shecco public affairs

comments on Draft 1 Version 3.0 ENERGY STAR Specification for Room Air Conditioners

25 January 2011

"EPA SEEKS COMMENT ON TECHNOLOGIES, BEST PRACTICES, AND ALTERNATIVES, THAT MAY BE INCORPORATED INTO ENERGY STAR RAC PROGRAM TO REDUCE THE REFRIGERANT-RELATED CLIMATE IMPACTS OF RACs[1]"

OUR MESSAGE: shecco advocates that the use of natural refrigerants hydrocarbons, with zero ozone depletion potential (ODP) and minimal global warming potential (GWP; most hydrocarbon refrigerants have GWP ≤ 3) is especially suitable for small appliances with low refrigerant charge such as room air conditioners.

On top of the minimal climate impact through direct effects (leakage of refrigerant), hydrocarbon refrigerants also ensure minimal climate impact through indirect effects thanks to significant energy savings that their use entails.

Regarding flammability and safety concerns associated with the use hydrocarbon refrigerants, equipment manufacturers in Europe and Asia have designed and tested household and commercial refrigerators and freezers for more than 10 to account for them, with the know-how now propagating into other applications encompassing small hydrocarbon charges, such as room air conditioners.

Indeed under the SNAP programme, the use of hydrocarbons is at the verge of being approved in the US for domestic refrigerators/freezers as well as plug-in retail equipment[2]. Following this first step, the approval of the use of hydrocarbons in small AC equipment would be the next rational step, that could lead to significant energy savings and emission cuts in the US and insure the industry against future policy developments that could place restrictions on the use of refrigerants with high GWP. Moreover, unlike the case of domestic refrigerators, a worldwide established technology that the US has been a laggard in adopting, the market for hydrocarbon room air conditioners is still emerging. Therefore, this type of equipment represents a market opportunity for the US industry.

Moreover, it is worth noting that the Energy Star equivalent programme in the EU, the so called European Ecolabel has recognised the carbon emissions savings that low GWP refrigerants can achieve, and therefore incentivises their use. Drawing on the European Ecolabel scheme, European decision makers are currently considering to include similar incentives pertaining low GWP for the specification of "Eco-design" criteria for room air conditioners, i.e. criteria that specify which room air-conditioning products will be allowed on the European market.

[1] ENERGY STAR® Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Draft 1 Version 3.0, http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/room_air_conditioners/ES_Draft1_V3_RAC_Specification.pdf

[2] Proposed rule making Protection of Stratospheric Ozone: Listing of Substitutes for Ozone- Depleting Substances—Hydrocarbon Refrigerants, http://www.gpo.gov/fdsys/pkg/FR-2010-05-10/pdf/2010-10959.pdf

This document provides an overview of European initiatives that promote the use of low-GWP refrigerants such as hydrocarbons, as well as the properties of hydrocarbons, their energy efficiency credentials, safety issues and the availability of products.

The European Ecolabel: the EU's Energy Star

The Energy Star equivalent programme in the EU, the so called European Ecolabel[3] has recognised the carbon emissions savings that low GWP refrigerants can achieve, and therefore incentivises their use. Indeed, the European Union (EU) decision regarding European Ecolabel criteria for heat pumps (note that heat pumps is the only refrigerant using product group for which Ecolabel criteria have been specified), provides a 15% incentive in terms of minimum energy efficiency requirements for the award of the Ecolabel if the product uses a refrigerant that has a GWP of less than 150[4].

Drawing on the European Ecolabel scheme, European decision makers are currently considering the inclusion of similar incentives pertaining low GWP refrigerants for the specification of "Eco-design" criteria for room air conditioners, i.e. criteria that specify which room air-conditioning products will be allowed on the European market.

Hydrocarbon refrigerants

Hydrocarbons are natural, non toxic non ozone depleting replacements for chemical refrigerants. They are safe to use with proper handling, highly energy efficient, able to replace CFCs and HFCs in existing systems without components or oils having to be changed. They also make sense from an economic point of view thanks to their low purchase price and the lower running costs for the systems relying on them.

