INVERTER-DRIVEN RESIDENTIAL HVAC HELPS ANSWER PEAK DEMAND

REPORT
2020

PATHWAY TO A MORE SUSTAINABLE PLANET

Eneref Institute examines how VRF inverter-driven air conditioners can help reduce global carbon emissions.

Eneref Institute

PR FOR PLANET EARTH

Across the US, few residential consumers benefit from the most efficient cooling technology because antiquated testing metrics have not kept up with the most recent advances. Worse still, utility rebates often incentivize older technologies.

As a result, in the United States alone, over 30 million metric tons of carbon dioxide are unnecessarily expelled into the atmosphere each year due to inefficient cooling systems installed in homes.

Any number of efficient technologies could fulfill residential space cooling needs and reduce global warming, including ceiling fans, solar thermal cooling, venting skylights and hydrothermal and geothermal. This report looks at inverter-driven systems because they benefit demand response programs without sacrificing cooling and heating capacity. Inverters are also the fastest option for upgrading or replacing the most commonly installed residential systems, and many companies offer systems for new home construction.

EXPECTED GROWTH IN AC DEMAND

Globally, air conditioning represents the fastest-growing energy demand in homes and buildings. Yet the average efficiency of air conditioners sold today is less than half the efficiency of systems available on store shelves—and only one third as efficient as the most efficient technology currently available, according to the International Energy Agency (IEA).

Air conditioners use about 6% of all electricity produced in the United States, at an annual cost to homeowners of about $29 billion. Three-quarters of all homes in the United States have air conditioners. As a result, roughly 117 million metric tons of carbon dioxide from powering air conditioners are released into the air each year, according to the US Department of Energy. Southern households are almost twice as likely to keep their air conditioning equipment on all summer long, according to a 2009 IEA report—pointing to the significant opportunity that exists for US consumers to reduce their energy load by using more efficient technology.

Globally, the $100 billion air conditioner industry represents 4.26 quadrillion BTUs of energy used per year—the energy equivalent of 350 average-sized coal-fired power plants running continuously for a year. In the US, air conditioners alone represent 1.28 quadrillion BTUs. North America saw an increase in air conditioner sales of 1.8% in 2016, up from the previous year. The largest market for air conditioners in the world, however, is China, representing 40% of the total global demand with a 3.5% sales increase in 2016. Of course, the increased energy demand from air conditioner sales now will further contribute to global warming in the future.

Without action to address energy efficiency, energy demand for space cooling will more than triple by 2050 according to the IEA—an increase equivalent to as much electricity as China and India use today.

To solve the problem of increasing demand, Fatih Birol, Executive Director of the International Energy Agency, says that governments should provide incentives for manufacturers and consumers to utilize more efficient air conditioning technology.

RESIDENTIAL GLOBAL GROWTH / SIZE

Ductless and ducted, mini-split, multi-split, traditional central systems, and heat pumps, are all good candidates for inverter-driven technology. In the Pacific Northwest and

Northeast, fewer homes have ductwork, and ductless mini-split heat pumps can be fitted without the expense of installing ducts. Whereas traditional systems force conditioned air through ducts, ductless systems circulate liquid refrigerant into the home through piping. For homes with existing ductwork, a central system with an inverter compressor presents a textbook example of efficiency.

Continuously variable refrigerant inverter systems are the most efficient on the market today. Inverter-driven technology uses sensors to precisely regulate energy output. Although these systems are 30% more efficient than traditional single-stage air conditioners, less than 5% of homes in the US use inverter-driven technology because, historically, they were more costly. Recently introduced lower-costing inverter systems are likely to disrupt the air conditioner market.

Globally, in regions where air conditioning technology is more recent, inverter-driven technology is more predominant—similar to the way in which mobile phone technology leapfrogged landlines in economically developing countries. Japan has the highest ratio of inverter-driven systems in the world and is the market leader with companies like Daikin, Toshiba, Mitsubishi, Fujitsu and Hitachi. Currently only Daikin has a large manufacturing facility in the US with a nearly half-billion dollar investment, just outside Houston, TX.

Depending on a home's existing system, inverter-driven technology could offer a path to reducing household energy use in the US and globally, explains John Winkler, Senior Research Engineer with NREL, a leading research lab that provides expert guidance to the DOE Office of Energy Efficiency and Renewable Energy.

HOMEBUILDERS MARKET

The growing energy demand for residential space cooling is driven by consumers' changing expectations of comfort, population growth, and increasing household size. In 1960, there were 52.8 million households in the US; by 2017, the US census counted 126.22 million. The amount of space in US homes has increased as well. From 1973 until today, the average US house size has grown from 1,660 square feet to 2,687, based on research published by the American Enterprise Institute.

