EUROPEAN LPG ASSOCIATION

Beyond the Gas Grid

An LPG Industry Roadmap

AEGPL EUROPE

AEGPL is the sole representative of the LPG (Liquefied Petroleum Gas) industry at European level, representing 24 national LPG Associations as well as distributors and equipment manufacturers from across Europe.

Our mission is to engage with EU decision-makers and the wider policy community in order to optimize the contribution that LPG - as a clean and immediately available energy source - can make to meeting Europe's energy and environmental challenges.

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AEGPL
Rue Belliard 15-17,
B - 1040 Brussels
Belgium

aegpl@aegpl.be
www.aegpl.eu

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EXECUTIVE SUMMARY

The next twenty years will be a defining period in the EU's efforts to establish an energy system that is at once sustainable, secure and economically competitive. Achieving this objective will require fundamental changes in the way Europeans produce, distribute and consume energy in key areas such as transport, power generation and the residential sector. Restructuring the energy model underpinning the residential sector constitutes a particular challenge since any policy designed to enhance its performance must be capable of addressing not just a handful of key infrastructure points but rather the millions of different buildings and building components of which it is composed.

However, given the sector's substantial environmental impact and the vast potential for improvement that has been identified[1], this is not a challenge that can be ignored. Households account for 25% of European energy consumption and 10% of Europe's carbon dioxide emissions[2]. They are also a significant and often underestimated source of air pollution. In addition, the European building stock as a whole constitutes a strategic weakness and an unnecessary drain on the economy since unrealised efficiency improvements translate directly into excessive spending on energy costs and an undue reliance on imported resources.

When considering how the energy performance of the domestic sector can be improved, policy-makers tend to focus on increasing the uptake of renewable energies and exploiting possible efficiency gains. Both strategies should indeed be pursued as a matter of priority, but, as this roadmap will demonstrate, positive results can also be achieved simply by reducing household consumption of liquid and solid fuels, and increasing the use of their more sustainable gaseous counterparts, natural gas and LPG. In this sense, the combination of renewables, energy efficiency and gas can be said to constitute an effective formula for managing the transition towards an energy system that is more compatible with the EU's strategic, environmental and economic objectives. While renewables and energy efficiency measures can be implemented all over Europe, the reach of the natural gas network and, by extension, its capacity to supply the European domestic energy market - is limited.

Beyond the Pipeline: Rethinking the Limits of Gas as a Domestic Fuel

A recent study designed to provide input to the European Commission in the context of the eco-design Directive featured a commonly-held misconception about the role of gas in the European residential energy model. The report finds that although significant primary energy savings can be achieved by encouraging end-users to switch from electric cooking equipment to gas-powered equivalents, the practical feasibility of such a policy is limited since "gas is not available in all parts of the EU"3.

This statement would be accurate if the only 'gas' suitable for use as a residential energy source were methane (natural gas). Fortunately, however, LPG, as a portable, easily transportable gaseous fuel, is available everywhere, even in remote regions such as mountains and islands, making it an effective complement to natural gas, whose reach is constrained by its reliance on a piped network. Once this broader notion of 'gas' is accepted and taken into account, the full potential of gaseous fuels to contribute to Europe's energy and environmental objectives in the residential sector becomes apparent. LPG currently responds to 17.4%[4] of the household energy demand in "off-grid Europe" (OGE) - the area not covered by the natural gas or district heating networks - and could potentially play twice as big a role by 2030.

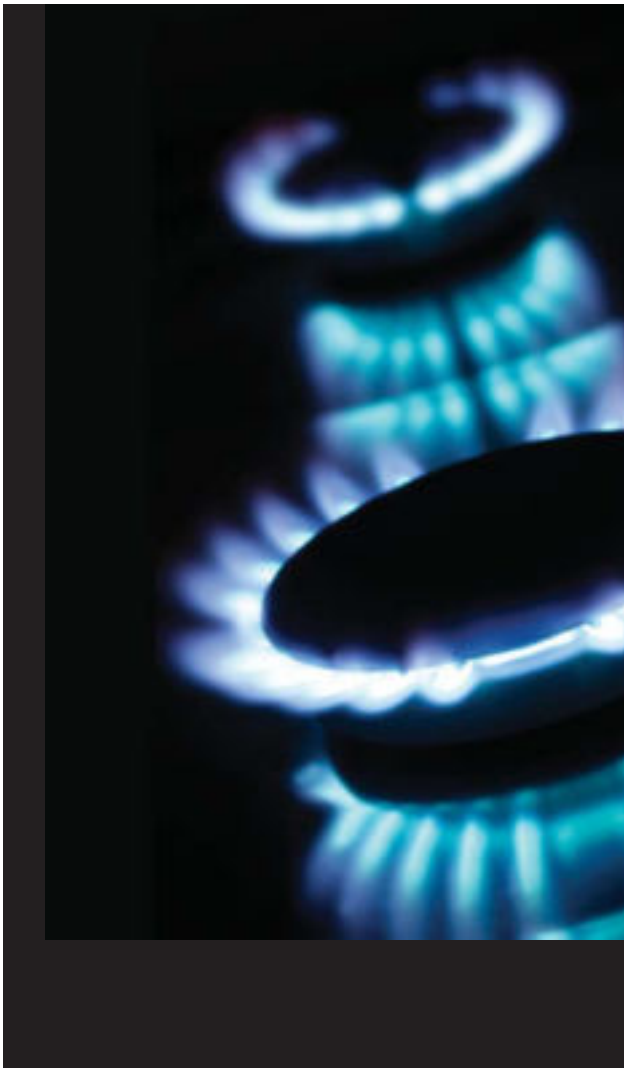
Though it is rarely analysed as an independent entity, OGE is comprised of 40.7 million households, making it a significant and distinctive part of the residential energy system. Indeed in 2010, OGE's residential sector accounted for 50.8 million tonnes oil equivalent (Toe) of energy consumption and generated 82 million tonnes of $C0_2$ emissions. On a related

note, OGE is the segment of the European residential energy system in which carbon intensive and polluting energy sources such as heating oil and coal play the most significant role. The continued presence of these fuels - and the associated possibility of replacing them with more sustainable alternatives, is at once a problem and an opportunity for European policy-makers and citizens alike. As with the energy system as a whole, an increased role for gaseous and renewable energies, including a gradual doubling of LPG's contribution by 2030, in tandem with a heightened focus on efficiency, would help optimize the energy performance of residential OGE today while paving the way towards the low carbon model of tomorrow.