Hydrocarbon refrigerants have been in use since 1867 and in conjunction with ammonia were the most widely used refrigerants prior to the introduction of chlorinated fluorocarbon refrigerants in the 1930s. Today, due to mounting environmental concern caused by the global warming potential of HFCs and the forthcoming ban of ozone depleting substances, hydrocarbons are at new considered as viable options in the

[3] More information on the EU Ecolabel can be found at http://ec.europa.eu/environment/ecolabel/

[4] The EU decision regarding Ecolabel criteria for heat pumps (2007/742/EC) states that "if the refrigerant has a GWP of less than 150 then the minimum requirements of the Coefficient of Performance (COP) and primary energy ratio (PER) in heating mode and the energy efficiency ratio (EER) in cooling mode […] shall be reduced by 15%", http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:301:0014:0025:EN:PDF

refrigeration technology.

comparing hydrocarbons with chemical refrigerants

The following table provides an overview of the different hydrocarbon refrigerants available and some of their properties.

Refrigerant	Name	Normal boiling point	Critical temperature
R-600a	Iso-butane	-11°C	135°C
"CARE 30"	Iso-butane/ propane mix	-31°C	115°C
R-290	propane	-42°C	97°C
R-1270	propylene	-48°C	92°C
"CARE 50"	Propane/ ethane mix	-49°C	91°C

Note: Mixtures have temperature glide: CARE 30 ~7 K, CARE 50 ~5 K

Source: GTZ Proklima 2008

The following table presents the environmental attributes of different hydrocarbon refrigerants in terms of Ozone Depletion Potential (ODP), atmospheric lifetime and Global Warming Potential and compares them to CFC, HCFC and HFC refrigerants.

Refrigerant	ODP (R11=1)	Atmospheric lifetime (y)	GWP(100) ($kgCO_2$ kg^{-1})
CFC 12	1.0	100	10720
HCFC R22	0.055	12	1780
HFC R134a	0	14	1410
HFC 404A	0	14 – 52	3862
HFC 407C	0	5 – 29	1750
HFC 410A	0	5 – 29	2060
Propane HC R290	0	0.04	6
Iso-butane HC R600a	0	0.02	7
Propylene HC R1270	0	0.001	5

Source: GTZ Proklima 2008

Energy efficiency of hydrocarbon air conditioning

This section provides first energy efficiency data related to a state-of–the-art hydrocarbon room AC and then energy efficiency data compiled by a study that reviewed 54 technical papers detailing experimental performance comparisons of various hydrocarbon and non-hydrocarbon refrigerants for applications such as air-conditioning and heat pumps.

Energy efficiency of a state-of –the-art hydrocarbon room air conditioning

A state-of-the-art hydrocarbon room air-conditioning system has been developed by the Chinese manufacturer Gree[5]. Gree in cooperation with GTZ Proklima and funded by the German Ministry for Environment[6], have deployed a demonstration project for hydrocarbon air conditioning produced by Gree in China. The hydrocarbon room air-conditioner bears the name GREE R290 Air Conditioner. The production line of the Gree

[5] Since 1995 Gree sales volume and market share has occupied the top ranking in the Chinese air conditioner industry. Since 2005 Gree sales volume of residential air conditioners occupied the first place globally. For 2008, 190 million units manufactured by Gree were sold worldwide. Gree products are sold in 200 countries.

[6] German Ministry for Environment, Nature Conservation and Nuclear Safety within the framework of the International Climate Initiative.

R290 was completed at the end of 2010 and the product will be marketed from 2011 onwards. Gree expects to sell 100.000 units annually, with a primary marketing focus in Europe and China.

The company will enter in the production phase of units with 9000 BTU and 12000 BTU, but is also currently testing the possibility to minimise the hydrocarbon refrigerant charge for larger units with 18000 BTU.

