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Exergy Partners has been asked to review the technical implications of complete electric conversion of residential heating and hot water systems from fossil fuels to electricity as directed in New Jersey's Energy Master Plan. There are a large number of variables that need to be considered to understand the technical implications in making this transition. In order to clarify the issues, four transition scenarios are presented from the simplest to the most complex for a 2,400 square foot single family home.

**Scenario #1: An existing fossil fuel furnace with central air-conditioning and water heater.** Clearly this is the easiest conversion. However, there are performance considerations that may significantly add to the installed cost.

1) The furnace must be replaced with a central air handler that contains a fan, reversable heat pump coil, electric resistance back up heating and controls.
2) The air conditioning outdoor unit with compressor, reversable heat pump coil and fan must be replaced with a heat pump outdoor unit.
3) The suction and liquid refrigerant lines may require replacement.
4) A big overlooked issue is powering the new electric resistance backup heat which can easily add 40 to 60 amps at 208 volts load to the home. This often will require an electric service upgrade.
5) Heat pumps require the same airflow in heating mode, as they do in cooling mode. Customers often complain of cool supply-air temperatures in heating mode using heat pumps. Many service technicians will reduce fan speed, in the central air handler, which will heat up supply air temperature but with less air flow. This solves the air temperature problem but creates a bigger issue when the outside temperatures fall, and the home fails to heat as expected because less air flow means less heat supplied to the home.
6) Replacing the existing water heater with a heat pump water heater requires that sufficient air supply is available to cool the heat pump condenser which generally requires additional space around the water heater. This usually means that the water heater is placed within the conditioned or living space (as opposed to a utility closet) which adds to the winter heating load since the heat pump is discharging cold air[1] into the living space.

[1] Heat pump water heaters draw heat from the space around the water heater in order to heat the water.

**Scenario #2: An existing fossil fuel furnace with no central air-conditioning and water heater.** In addition to scenario #1 considerations, an examination of the ductwork will be required. The existing ductwork being designed for heating will generally locate the supply diffusers low in rooms and return air grills high in the rooms to allow for proper air distribution. Air conditioning would generally require the opposite[2]. To accomplish proper cooling air distribution may require relocating some ductwork, supply diffusers and returns. Furthermore, ductwork designed for a fossil-fueled furnace to provide heating only can be too small to accommodate air conditioning air flow requirements. Properly designed fossil fueled furnace ductwork can accommodate about 60% to 65% of the of the required air conditioning air flow. This provides two options:

1) Do not change the ductwork and increase the air flow for proper air conditioning, which will significantly increase the noise generated by the air flowing through the ductwork, diffusers, and returns, or
2) Modify the ductwork, diffusers and returns which may require significant addition ductwork and/or construction requirements.

**Scenario #3: An existing fossil fuel boiler with 180°F baseboard radiant hot water heating.** There are no air to water heat pumps that can deliver 180°F hot water particularly at low ambient temperatures[3]. Furthermore, providing cooling through baseboard radiant systems is not possible for two major reasons: 1) radiant heat transfer for the baseboard coils would not sufficiently cool the space, and 2) the cold radiant coils would condense moisture in the air and cause water damage to the home. This conversion scenario would require the following considerations:

1) The boiler would need to be replaced by a mini-split ductless heat pump or heat pumps equipped with electric backup and enough head[4](s) to provide space conditioning for the entire house. This means one head per room which may also require bathrooms requiring head(s), depending on the home layout.
2) This requires providing two refrigerant lines and one condensate line to each of the heads.
3) Location of the heat pump heads is also critical to the cost. There are length and height limitations between the outdoor unit and the head. This can require more outdoor units and/or more installation expense for the refrigerant lines.
4) The condensate line , required for each head to remove condensed water during air conditioning, can also cost more to install particularly if the only location for the head is an interior wall which can also require a condensate pump.
5) Multiple heads, outdoor units, refrigerant lines and condensate lines can provide location difficulties and can have an esthetic impact on a home's appearance and valuation.
6) This requires providing electric power to each head and also to each outdoor unit which contains the compressor, outdoor coil and fan.

[2] This is because hot air rises and cold air falls.
[3] Because of the high cost of geothermal heat pumps, they have not been covered in this assessment.
[4] Wall Mounted or ceiling mounted zone unit with coil, fan, filter, condensate recovery, electric backup capacity and control

7) A big overlooked issue is powering the new heat pump equipment and electric resistance backup heat. This often will require an electric service upgrade.
8) This would make the radiant heating system not functional. Considering that the hydronic system would not be used, the cost of removing the existing heating system including baseboard radiant heating systems should also be considered.
9) Adding these new electric loads may require an electric service upgrade.
10) Replacing the existing water heater with a heat pump water heater requires that sufficient air supply is available requiring additional space to cool the heat pump condenser. This usually means that the water heater is placed within the conditioned space which adds to the winter heating load and reduces the summer cooling load.

**Scenario #4: An existing fossil fuel boiler with steam radiant heating and hot water heating.** There are no heat pumps that can steam[5]. Conversion to electricity in this case would likely require all of scenario 3. Consideration should be noted that many steam heating systems in New Jersey, are found in older suburban homes near New York City and Philadelphia, as well as, rowhouses which have brick or masonry floors and walls. The expense of penetrating these walls and/or floors must be taken into considerations as these structures will substantially increase installation cost. Note that complete conversion to electricity would render the existing steam system as not functional. Furthermore, rowhouses would likely require that the outdoor units be placed on the roofs or hung on the front and back walls of the homes, each option having location, esthetic and/or technical issues to consider. Considering that the steam heating system would not be used, the cost of removing the existing heating system including radiators and plumbing should also be considered.