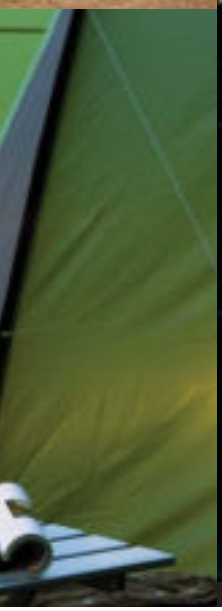
LPG as Part of a More Sustainable Residential Energy Model

Independent econometric modelling analysis carried out using PRIMES, the principal energy scenario tool used by the European Commission, suggests that LPG could make a significant contribution to the pursuit of Europe's energy objectives by displacing a significant share of liquid and solid residential fuel between today and 2030. Specifically, the doubling of LPG's share in residential OGE would generate 184 million tonnes in avoided $C0_2$ emissions, a 7% improvement in overall energy efficiency of the European residential sector, and a 2% increase in the role of solar energy and geothermal heat as compared to the Reference case[5].

This document is designed to (a) demonstrate the potential contribution of LPG to enhancing the overall sustainability of off-grid Europe's residential sector, and (b) identify the principles and practices which the LPG industry and policy-makers at local, national and European level can apply in order to transform this potential into reality. It is, as the title suggests, a roadmap to a more sustainable, secure and competitive energy model for Europe in general and "off-grid" Europe in particular.



[1] See the Energy Efficiency Action Plan, DG Energy, European Commission, 2011
[2] EU Energy Transport in Figures, Statistical Pocket book, DG Energy, European Commission, 2010
[3] Preparatory Studies for Eco-design Requirements of EuPs, Lot 23, Task 6, bioIntelligence Service, March 2010
[4] All data on OGE was produced in 2011 by the E3M Lab of the Technical Institute of Communication and Communication Systems of the National Technical University of Athens, using the PRIMES model. PRIMES is a modelling tool designed to provide forecasting, scenario construction and policy impact analysis for EU energy markets up to the year 2030. It is used primarily in the field of energy and environmental policy, notably by various departments within the European Commission, to analyse, among other things, impacts of carbon emission trading, renewables and energy efficiency policies on energy markets in the 27 Member States.
Subsequent references to findings in this document obtained using PRIMES will come under the heading 'PRIMES'. For more information, visit E3MLab of the National Technical University of Athens at http://www.e3mlab.ntua.gr/e3mlab/
[5] PRIMES



PART 1. LPG IN A NUTSHELL

What is LPG and Where Does It Come From?

LPG is a blanket denomination covering propane (C3H8) and butane (C4H10), two naturally occurring gases which are easily converted to liquid form through the application of moderate pressure.

LPG is primarily derived during the exploitation of natural gas (the origin of 66% of global LPG supply) and oil fields. It is also produced in refineries. It is a highly versatile energy source with hundreds of applications in the home, in industry and in agriculture. It is also Europe's leading alternative road transport fuel. Often underexploited in the past due to unsustainable practices such as flaring and venting, it is increasingly being recognized as a unique and valuable energy resource that can contribute to addressing Europe's various energy and environmental imperatives.

The fact that it can be easily liquefied and transported makes LPG a highly versatile energy alternative suitable for hundreds of different applications. LPG already responds to the different energy demands of more than 120 million EU citizens. The most common applications for LPG include:

- Space and water heating
- Cooking
- Industrial processing and heating
- Automotive transport
- Agriculture
- Power generation

How does LPG Contribute to the Pursuit of Europe's Energy and Environmental Objectives?

• Lower Carbon

LPG is a lower carbon alternative to liquid and solid fossil fuels. Its combustion emits 49% less carbon dioxide than coal and 17% less than heating oil[6]. LPG also emits almost no black carbon, which scientists now believe is the second biggest contributor to climate change globally and is perhaps the single biggest cause of arctic warming[7].

[6] Based on emission factors set out in European Commission Decision 2007/589/EC
[7] See the final report of the EU Arctic Footprint and Policy Assessment, Ecologic Institute, Berlin, December 2010

Black Carbon and Climate Change: Gaseous Fuels to the Forefront

Though it has rightly been identified as a priority in the fight against climate change, carbon dioxide is not the only emission that policy-makers need to address. Over the past few years, the scientific evidence on the link between climate change and black carbon, a product of in-complete combustion of fuels, notably diesel and biomass, has become increasingly convincing. Climate scientists globally are now in broad agreement that as well as reducing carbon-dioxide emissions, it is also necessary to adopt policy measures to curtail black carbon emissions.

While there is still research to be done to more accurately quantify and understand the impact of black carbon, scientists are now saying that:

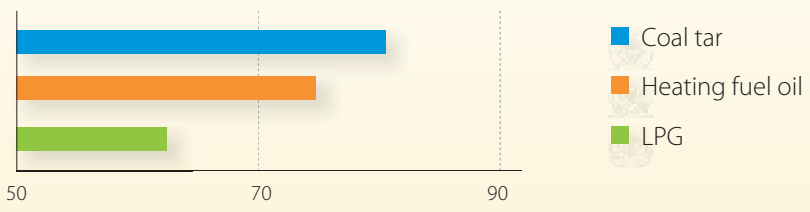
- Black carbon is responsible for around 20% of global warming, making it the second biggest contributor, behind carbon dioxide.
- The EU is the source of as much as 59% of black carbon emissions in the arctic, a region in which they have a disproportionately high impact.
- As black carbon has an atmospheric lifespan of only a few weeks, emissions cuts have a practically immediate effect, whereas reductions in carbon-dioxide emissions, although essential in the fight against global warming, take as long as 100 years to make an impact on the climate.

In a 2010 report the United Nations Economic Commission for Europe (UNECE) identified the residential sector as having the highest black carbon mitigation potential. LPG, as a clean burning gaseous fuel whose combustion produces particularly low levels of black carbon, can help make these potential reductions a reality.

Policy-makers should be aware of the potential tradeoffs associated with the promotion of fuels such as biomass which may ostensibly constitute a means of reducing carbon dioxide emissions while contributing to the problem of climate change through their black carbon emissions. As the UNECE notes, "the use of biomass is growing in some countries due in part to a desire to decrease CO_2 emissions from fossil fuel use. This may result in the increase of local and regional levels of BC".

Though more research needs to be carried out, it is already clear that black carbon mitigation has the potential to play a meaningful role in European and global efforts to address climate change. The LPG industry stands ready to contribute.