The Gree product fulfills all the safety standards that are in place and has passed all tests that have granted the product VDE[7] and GS[8] certification.

Regarding the energy efficiency of this product, the coefficient of performance (COP) of the GREE R290 air conditioner is between 3.52 and 3.55 depending on the model and hence is better than the "A" rating of the EU efficiency labeling for air conditioners (Source: Gree Electric 2009)

Capacity **kw (Btu)**	**COP** **w/w**	**Charge** **gram**	**Max noise (Inside)** **Db**	**Max noise (Outside)** **Db**	**Size** **mm**
2.7 (9K)	3.55	265	38	52	Outdoor unit 830x284x205 Indoor unit 760x257x541
3.2 (11K)	3.54	310	41	52	
3.5 (12K)	3.52	330	41	52	

Source: Gree Electric 2009

[7] VDE is the Association for Electrical, Electronic &Information Technologies is one of the largest technical and scientific associations in Europe with more than 34 000 members; http://www.vde.de/EN/Pages/Homepage.aspx

[8] GS is the Germany's safety certification mark

A review of 54 technical papers

Colbourne and Suen (2000), reviewed 54 technical papers detailing experimental performance comparisons of various hydrocarbon and non-hydrocarbon refrigerants for applications such as air-conditioning and heat pumps.

In order to help determine the effect of performance through the use of various refrigerants in real systems, the authors reviewed all obtainable technical papers that detail experimental results comparing HC refrigerants and non-HC refrigerants. The results obtained for air conditioning and heat pump application are presented in the two following figures.