**Scenario #5: An existing fossil fuel boiler with steam radiant heating, water heating and ducted air conditioning.** There are no heat pumps that can steam[6]. Consideration should be noted that many steam heating systems in New Jersey, are found in older suburban homes near New York City and Philadelphia, as well as, rowhouses which have brick or masonry floors and walls. The expense of penetrating these walls and/or floors must be taken into considerations as these structures will substantially increase installation cost. Furthermore, rowhouses would likely require that the outdoor unit be placed on the roof. This conversion scenario would require the following considerations:

1) The existing air conditioning air handler must be replaced with a central air handler that contains a fan, reversable heat pump coil, electric resistance back up heating and controls.
2) The air conditioning outdoor unit with compressor, reversable heat pump coil and fan must be replaced with a heat pump outdoor unit.
3) The suction and liquid refrigerant lines may require replacement.
4) A big overlooked issue is powering the new electric resistance backup heat which can easily add 40 to 60 amps at 208 volts load to the home. This often will require an electric service upgrade.
5) Heat pumps require the same airflow in heating mode as they do in cooling mode. Customers often complain of cool supply-air temperatures in heating mode using heat pumps. Many service technicians will reduce fan speed, in the central air handler, which will heat up supply air temperature but with less air flow. This solves the air temperature problem but creates a bigger

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[5] Because of the high cost of geothermal heat pumps, they have not been covered in this assessment.
[6] Because of the high cost of geothermal heat pumps, they have not been covered in this assessment.

issue when the outside temperatures fall, and the home fails to heat as expected because less air flow means less heat supplied to the home.

6) Replacing the existing water heater with a heat pump water heater requires that sufficient air supply is available to cool the heat pump condenser which generally requires additional space around the water heater. This usually means that the water heater is placed within the conditioned or living space (as opposed to a utility closet) which adds to the winter heating load since the heat pump is discharging cold air[7] into the living space.

**Additional Technical Considerations:**
Most heat pumps currently use R410A as the refrigerant which replaced R22 that the U.S. EPA phased out[8] because of its ozone depletion characteristics. R410A is a high global warming potential (GWP) refrigerant that will be phased out in the coming years according to the EPA[9]. Accelerating the use of R410A today might not be the best GHG reduction policy as only a few manufacturers have introduced products with the new lower GWP such as R32 and R-454B.

When considering the on peak impact for electric conversions, one must consider winter peak timing which will occur on the coldest days of the year. This will require assessing the impact of electric resistance backup heat and electric heat pump water heating which will add substantially to the electric current winter peak demand in New Jersey.

**Other Considerations:**
There is a great deal of confusion regarding the actual cost of conversion to whole house electric heating. The highly referenced American Council for an Energy-Efficient Economy (ACEEE) Study[10] stated "For ductless heat pumps, costs come from an ACEEE analysis of a Massachusetts database of installed costs for this equipment. We looked at homes installing two or more multi-head heat pumps, finding an average cost of $7,065 per heat pump." Further review of the Massachusetts database[11] revealed that only 7.2% of the homes converted had the capacity to serve the heating load. Note the average cost of these whole home conversions was $21,572[12] and the median size was 1,912 square feet. It should be noted that there was no data regarding what was done with the incumbent heating

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[7] Heat pump water heaters draw heat from the space around the water heater in order to heat the water.

[8] As a Party to the Montreal Protocol, the United States must incrementally decrease R22 consumption and production, culminating in a complete R22 phaseout in 2030. R22 usage must be reduced to at least 90 percent below baseline levels in 2015 and to at least 99.5 percent below baseline levels in 2020.

[9] The Kigali Amendment to the Montreal Protocol is an international agreement designed to phase down the use of hydrofluorocarbons (HFC) with higher GWPs, such as R-410A. The U.S. Environmental Protection Agency (EPA), on May 3, 2021, proposed its first rule under the American Innovation and Manufacturing (AIM) Act of 2020 to phase down the production and consumption of hydrofluorocarbons (HFCs), highly potent greenhouse gases commonly used in refrigerators, air conditioners, and many other applications. The AIM Act directs EPA to sharply reduce production and consumption of these harmful pollutants by using an allowance allocation and trading program. This phasedown will decrease the production and import of HFCs in the United States by 85% over the next 15 years. A global HFC phasedown is expected to avoid up to 0.5 °C of global warming by 2100.

[10] "Energy Savings, Consumer Economics, and Greenhouse Gas Emissions Reductions from Replacing Oil and Propane Furnaces, Boilers, and Water Heaters with Air-Source Heat Pumps", Steven Nadel, July 2018, Report A1803

[11] Review was conducted by Diversified Energy Specialists.

[12] This cost is for heating only and does not necessarily include the standby electric heating requirement for low ambient temperature operation, nor does it include a heat pump water heater.

system although it is our experience in Massachusetts that the existing heating system was kept functioning and likely provided standby heating during cold weather.

A recent review[13] of New York State Energy Research and Development Authority (NYSERDA) 2017-2019 Air Sourced Heat Pump Program showed that, of the 9,730 applications for rebates, 5,756 were from single family homes. Only 6.7% of these homes installed systems with the capacity to heat the entire home. The remainder of the applications were for systems that partially heated the home. The NYSERDA Program whole house heating conversion cost for a 2,000 to a 2,500 square foot home averaged $21,926[7]. Note: 45% of these whole house applications specifically indicated that another system was used as a secondary heat source and the remaining applications did not complete this section of the application.

If you have any questions regarding this information, Exergy would be pleased to provide additional information.

Sincerely yours,

Richard S. Sweetser
President

[13] Review was conducted by Diversified Energy Specialists.