-term reliability.

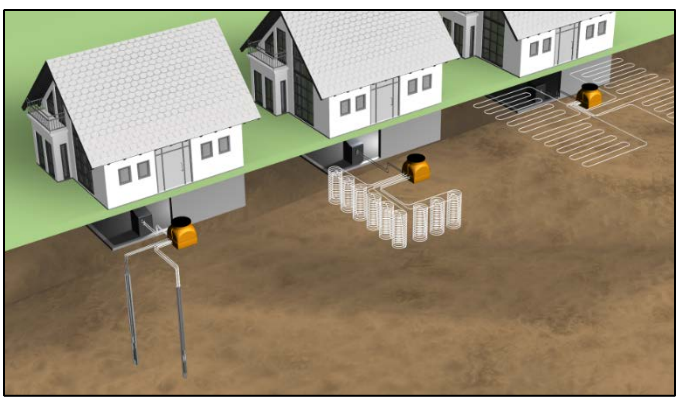
Although both water-to-air and water-to-water geothermal systems are available (with so-called desuperheater coils that also produce domestic hot water), we recommend connecting water-to-water geothermal systems to hydronic radiant heating and cooling distribution for the optimal overall system efficiency.

How this can help your design

- Geothermal systems can contribute to **Energy Performance, Engineering, Resilience, Financial Affordability,** and **Innovation**
- Geothermal systems, especially when connected to PV solar systems, generate much lower carbon emissions than fossil fuels
- Geo systems have significantly reduced monthly operating costs
- Ground source heat pumps have no outdoor equipment (e.g. condensers) which make noise and are subject to weathering and exposure
- Life expectancies for geothermal heat pumps are in the 25+ year range, as compared with air-to-water heat pumps which are subject to outdoor weathering
- Indoor heat pumps are quiet and compact
- Ground loop piping is buried underground, is long-lasting and maintenance-free
- Water-to-water geothermal heat pumps can deliver COPs (coefficients of performance) better than 5.0

Helpful Webpages:

- https://plasticpipe.org/building-construction/bcd-geo.html
- https://plasticpipe.org/pdf/tn-55-geo-applications.pdf
- https://www.geoexchange.org/
- https://www.geohourly.com/
- www.igshpa.org



HYDRONIC/RADIANT HEATING

People are exothermic heat generators, and the function of indoor space conditioning systems is actually to control the heat loss of our bodies to keep people comfortable. And while designing for building efficiency is important, the first priority should always be on occupant comfort. So we need to understand how occupants exchange heat with our environments.

Heat emission from the human body occurs via four modes of transfer (and proportions):

- Radiation (~45%)
- Convection (~30%)
- Evaporation (~20%)
- Conduction (~5%)

Our bodies radiate heat to any surface in line-of-sight which is cooler than our surface temperature, approximately 85°F (29°C). Excessively cold surfaces surrounding the body increase heat loss and reduce comfort. Air-based heating systems surround people with hot, dry air to offset this heat loss, but are never truly comfortable.

However, when a space is heated through exposed surfaces, then the resulting higher **Mean Radiant Temperature** (MRT – average temperature of the surfaces) reduces the radiant heat loss from human body. Indoor air does not have to be so hot for comfort, so it can be cooler and fresher, with better health and comfort. This also leads to lower heat loss, since less hot air escapes the structure. Finally, when heat is delivered through warm floors, temperature stratification is reduced, and the warmest air is actually just above the floor.

Hydronic heating systems utilize water as a heat-transfer medium. Hydronic systems are more efficient than refrigerant-based systems due to the high specific heat of water and the fact that hydronic circulators (pumps) utilize a fraction of the electrical energy required by compressors. Water is the natural refrigerant, with no environmental concerns related to leakage, CFCs, or flammability.

Hydronic circulators normally use variable-speed motors (a.k.a. electronically commutating motors, ECM) to deliver only the amount of heat energy that is needed at any moment in time. This is one of the reasons why hydronic heating systems are also more efficient than air-based systems, since these small circulators typically draw 75 – 90% less energy to transfer heat as compared with fans.

Hydronic heating is a 100-year-old technology that is constantly evolving. Although some hydronic systems use fan coils or radiators to transfer thermal energy to a space, the most efficient hydronic systems use radiant surfaces.

In a radiant heating system, heated fluid is distributed through small diameter plastic tubing embedded in the floors, walls, or ceilings. These systems are known as “closed loop” heating systems, with the same fluid (e.g. water) circulating throughout the system. Such heated surfaces emit more than 50% of their heat energy through infrared emissions, and are therefore known as **radiant** heating systems.

With large heated surfaces, radiant systems can provide enough thermal energy to heat a high-performance home or building with very low water temperatures, typically less than 100°F (40°C). The heated surface temperatures are even lower, typically lower than 78°F (25°C), depending on location and heat loads. Radiant systems are safe, gentle, steady and invisible.

In a hydronic radiant heating system, each circuit or loop of tubing typically covers 150 - 250 ft^2 of floor, wall or ceiling area, so that each room may have its own circuit of tubing. Multiple circuits of tubing are connected to distribution manifolds, which are hidden within walls or under floors. These manifolds often include flow control valves for each circuit. For room-by-room zoning, low power electric actuators open and close those valves based on heating demand. These actuators often draw less than 4 VA (volt-amps, or Watts) of power when operating, and allow for room-by-room zoning of the heat supply with no noise. Room-by-room zoning is the most comfortable and efficient strategy.