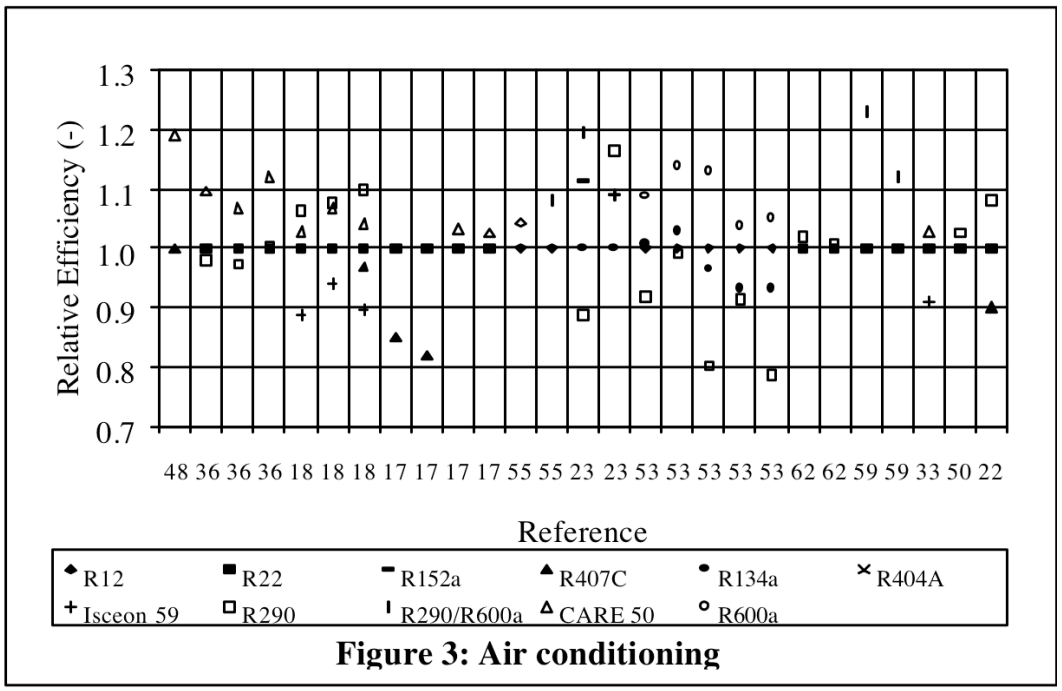


Figure 3: Air conditioning

Source: Colbourne and Suen, 2000

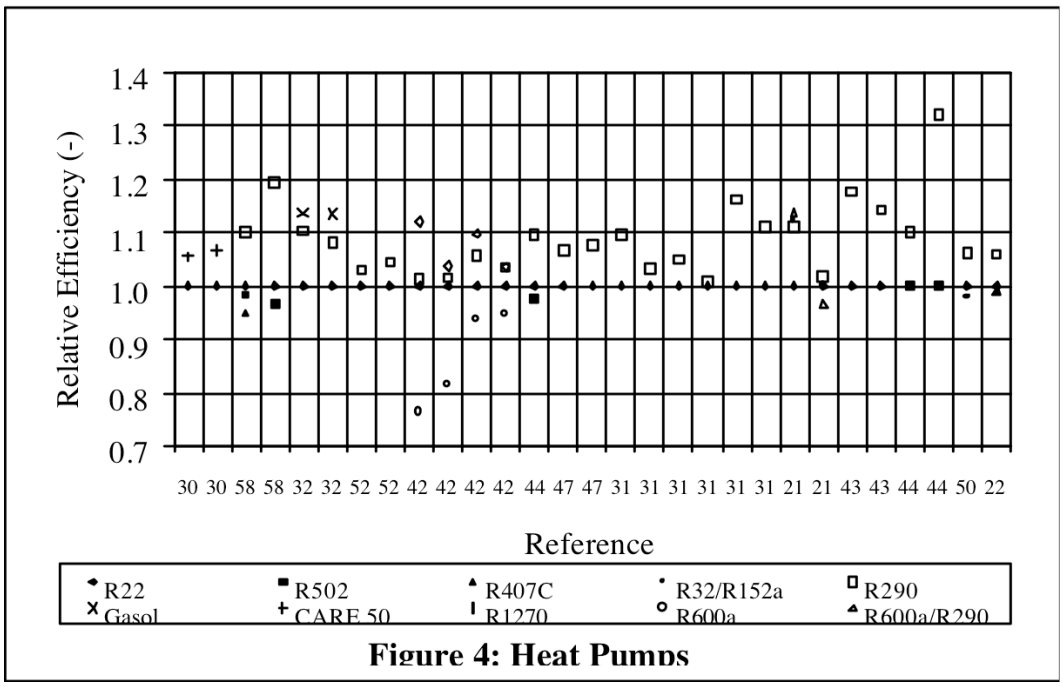


Figure 4: Heat Pumps

Source: Colbourne and Suen, 2000

From the review of experimental data, it can be seen that a significantly higher number of experiments show favourable performance using HCs than with fluorinated refrigerants.. Whilst HCs do not always offer the highest COP, it is the case in approximately 90% of the cases reviewed. Depending upon the type of application there is an average improvement of approximately 10%.

An analysis of the data is shown in the following table:

Table 2: Summary of Results of Experimental Data

Application	Proportion of cases where HCs give best performance (COP)				Mean improv.
	<10% improv.	10-20% improv.	>20% improv.	Total	
Air Conditioning	63.0 %	25.9 %	3.7 %	92.6 %	8.8 %
Heat Pumps	58.6 %	37.9 %	3.4 %	100.0 %	9.6 %

Considering the system component performance review, the use of certain HCs also indicates favourable performance over CFCs, HCFCs and HFCs. In comparison with R22, the higher-pressure hydrocarbons, particularly R1270 and CARE50 (proprietary blend of R170/R290) offer favourable reductions in approach temperature differences in both evaporator and condenser, benefits in terms of pressure loss and compression COP. These are generally due to the beneficial thermodynamic transport properties inherent in HCs such as low viscosity and high thermal conductivity. The benefits of these properties are detailed in Table 1. The two HFCs that provide similar performance indicators to these high-pressure hydrocarbons are R407C and R410A. Whilst very little experimental work has

compared the performance R410A and HC, several sets of test data are detailed in section 2, which shows a drop in system COP when using R407C instead of HCs and R22.