Figure 1: **$C0_2$ Emission Factors of a Selection of Residential Fuels**

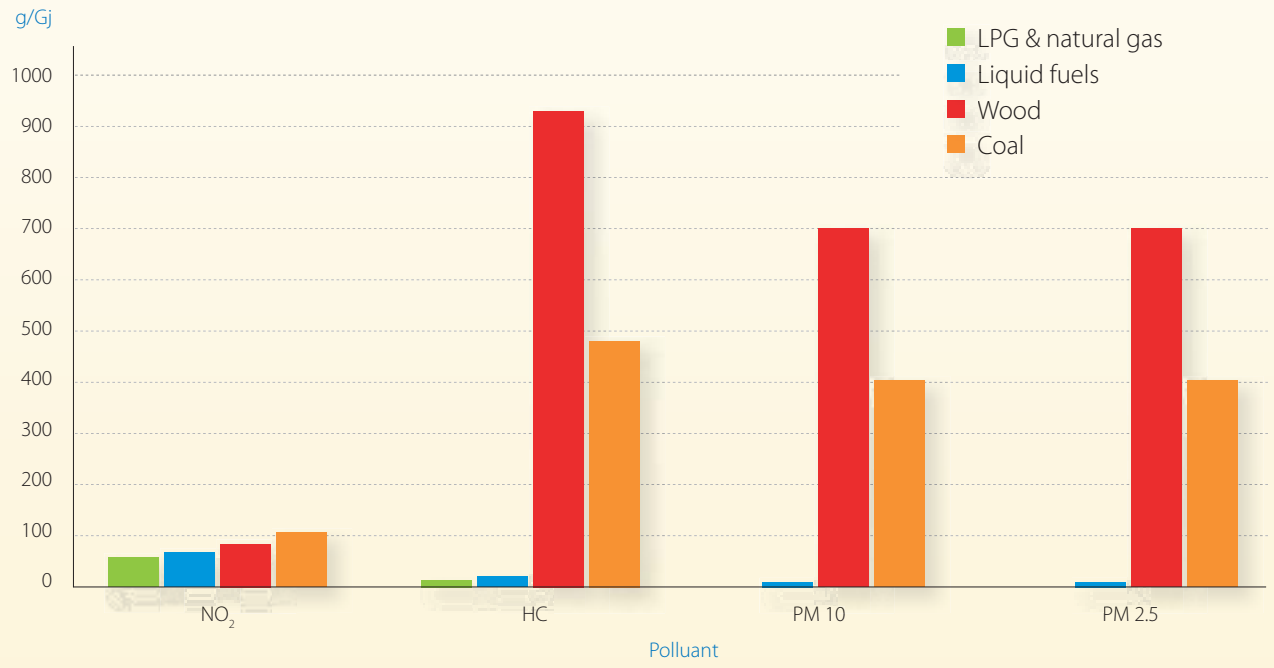


Source: United Nations Intergovernmental Panel on Climate Change

• Clean

Pollution of air at a local level can seriously influence health. Polluted air not only affects humans through respiratory ailments and cancers, but also afflicts plants, animals, and even buildings (via acidic decay and deposition of soot, for example). LPG produces low levels of particle and NO_x emissions, meaning that it does not pollute the air as much as many other energy sources. LPG can therefore contribute significantly to preserving both indoor and outdoor air quality.

Figure 2: **Stationary-combustion priority polluant emissions by fuel type**

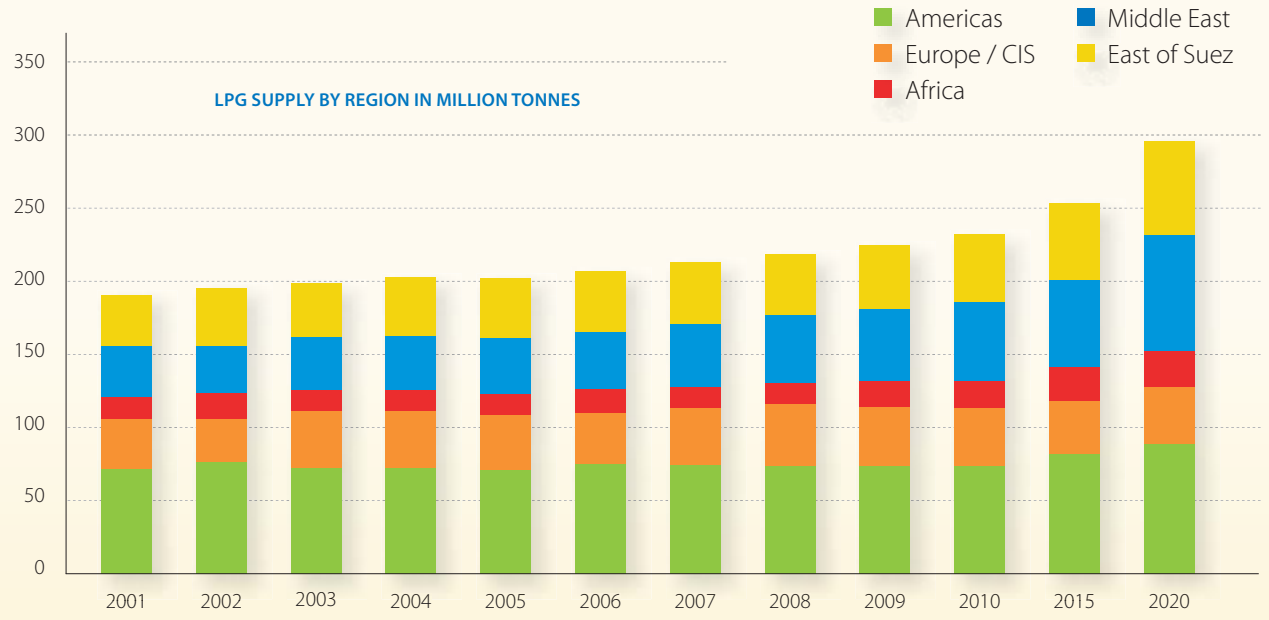


Source: LPG and Local Air Quality, A Scientific Review, Atlantic Consulting, 2009

• Secure

Due to its diverse origins and the fact that it is easily transportable, LPG offers a secure alternative to other energy sources which are part of a grid system. Not only is LPG produced in Europe in large quantities, when it is imported, it arrives from the north, south, east and west. Moreover, its status as a by-product of natural gas production - whose global production is projected to double worldwide by 2030[8] - makes its long term global supply outlook significantly more robust than that of its purely petroleum-based counterparts, particularly since the production of liquefied natural gas (LNG), an emerging solution to concerns over natural gas supply security, offers the potential to generate additional LPG yields. Projected global LPG supply levels suggest that it will be entirely possible to meet growing demand in the coming years.