INVERTERS HELP SOLVE PEAK DEMAND PROBLEM

A demand-enabled inverter air conditioner can provide automatic demand response by varying the cooling and heating capacity with little sacrifice to comfort. This allows energy providers to manage consumer electricity load during peak periods at pre-programmed levels when demand threatens to outpace the supply.

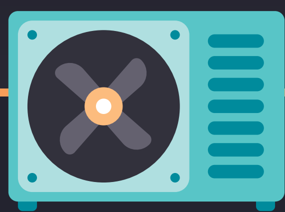
In demand-enabled units, a control loop feedback mechanism adjusts the operating frequency of the variable-speed compressor to regulate the indoor air temperature to user definable weightings. Demand response participants can choose trade-offs among electricity costs or thermal comfort, by allowing the AC unit to automatically respond to dynamic electricity prices. This eases the changes needed in electric usage by end-use customers from their normal consumption patterns, in order to respond to incentives during high electricity market prices or when the provider's reliability is jeopardized.

ENERGY USE METRICS: SEER VS EER

While inverter-driven technology could mitigate the increasing energy demand for space heating and cooling in the US, standing in the way of greater deployment are the methods used to measure and rate the efficiency of residential air conditioners and heat pumps. Conventional air conditioning systems are rated on their Seasonal Energy Efficiency Ratio

ENERGY *of* GLOBAL AC USAGE

GLOBALLY, *the $100 billion air conditioner industry represents 4.26 quadrillion BTUs of energy per year. The energy equivalent of 350 coal-fired power plants running for a year.*



4.26

QUADRILLION BTUs OF ENERGY PER YEAR

350

AVERAGE-SIZED COAL-FIRED POWER PLANTS

(SEER) score, which measures energy used over time, and Energy Efficiency Ratio (EER), which measures energy use at a single point in time. Both metrics were developed with guidance from the Air Conditioning, Heating, and Refrigeration Institute (AHRI). The higher the SEER or EER rating, the more efficient the central air conditioner or heat pump.

Utility companies, along with regulating agencies, often develop incentive programs using one or both performance rating metrics, offering homeowners and building owners more money for higher-rated products. While this is a sound policy for driving consumers to use less energy in heating and cooling their homes, the reliance on EER has its shortcomings when coupled with Inverter-driven products.

Utility companies often use the EER metric to set rebates for high-efficiency units. However, the test procedure for EER assumes a constant outdoor air temperature of 95°F and measures the unit's capability of providing cold air at that outdoor air temperature. Outdoor temperatures only reach and cross 95°F in peak summers in the US. Inverter-driven systems perform significantly better at temperatures below 95°F because of their ability to throttle down, on demand.

A more practical rating method for inverter-driven units is the Seasonal Energy Efficiency Ratio, or SEER, metric. Unlike EER calculations that assume a constant outside temperature of 95°F, SEER accounts for real-world seasonal climate variances. SEER is determined by dividing the cooling output in BTUs by the electric energy input in Watt-hours during a typical cooling season in the US. Holding all technologies to a single metric is disadvantageous for manufacturers, utility companies and consumers alike.

EER TEST PENALIZES INVERTER TECHNOLOGY

Until recently, EER has proven to be an effective metric to score most air conditioners. However, because inverter-driven technology is more efficient under real-world conditions, rebates based on EER alone unfairly penalize inverter technology. Unlike single- or multi-stage technology, inverter-driven technology adjusts compressor speed, and thus how much electricity is drawn by the unit. Inverter systems can operate much more efficiently at partial load conditions, whereas single- and two-stage units only operate at full load or under high-speed operating conditions. The EER score tests all air conditioners at full load, which is generally needed on hotter days.

In fact, in most parts of the US, peak demand for energy represents just 8% of the hours in a year, according to Neil Petchers, CEO of Noresco and author of Combined Heating, Cooling & Power Handbook.

Measuring the performance of inverter technology with an EER score is like testing a hybrid car as a racecar on a racetrack. In the same way that a racecar is designed only for maximum speed, the EER score is based on peak demand, all day, every day. Yet like the inverter, the hybrid car is significantly more efficient for everyday driving conditions.

TESTS ARE NOT DRIVING EFFICIENCY

Research by Eneref Institute has found that chasing an EER score for inverter-driven units has kept some US manufacturers from designing systems that may perform more efficiently in real-world conditions. For inverter-driven systems to satisfy both the EER score as well as the real-world SEER score, manufacturers overengineer units by inserting extra coil, refrigerant and compressor capabilities to

THE *SciBox:*

HOW INVERTERS SAVE ENERGY

Inverter systems are the most efficient on the market today.