As thermodynamic and transport properties of a refrigerant have a fundamental effect on system performance, the authors also assessed a number of system components for a variety of refrigerants.

Considering this system component performance review, the authors found that the use of certain HCs also indicates favourable performance over CFCs, HCFCs and HFCs. In comparison with R22, the higher-pressure hydrocarbons, particularly R1270 and CARE50 (proprietary blend of R170/R290) offer favourable reductions in approach temperature differences in both evaporator and condenser, benefits in terms of pressure loss and compression COP. These are generally due to the beneficial thermodynamic transport properties inherent in HCs such as low viscosity and high thermal conductivity. The benefits of these properties are detailed in Table 1. The two HFCs that provide similar performance indicators to these high-pressure hydrocarbons are R407C and R410A. Whilst very little experimental work has compared the performance R410A and HC, several sets of test data that are detailed in this study show a drop in system COP when using R407C instead of HCs and R22.

Without applying detail system simulations to the applications described in this study, a rating system has been used to indicate which refrigerants are most favourable with respect to the parameters that effect energy efficiency. The rating detailed in Table 3 is provided as a number (1-4) with 1 indicating the best component performance relative to R22.

Table 3: Summary of Component Performance Results

Rating	Compressor (LT/HT)	Pressure Loss	Evaporator Temp.	Condenser Temp.
1	R410A / CARE50	R1270	CARE50	R600a
2	CARE50 / R410A	CARE50	R407C	R134a
3	R407C / R407C	R290	R1270	R1270
4	R1270 / R1270	R410A	R404A	R507

The frequency of hydrocarbons within the upper ratings of component performance corresponds with the summarised results of the experimental work. The relationship between refrigerant properties and performance indicators suggests that amongst others, the high thermal conductivity and low viscosity of these fluids is a significant contributory factor.

Affordability of hydrocarbon air conditioners

System affordability

The R290 containing air conditioners can be produced cheaper than R22 products, because:

• Narrower tubes can be used in the condenser and evaporator since R290 has better heat transfer properties and a lower pressure drop.
• R290 refrigerant is even cheaper than f-gases. Since R22 air conditioners are cheaper than R407C and R410A units, one can conclude that R290 air conditioners will be much cheaper than R410A units (Gree Electric 2009)

Compressor affordability

Gree's R290 compressors currently cost only as much as a R410A compressor. Cost is likely to go down when production increases (Gree Electric 2009).

Costs of HC conversions

GTZ Proklima has carried out work on gathering reliable information on the cost of converting to hydrocarbon refrigerants and the associated CO2-eq cost-effectiveness through analysing costs of demonstration projects already carried out and discussing with other manufacturers[9]. The costs associated with the change of refrigerant comprise three aspects, including investment costs (product development, production line, internal training), product costs (materials, safety devices) and in-use cost (energy consumption, refrigerant, technician tooling), with the latter one representing less than 1% of total costs.

The GTZ study was concerned with two different types of products, namely room air conditioners and stand alone commercial refrigeration. The average investment cost per unit has been estimated at $13 for room air conditioners and $11 for stand alone commercial refrigeration. Product costs has been estimated at +$4/unit for converting air conditioners from R22 to R290 (propane) and at $-29/unit for converting air conditioners from R410A to R290. For stand alone commercial refrigeration products, costs have been estimated at +$6/unit when converting from R134a to R290 and at +$1/unit when converting from R404A to R290. Overall, shifting to hydrocarbons has been found to provide excellent cost-effective emissions reduction.

It is thus surprising that hydrocarbons have not been taken up more widely, though this is

[9] Read presentation on the issue at
http://www.atmosphere2010.com/files/speakers/presentations/pdf/Hasse-Proklima_education_session.pdf

anticipated to change.