Figure 3: **Projected LPG Supply by Region (in million tonnes)**



Source: Purvin and Gertz

[8] See the publication 'The Role of Natural Gas in a Sustainable Energy Market", published jointly by the International Gas Union and Eurogas.

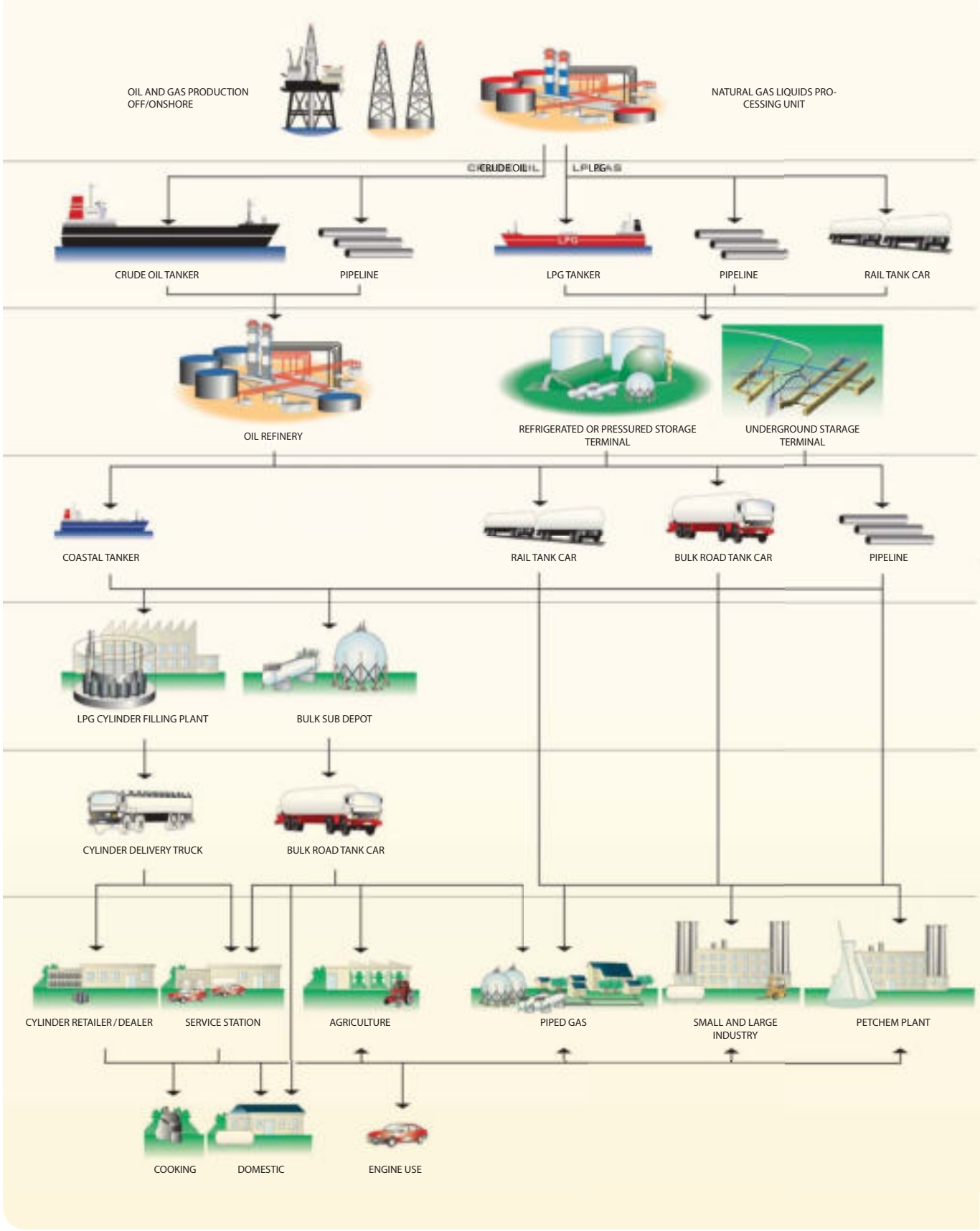
• Portable

LPG can be used practically anywhere. From emergency relief operations to isolated islands to ski resorts at altitude - LPG can reach places other energies cannot. In Europe, LPG has a flexible and decentralized distribution network which reaches beyond energy grids, facilitating development and activity in areas with a low population density. LPG can also be used in small scale gas networks which mimic the system efficiency of the natural gas grid by servicing entire communities via piped networks connected to a single storage site. Such networks are ideally suited to the needs of peri-urban communities which are not served by the natural grid but are nevertheless densely populated.

• Efficient

Gaseous fuels such as LPG offer inherently high efficiency, an advantage that has been further enhanced by the emergence of performance-optimising technology such as condensing boilers, renewable/LPG hybrid systems and gas-powered micro-cogeneration units. In view of the environmental, economic, and strategic benefits associated with a reduction of energy demand, a switch to LPG from other, less efficient alternatives is a smart move that yields benefits for individual end-users and society as a whole.

Figure 4: **Overview of the LPG production and distribution chain**



Source: World LP Gas Association

STEP 1 Production
The production of "field grade LPG" is the result of the treatment of NGLs. This treatment is necessary to produce:
a) Oils that are suitable for transport to refineries and
b) Natural gases that correspond with commercial specifications.

STEP 2 Transportation
While crude oil is transported from the production sites to refineries by tankers or pipelines, LPG is transported to storage terminals by large LP Gas carriers, pipelines or train.

STEP 3 Refining and storage
Butane and propane can also result from the oil refining processes. LPG storage terminals store products that are imported in large quantities.

STEP 4 Transportation
The LPG is then delivered by train, road, coastal tanker or pipeline to cylinder filling plants and intermediate-size storage areas.

STEP 5 Bottling and storage
Cylinders are filled with butane and propane at bottling plants. LPG is generally stored in pressurised tanks (vessels or spheres) in intermediary storage centres.

STEP 6 Distribution
LPG can be transported virtually anywhere, either in cylinders or bulk. Trucks transport butane and propane cylinders from the bottling plant to retailers, as well as to private and professional customers. Meanwhile, small bulk trucks distribute LPG from the storage centres to various consumers.

STEP 7 End users
LPG is easily available to end users through cylinder sales points such as commercial stores or service stations close to their locations. Customers requiring larger volumes can purchase LPG in bulk.