How this can help your design
Heating a space with hydronic radiant surfaces is efficient, silent, invisible, clean, controllable, reliable, maintenance-free and extremely comfortable.

Hydronic heating systems can contribute to **Energy Performance, Engineering, Architecture, Market Appeal, Financial Affordability, Operation, Comfort & Environmental Quality,** and **Innovation**

- Thanks to its high specific heat as compared with air, water is a much better conductor of heat energy
    - A nominal 3/4 water pipe can transfer the same heat energy as a 14 x 8 inch duct
    - A hydronic circulator moving warm fluid can deliver the same thermal energy as an air fan with 75 - 90% less electrical consumption
- Radiant systems can improve comfort while reducing energy consumption for heating and cooling
- Radiant systems also have reduced operational costs and maintenance costs
- Because radiant heating systems can heat a space with very low water temperature, the efficiency of the heat source is typically improved
    - Better efficiencies for fossil-fuel devices operating in condensing mode
    - Better efficiencies for air-to-water or water-to-water heat pumps, higher COPs
    - This means that heat pumps can be smaller and draw lower electrical loads
- Since radiant pipes are embedded in floors, walls or ceilings, there is more available space on floors and less space lost to ductwork
- Many designers use radiant heating systems to improve energy efficiency and comfort, and to achieve green/sustainable certifications and recognition, such as LEED®
- Radiant systems are easily integrated into the mechanical environment of a building and can be combined with geothermal and traditional HVAC for higher performing, hybrid systems
- Combined radiant heating and cooling systems provide uniform and efficient heating and cooling, and are a cost effective way for your building to achieve a higher level of energy performance

Helpful Webpages:

- https://plasticpipe.org/building-construction/bcd-radiant-systems.html
- http://www.healthyheating.com/
- www.radiantpros.org
- http://www.radiantprofessionalsalliance.org/HIA/Pages/default.aspx
- http://www.radiantprofessionalsalliance.org/Pages/Benefits.aspx
- https://www.energy.gov/energysaver/home-heating-systems/radiant-heating?utm_campaign=Social%20Media%20Q4&utm_content=78021754&utm_medium=social&utm_source=linkedin
- http://www.radiantprofessionalsalliance.org/Pages/RadiantHydronicsReport.aspx
- http://digital.bnpmedia.com/publication/?i=467366#{"issue_id":467366,"page":0}
- http://www.radiantprofessionalsalliance.org/Pages/RadiantLivingMagazine.aspx

HYDRONIC/RADIANT COOLING

Typically designed in conjunction with radiant heating, hydronic radiant cooling systems circulate chilled fluid through the same network of embedded plastic tubing that uses warm fluid during heating system operation. This network of tubes can turn floors, walls, and ceilings of a conditioned space into cooled surfaces that evenly absorb sensible heat energy including radiant energy from solar gain, people, lights, computers, etc. in addition to convective heat transfer from the air.

When dehumidification and fresh air are needed, radiant surface cooling allows for more efficiently-sized air-based systems to meet a building's fresh air and dehumidification requirements and to address latent heat loads. This significantly reduces the demand on the air-side system and the overall energy consumption, thanks to reduced fan loads.

A typical radiant cooled space will use 75°F (24°C) air temperature with no greater than 50% relative humidity, yielding a low 54°F (12°C) dew point temperature. To maximize system capacity, supply-water temperature is typically set between 57°F (14°C) and 61°F (16°C). Control systems modulate water temperatures through the tubing to make sure that surfaces always stay above the dew point of the space.

The ideal energy sources for the heated and chilled fluid for hydronic heating and cooling systems are geothermal heat pumps and air-to-water heat pumps. Including thermal solar collectors

How this can help your design

Hydronic heating systems can contribute to **Energy Performance, Engineering, Architecture, Market Appeal, Financial Affordability, Operation, Comfort & Environmental Quality,** and **Innovation.** See Hydronic/Radiant Heating above for more details.

Helpful Webpages:
See Hydronic/Radiant Heating above

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THERMAL SOLAR

Thermal solar collectors are used to generate hot water, even in cold climates. Not only can this hot water be used for domestic (plumbing) uses, but it can also be used to heat a building using hydronic distribution (see below). Evacuated tube collectors even work with a minimum of daylight.

Thermal solar systems typically do not use plastic tubing materials due to the elevated temperatures which can be achieved in the fluid. But thermal solar is a good energy source for hydronic heating and domestic hot water.

How this can help your design

A thermal solar system can collect much of the energy needed for domestic hot water and indoor space heating, depending on the climate and heat loss of the building.

Helpful Webpages:

- https://www.eia.gov/energyexplained/index.php?page=solar_thermal_collectors
- https://www.renewableenergyhub.us/solar-thermal-information/the-different-types-of-solar-thermal-panel-collectors.html
- https://www.energy.gov/energysaver/home-heating-systems/active-solar-heating

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ORGANIZATION WEBSITE

- https://plasticpipe.org/building-construction/index.html

ADDITIONAL SOURCES OF INFORMATION

- https://nfsa.org/
- www.igshpa.org
- https://www.nfpa.org/
- https://new.usgbc.org/
- www.geoexchange.org
- http://www.healthyheating.com/
- http://www.radiantprofessionalsalliance.org
- https://plasticpipe.org/building-construction/bcd-presentations.html
- https://plasticpipe.org/building-construction/bcd-case_studies.html