Hydrocarbon safety

About safety in general

Like many commonly used commodities such as petrol, natural gas and electricity, the use of hydrocarbon refrigerants requires common sense and observance of adequate safety procedures. Hydrocarbons are used safely in all walks of life from hairspray and cooking gas to fuels for cars and airplanes.

As hydrocarbons are classified as flammable in international safety standards, their use in charges of up to 150 grams per systems must follow certain guidelines. However, a major problem for the global application of hydrocarbons is the lack of consistency from country to country, with some posing weaker or stricter legal requirements, and others still completely banning hydrocarbons from certain applications. The USA might serve as the best example of a world market currently in the process of lifting bans on the use of hydrocarbons in applications other than industrial process refrigeration.

The Australian standard AS 1677-1988 includes comprehensive procedures for the safe storage, handling and use of all refrigerants, including hydrocarbons.
Safety discussions over the use of hydrocarbon refrigerants already took place 12 years ago for the case of hydrocarbon (R600a) refrigerators, relying on the "Greenfreeze" technology. Although initially there was industry resistance to this technology, nowadays there are more than 300,000,000 domestic refrigerated appliances operating on hydrocarbons, a proof that hydrocarbons can be safely used. Greenfreeze has become the dominant technology in Europe. Many models of Greenfreeze refrigerators are now on sale in Germany, Austria, Denmark, France, Italy, the Netherlands, Switzerland and UK. All major European companies are marketing Greenfreeze technology-based refrigerators[10]. 100% of the German market has converted to Greenfreeze technology.

Research by international risk assessment engineers[11] indicate an extremely low risk to motor vehicle occupants from accidental release of hydrocarbon refrigerant.

[10] Bosch, Siemens, Electrolux, Liebherr, Miele, Quelle, Vestfrost, Whirlpool, Bauknecht, Foron, AEG.

[11] The Arthur D. Little Group. Also, the School of Mechanical and Manufacturing Engineering University of N.S.W.

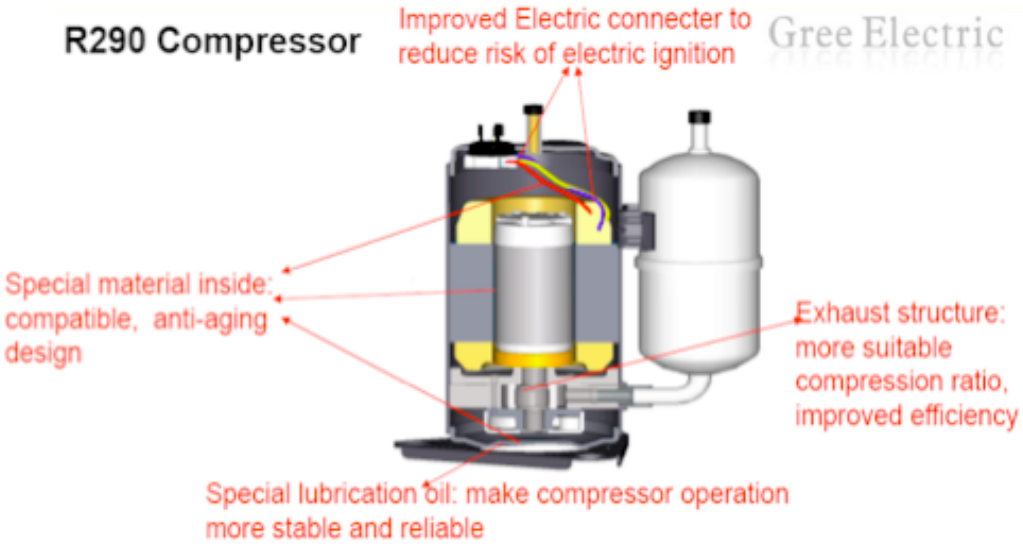
The most significant point to be made is that there is a total lack of technical evidence to refute the case for hydrocarbon refrigerants.

About safety in particular - hydrocarbon air conditioning

Similar to the case of hydrocarbon residential refrigeration appliances, several safety product features are incorporated in the design of hydrocarbon air conditioners.