Equipment manufactures
Companies around the world provide filling, storage, controlling and safety equipment as well as services to the LPG industry and end users.

tank manufacturing

cylinder manufacturing

engine use LPG equipment

LPG appliances and equipment

Source: World LP Gas Association

PART 2. A CHALLENGING EU ENERGY CONTEXT

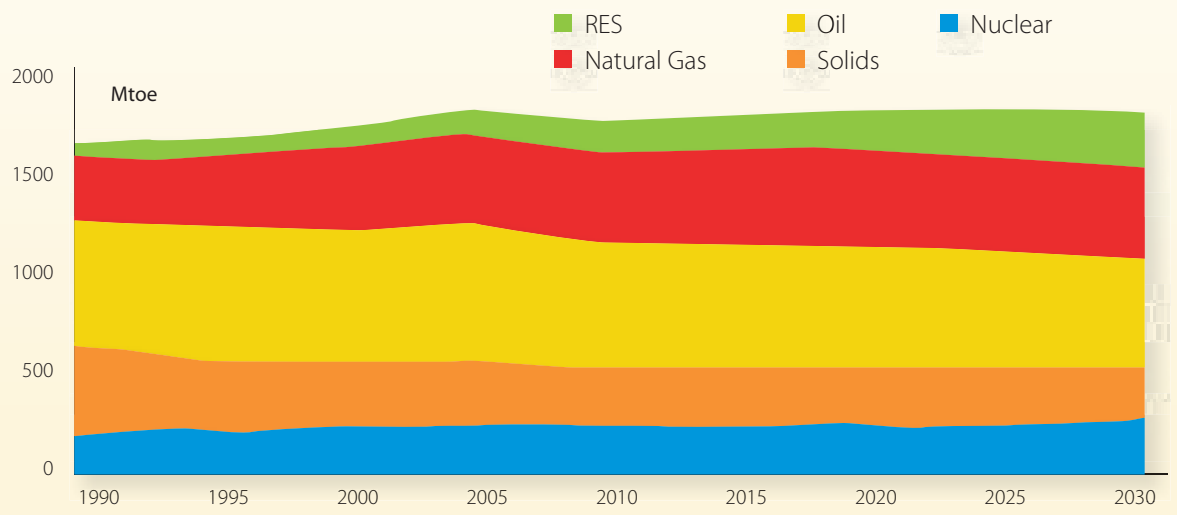
The Transition to a Low Carbon Energy Model: Far from an Overnight Process

The contribution of LPG to meeting Europe's domestic energy needs in the coming decades will depend to a large extent on the evolution of the European energy system as a whole. Since 2006, the European Union has made energy policy an increasingly high priority, specifically with a view to steering the European market away from fossil fuels towards a new system powered by renewable, low carbon alternatives. Five years on, Europe's various energy and environmental challenges - most notably climate change - remain near the top of the public policy agenda, and the European Commission rightly continues to stress the importance of developing new and enduring solutions. However, the increasing focus on energy and climate policy has been accompanied by a growing awareness of the practical difficulties associated with efforts to fundamentally reshape an energy system, and by extension, the central role that fossil fuels, including LPG, will continue to play in Europe and around the world over the coming decades.

Fossil fuels at the heart of the European energy mix (whether we like it or not)

A cursory glance at today's European energy model reveals the extent of its dependence on conventional resources. Roughly 98% of Europe's cars run on oil, with LPG, itself a fossil fuel, the most widely used alternative. Similarly, power generation continues to be dominated by coal, natural gas, and nuclear, and there is little or no certainty as to the capacity of carbon sequestration or renewable technology to provide reliable and adequate alternatives at an acceptable cost, certainly not before the 2030 horizon of this Roadmap. Despite the diversification associated with the emergence of biomass and other renewable energy sources, the residential sector also looks set to remain heavily reliant on conventional fuels for at least the next two decades. Indeed, recent projections foresee only a 22% for share renewables in 2030.

Figure 5: **Projected Evolution of EU Primary Energy Demand Through 2030**



Source: Energy trends to 2030 (2009 update), DG Energy, European Commission

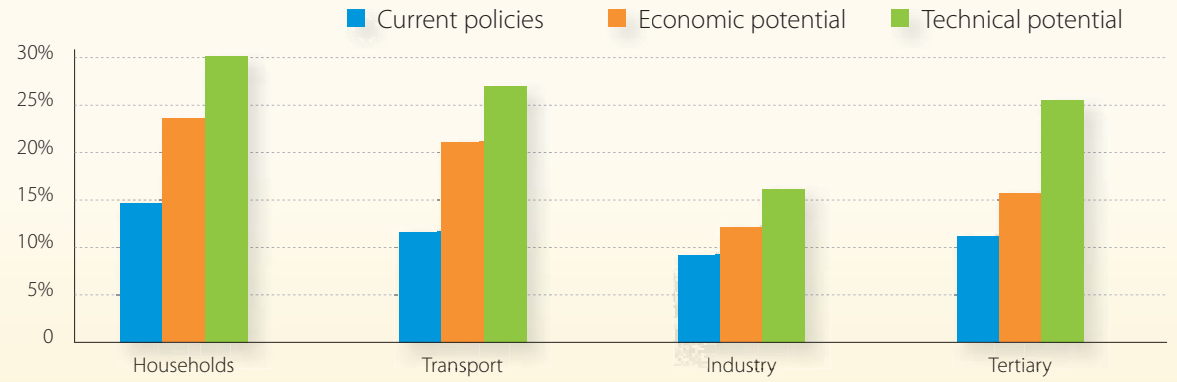
The fact that the EU has established what is broadly considered an ambitious target of a 20% share for renewable energy by 2020 - thereby setting an implicit objective of an 80% share for non-renewable resources - is itself a testament to the massive scale of the decarbonisation challenge. The obstacles, both technical and economic, are considerable and should be neither underestimated nor understated. Though it might be appealing to imagine otherwise, fossil fuels are not yet fading vestiges of an irresponsible past, but rather vital features of the modern European economy. They are also highly varied, offering distinct advantages and drawbacks, meaning they should not be perceived as a monolithic entity. Gaseous fuels such as methane and LPG, for example, in addition to their immediate availability, offer a series of comparative advantages, including relatively low C02 and pollutant emissions and high levels of efficiency.

Rather than developing a policy framework designed to eliminate all fossil fuels from the energy system, the EU should examine opportunities to ensure that the contribution of these cleaner, gaseous fuels is optimized.