AT INITIAL START-UP, INVERTER UNITS *reach a designated set temperature and then reduce capacity as the set temperature is achieved by slowing the compressor speed, which in turn drops the refrigerant flow rate. The compressor rarely shuts off completely. The system maintains the set temperature by constantly monitoring the capacity needs—ramping up or down to meet those needs based on the demand. Constant-speed units, on the other hand, run at full capacity and then shut off, resulting in a stop-start cycle that requires higher power consumption. They create wide temperature swings because when the unit is off, it is not dehumidifying or cooling until it starts up again.*

hit extreme climatic conditions, adding unnecessary cost. In this way, homeowners are charged for technology they may rarely utilize. Giving precedence to SEER for inverter units could bring their price point more in line with single-stage units.

In new home construction, ductless inverter systems reduce construction costs and add additional space by eliminating the need for ductwork. For homeowners, the total cost of ownership for a ductless inverter-driven system can be, in fact, lower than single-stage systems over the life of the system. Inverter systems typically operate at full capacity only 8% of the time, significantly reducing energy costs. And inverter-driven systems are less sensitive to matching the size of the unit to the load; picking the right unit size becomes less critical because inverters have a varying capacity.

REBATES SHOULD INCENTIVIZE BEST INVERTER DESIGN

Typically, utility rebates in the US are based on 16 SEER and 13 EER score — determined by the ratio of cooling output to energy input. The higher the score, the more efficient. Many rebates do recognize SEER but still require an EER score, adding unnecessary expense to inverter-driven systems. While some recently introduced inverter-driven systems are competitively priced with two-stage systems, the most efficient inverter-driven systems remain costly for too many consumers. However, if EER requirements were eliminated for inverter systems altogether, costs for even the most efficient inverter systems might line up to conventional systems.

"If the costs were the same, then I would hope we would all have inverter-driven variable speed technology systems because we'd save energy and operating cost," explained William Goetzler, lead author of the report Research & Development Opportunities for Joining Technologies in HVAC&R and Navigant Managing Director. "We would be more comfortable. We'd reduce our carbon footprint. There's really no downside."

USE LOW GWP REFRIGERANTS

One important factor to reduce global warming is the type of refrigerant used to transfer heat. Several new refrigerants offer a balance of key factors including efficiency, greenhouse gas mitigation, cost, safety and ability to commercialize. For example, R-32, already available on the market, has one-third of the global warming potential and is more efficient than R-410A, the most common refrigerant in traditional air conditioners (see Eneref Report: *Examination of the Use of R32 Refrigerant in Window Air Conditioners*). Other new refrigerants also show promise in the near future.

HOW STATES CAN INFLUENCE CHANGE

The roadmap to more efficient residential air conditioners should begin at the state level. For example, NYSERDA has determined that the heating and cooling of buildings represents 32% of New York State's combustion-related greenhouse gas (GHG) emissions. Inverter-driven systems could lower the greenhouse gas emissions for New York. In almost all California climates, homeowners would see an energy reduction with inverters.

In a 2011, IEA set a performance target of a 20% to 40% efficiency improvement of installed AC equipment by 2030. A 30% improvement by 2030 could reduce global CO^2 emissions by up to 25 billion metric tons over the lifetime of the equipment, according to a 2016 US Department of Energy report — which is equivalent to eliminating the annual emissions of 1,550 coal-fired power plants. Many manufacturers have incorporated inverter-driven variable-speed compressors and fans to reach the global building energy efficiency goals set by IEA. Now it's time for the government agencies to reward—rather than penalize—more efficient inverter-driven technology.

v66-9

PR FOR PLANET EARTH™

Every organization must harness their capacity to improve our planet and society.

Right now, we need to make unprecedented changes to ensure a sustainable and equitable society. Limiting global warming requires rapid and far-reaching transitions in land, energy, industry, buildings, transport and cities. Every extra bit of warming matters to reduce irreversible harm to our ecosystems.

We encourage organizations to grow sustainably and act responsibly by raising awareness for clear, specific solutions that offer an efficient use of natural resources, demonstrate social responsibility and foster a peaceful, earth-friendly economy.

™Eneref Institute

Eneref Institute

WASHINGTON. LONDON. NAIROBI. BOGOTA. MANILA

twitter.com/eneref facebook.com/eneref vimeo.com/eneref

917.779.8600 | eneref.org