Gree R290 AC designs achieved lower refrigerant charge size than is currently required by international standards for R290 air conditioners (IEC 60335-2-40).

Additional features include a special compressor design and refrigerant leak alarm system. The R290 air conditioners will achieve CE marking (i.e., compliant to EU legislation on safety standards).



(Source: Gree Electric 2009)

With the refrigerant leak alarm system, should a leak be detected in the AC system:

* The compressor will stop operating at once. This avoids high temperature and protects the compressor.

* The fans will keep on running (indoor and outdoor). This dilutes the leaking refrigerant through the air flow and thereby avoids gathering gas in the small area and flammable concentrations.

* A special audible alarm and flashing light signal will turn on. This alarms the owner to open the door or window of the room for ventilation and to call the service telephone number.

Theory of the alarm system in GREE hydrocarbon air conditioner

As refrigerant leaks out, the performance of the system will drop.

• The operating parameters of a leaking air conditioning system are different compared to a normally functioning air condition unit.
• As the air conditioning system leaks, the system pressure, refrigerant and air temperatures, electric current, etc. will all change.
• An electronic control device detects this intelligently and recognises that a leak is really happening, thereby triggering the alarm and shutting the air conditioner down.

hydrocarbon room air-conditioning in serial production

Since 1995, the large Italian manufacturer **De'Longhi** has sold its popular propane cooled portable air conditioners called Pinguino ECO on the European market.

Britisg company **Earthcare Products Limited** has developed a new range of heat pump air conditioning split systems, in partnership with the UK Government's Department of the Environment, Transport and the Regions (DETR). These systems minimise environmental impact through the combination of natural refrigerants and optimised efficiency. The result is an efficiency gain of 20% over the original HCFC22 systems.

Additionally, **Elstar Company** of the UK is producing a variety of hydrocarbon based split-air conditioners for both home and office use.

Benson Air Conditioning of Australia is marketing split-unit domestic hydrocarbon air-conditioners, manufactured in China and Thailand. According to the company, the hydrocarbon units perform with 15-20% better energy efficiency than the company's comparable previous R22 range. Benson sells 5 models with the following heating/cooling capacity and associated Energy Star Ratings under Australia's MEPS scheme:

Type	Cooling Size	Energy Rating	HC Charge
Wall Mounted Split Systems	2.31 kW / 2.6 kW	4.5/5.5 star	300g
	3.4 kW / 3.4kW	4.5/4.5 star	
	5.1 kW / 5.6 kW	4/3.5 star	
	6.3 kW / 6.6 kW	4/4 star	
	8.2 kW / 8.4 kW	4/3 star	
Ducted Systems			
Single phase	10.3 kW / 10.4 kW	3/3.5 star	
	12.3 kW / 12.1 kW	5/4.5 star	
	16.3 kW / 16.2kW	3.5/4 star	
Three phase	12.8 kW / 12.8kW	4.5/4.5 star	
	17.5 kW / 17.1kW	4/5 star	1.2 kg

As already mentioned, **Gree Electric Appliances of China** is about to market a highly efficient hydrocarbon air-conditioner, with COP of 3.6, energy efficiency 15% better than corresponding HCFC-22 unit, and total hydrocarbon charge less than 300 grams. This is set to change the market globally, as Gree since 2005 has occupied the first place globally in sales volume of residential air conditioners.

In China and India together, at least five major manufacturers are now introducing R-290 production lines.
Over 20 heat pump and AC manufacturers offer products with hydrocarbons in Europe. (Palm, 2008 B. Palm, Hydrocarbons as refrigerants in small heat pump and refrigeration systems – a review, Int. J. Refrigeration 31, 2008). Moreover, it is worth noting that until 2004, up to 50% of domestic heat pumps sold in EU used R-290. The reason for the decline was a result of the European Pressure Equipment Directive and the compressor manufacturers not being prepared to carry out the approval procedures for relatively low volumes.

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