The Residential Sector as a Priority

Perhaps the most significant energy-related feature of Europe's contemporary residential sector is its significant potential for improvement as regards its efficiency and environmental impacts. Indeed, the European Commission has identified the sector, which accounts for 25% of final energy use in the EU[9] as a top priority to be addressed as the EU pursues its target of a 20% improvement in energy efficiency by 2020.

Figure 6: **Final energy savings potential in EU 27 in 2020** (as percentage of the projections done in 2007)



Source: European Commission

[9] According to the impact assessment which accompanied the Commission's 2011 Energy Efficiency Action Plan (EEAP)

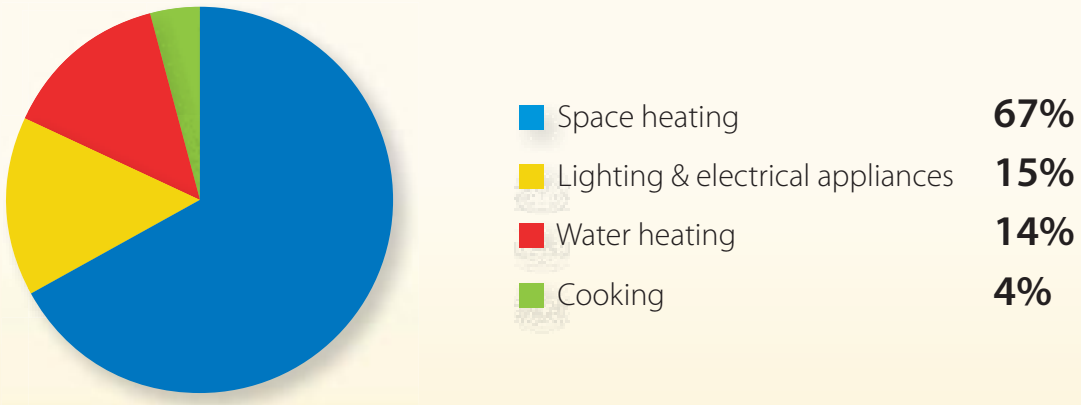
This high potential is highly relevant in the case of LPG since its primary domestic applications, space/water heating and cooking, account for a combined total of 85% of the energy consumption in a typical European home (see figure 7). Appliances such as boilers and water heaters are a particularly significant source of potential efficiency gains since their lifecycles are considerably shorter than those of the buildings in which they are installed. The EU building stock renewal and deep renovation rates, for example, are both only approximately 1% per annum[10], and the pursuit of improved building efficiency through measures such as enhanced insulation must be balanced against the need to maintain appropriate ventilation levels. Significant improvements can, however, be achieved through replacement of inefficient appliances by available and affordable technologies such as the condensing boiler, which utilizes the latent heat of water produced from the burning of fuel, in addition to the standard sensible heat, to increase its efficiency. Condensing technology, an established and cost-effective solution has a demonstrated potential to increase boilers efficiency by 15-20 percent as compared to their conventional equivalents[11].

The residential sector is characterized by the uniquely high degree of importance that end-users attach to purchase/investment decisions, including those linked to energy choices. For a broad range of practical, ideological, or economic reasons, individuals often have strong preferences as regards the energy source(s) with which they meet their domestic needs. As such, it is essential that citizens in all regions, including OGE, have access to the full range of fuel options, including gas. Public policy has a role to play in ensuring that this is the case.

Ensuring a Rational Allocation of Resources

If Europe is to successfully navigate what will undoubtedly be a challenging few decades to come, a delicate balance between ambition and pragmatism will be required. More specifically, this will mean fostering the emergence of effective new technologies without losing sight of opportunities to make better use of the established, affordable and immediately available conventional energies which will inevitably continue to form the backbone of the European energy model for the foreseeable future. It will mean accepting the notion that, as a complement to renewable energy and additional energy efficiency measures, certain fossil fuels are not simply a necessary evil, but genuine contributors to the development of a more sustainable residential energy system in Europe. The emergence of hybrid technology combining the environmental benefits of renewable energy with the reliability of a conventional fuel is an encouraging illustration of this potential. In addition to their practical advantages, such systems also constitute a symbolic rejection of a polemic dichotomy between renewable and non-renewable energies. Instead, they foster a holistic vision of a system in which all available resources are intelligently mobilized with a view to meeting energy demand and limiting the impact on the environment. Similarly, the replacement of fuels such as diesel and coal with cleaner-burning gaseous alternatives may not constitute an outright energy revolution but it is undoubtedly an achievable practical step in the right direction.

Figure 7: **Typical breakdown of residential energy consumption by application**



Source: Odyssee indicators, Build-up (featured in the Communication from the European Commission on Energy Efficiency Plan 2011 COM(2011) 109 final)

"Discussions of our energy options too often simplify the world into good guys and bad guys. Fossil fuels are bad because they do not endure forever and can be used in a toxic manner - so we should switch quickly away from them. But reality is more complex. Fossil fuels are a product of solar energy that like any other form of energy have more or less impacts and risks depending on how carefully we exploit them. We must not confuse means and ends. The end is to have a clean, low-cost and enduring energy system."

Mark Jaccard, Sustainable Fossil Fuels: The Unusual Suspect in the Quest for Clean and Enduring Energy, 2005

LPG…can act as a bridge between our existing oil habits and a cleaner, less oil intensive future. To begin with, it contains more hydrogen and less carbon, so it is both better for the planet and also more easily refined into hydrogen (for fuel cells). LPG would also allow us to continue to use some of our existing refining and distribution assets."

Paul Middleton, The End of Oil, 2007

More so than ever, in the light of renewed uncertainty as to the future of nuclear power in Europe, an intelligent combination of the most sustainable fossil fuels, renewables and improved efficiency will be essential if the EU is to effectively manage the transition towards a more sustainable, secure and competitive domestic energy mix.

[10] For details, please see the paper 'The Fundamental Importance of Buildings in Future EU Energy Saving Policies, published in July, 2010 by the Energy Efficiency Action Plan Task Force of the Construction Sector.

[11] For more information on condensing technology, consult the European Heating Industry (EHI) report on Efficient Systems and Renewable Energies for Thermal Comfort.

Off-Grid Europe: More than just a Niche

While Europe has achieved more or less total coverage as regards electricity, the same cannot be said of natural gas. The structure of this segment of the total energy system merits specific consideration since (a) the presence or absence of natural gas is an important variable in shaping the energy performance of buildings in a given region and (b) OGE is sufficiently significant (in terms of households and energy consumption) so as to have an impact on the European energy system as a whole.

19% of EU households12 are off-grid, meaning their energy options are more restricted than those with access to the natural gas network. As a result, the role of heating oil and solid fuels in the OGE residential energy model is more than twice as large as it is in the overall residential energy mix. In 2010, OGE's 40 million households used 51 million Toe and generated 82 million tonnes of C02 emissions; more than the entire residential sectors in both France and the UK. Since off-grid homes are, as a general rule, located in rural or peri-urban areas whose buildings tend to be older, larger, and less energy efficient than their urban counterparts, the case for the use of sustainable fuels in such buildings is particularly compelling.

The comparatively high share of relatively carbon intensive energies such as heating oil and coal suggests that there is considerable room for improvement as regards the OGE residential fuel mix. More specifically, it is clear that the performance of the entire system could be significantly enhanced through a more widespread uptake of renewables, gaseous fuels, and energy efficient building solutions over the coming two decades and beyond.

Figure 8: **A Selection of Energy Indicators for OGE in 2010**

Indicator	OGE - Residential Sector	
Households	40.7 million	
Energy consumption (Toe)	50.8 million	
Combined role of diesel and solid fuels (as a percentage and in Toe)	33.6%	17 million
Role of LPG (as a percentage and in Toe)	17.4%	8.8 million
$C0_2$ Emissions ($KtC0_2$)	82009.1	
Final energy consumption per household (Toe)	1.25	

Source: PRIMES

Figure 9: **2010 EU-27 Total Residential Energy Mix**

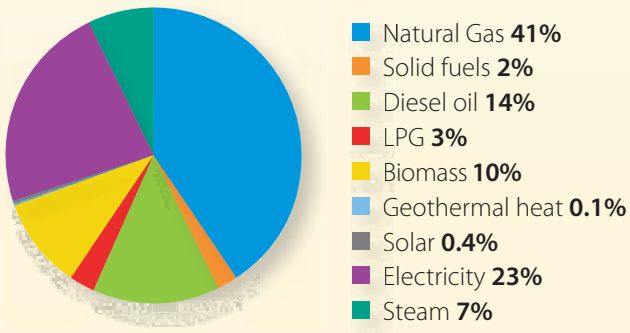
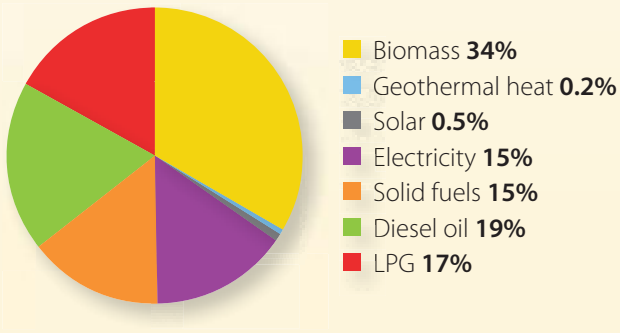


Figure 10: **2010 EU-27 OGE Residential Energy Mix**



Source: Energy trends to 2030 (2009 update), European Commission

[12] PRIMES

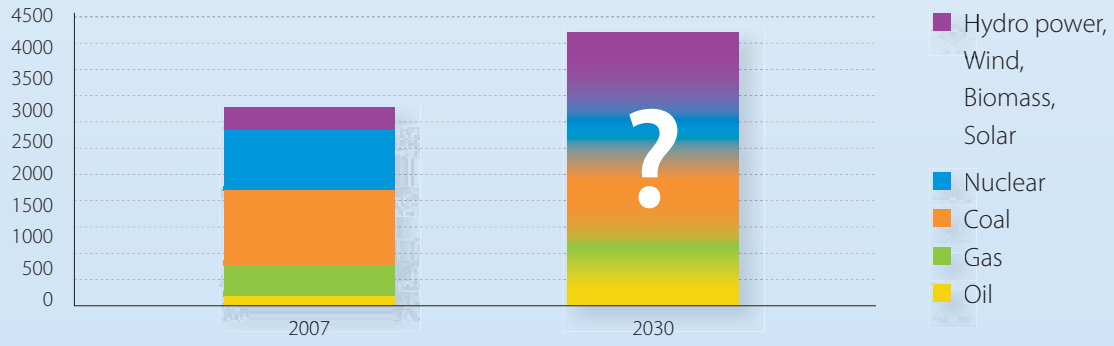
Electricity to the Rescue?

In seeking to reduce the carbon footprint of houses in OGE, it might be tempting to turn to electricity as a heating and cooking solution on the grounds that it produces no on site carbon dioxide emissions and is available more or less everywhere in Europe. Such a vision glosses over the practical reality that the EU's power generation model is still relatively carbon-intensive and will remain so through at least 2030.

The role of coal in electricity production in the EU-27 for example, is projected to decline only modestly, from 26% in 2010 to 22% in 2030[13], and even this assumption may need to be revisited in view of ongoing debates regarding the future of nuclear energy in Europe. Renewable-derived production is increasing but remains subject to concerns over intermittency and costs. The emergence of carbon capture and storage (CCS) technology is an interesting prospect, but, as the European Commission has acknowledged, "its risks and benefits are still being tested through pilot plants"[14], meaning its real potential to contribute to Europe's decarbonisation strategy has not yet been established. The use of electricity for key domestic applications such as heating and cooking is also problematic from an energy efficiency perspective due to losses associated with (a) the transformation of resources from primary to final energy and (b) losses during power transmission. This is particularly relevant for OGE households, which tend to be located at a considerable distance from the power plants that supply their electricity.

As an example, electric stoves have been shown to consume 64% more primary energy over a full cooking cycle than their gaseous-fuelled counterparts[15].

Figure 11: **Expected growth in electricity generation in billion (10^9) kWh in the EU**

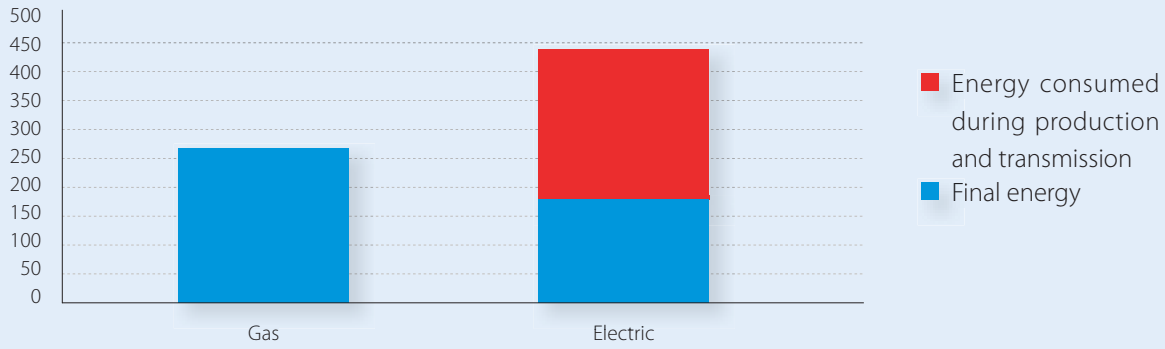


Source: VGP Power Tech, Facts and Figures, Electricity Generation, 2009/2010, based on data from Eurostat and the International Energy Agency IEA

[13] Energy trends to 2030 (2009 update), European Commission
[14] Energy infrastructure priorities for 2020 and beyond -A Blueprint for an integrated European energy network, DG Energy, European Commission, 2010
[15] Based on testing carried out by CRIGEN (Center for Research and Innovation in Natural Gas and New Energies), GDF SUEZ, using a typical example of both gas and electric domestic stovetops. The specific test in question involved bringing heating water to 90°C and maintaining the temperature for 20 minutes.

Primary Energy Consumption of Typical Gas and Electric Stovetops

Figure 12: **Comparative energy efficiency of gas and electric stoves**



Above and beyond concerns as to the true environmental impact of electricity production, it must be acknowledged that Europe's capacity to meet growing power generation demand is not unlimited. As the European Commission observed in its 2010 Communication on Energy Infrastructure Priorities for 2020 and Beyond, "electricity grids must be upgraded and modernized to meet increasing demand due to a major shift in the overall energy value chain and mix but also because of the multiplication of applications and technologies relying on electricity as an energy source (heat pumps, electric vehicles, hydrogen and fuel cells, information and communication devices etc.)"[16]. In this same report, the Commission notes that 200 billion Euros need to be invested in energy transmission networks - of which the electricity grid is a central element - by 2020, and that only half of this amount will be taken up by the market, leaving already strained public finances to make up the difference. Electricity is and will no doubt remain a vital feature of the European energy system, but its potential as a panacea should not be overstated. Until there is greater clarity as to how the technical and economic gaps outlined above can be filled, an unduly aggressive electrification policy would pose significant strategic, environmental, and economic risks.

Source: CFBP / GrDF study on cooking energy efficiency, carried out by CRIGEN (Center for Research and Innovation in Natural Gas and New Energies), GDF SUEZ 2010

[16] Energy infrastructure priorities for 2020 and beyond -A Blueprint for an integrated European energy network, DG Energy, European Commission, 2010

PART 3. LPG AS A SUSTAINABLE OFF-GRID ENERGY

LPG: The Natural Off-Grid Alternative

As a clean burning, lower carbon gaseous fuel, LPG is ideally suited to helping address the energy challenges of OGE. Thanks to its portability and highly flexible distribution network, LPG is available everywhere. Though LPG is perhaps best known as an alternative transport fuel, it is primarily used in Europe in the residential sector, where it helps meet the heating, cooking and even electricity needs of millions of citizens every day. The availability of LPG means that Europe's gaseous fuel supply network has unlimited reach.

For decades, LPG has provided households in OGE with a gaseous fuel alternative to meet their most important energy needs, notably space/water heating and cooking. Since the underlying technology is essentially identical to that used in natural gas-powered equipment, LPG-fuelled appliances have benefited from various technological advances that have made them significantly more fuel-efficient and, by extension, cleaner and less C02-intensive.

Due to its physical characteristics and ease of use, LPG enables and facilitates the use of a wide range of technical solutions for space and water heating. Today, LPG is widely

used as recommended as an ideal fuel for use in central heating systems, condensing boilers, hybrid systems (solar thermal combined with gas), instantaneous water-heaters, micro-cogeneration units (currently based primarily on Stirling or combustion technology, but, over time relying increasingly on fuel cells), and, looking forward, LPG-powered heat pumps.

It is important to note that the home appliance sector, which had for some time been characterized by simple consolidation of established technologies, has gone through a sharp technological acceleration over the past 10 years. In particular, easy installation ("plug and play") and widespread use of digitally controlled equipment should be highlighted. Nevertheless, although almost uniformly applied in urban centres (especially in new-build houses), this revolution is some way from reaching all regions of Europe and all socio-economic groups, due to, among other reasons, cultural conservatism and the high cost of investing in infrastructure.

The manufacturers of these LPG-fuelled devices exhibit an increasing commitment to enhancing energy efficiency and reducing the impact of their products on both the environment and human health.

LPG and Solar Energy: An Emerging Partnership

Solar water heating has existed since antiquity and has been used in applications such as bathing, hand-washing, and space heating. Modern technology has made the process far more efficient, and more recently, its coupling with an auxiliary energy source such as LPG has boosted its dissemination across all regions of Europe, even in more northerly areas.

A solar hot water system begins with a flat plate solar collector, usually placed on the roof of the house. Copper pipes inside the collector heat up and transfer the heat to a non-toxic fluid. The hot liquid flows down to a boiler to pre-heat the water for the house through a heat exchanger (see diagram). After transferring its heat, the fluid (which does not come in contact with the hot water for the home) is circulated back up to the collectors to heat up again. The heated water is kept in a large insulated storage tank, so even a morning shower can be solar heated (or pre-heated) from the previous day.

In some parts of Europe, solar thermal systems can provide up to 80% of a home's hot water needs. When this is not the case, LPG can be used as a primary or complementary source of energy to heat the water in storage. These modern systems —often referred to as hybrids — combine the reliability of a conventional fuel with the numerous benefits of renewable energy to provide warm water for millions of end-users across Europe. Hybrid solutions can also be designed to meet space-heating needs.

By helping to overcome the inherently intermittent nature of solar-thermal energy (the sun does not shine every day and consequently cannot guarantee a permanent, natural heating of water), LPG is accelerating the development of renewable systems in the water and space heating sectors.

Micro-cogeneration: Turning Buildings into Sustainable Power Plants

Often referred to as micro-combined heat and power (micro-CHP), this highly efficient technology is in fact a residential-scale version (<50 kW electricity/hour) of co-generation, a well-established and widely-used industrial practice. It is an integrated system which provides simultaneous production of both electricity and heat using a single fuel source such as natural gas or LPG. The motor, which can be based on internal combustion or Stirling technology, features an alternator

which transforms mechanical energy into electricity which can either be used to meet the power needs of the home or be sold back into the electricity grid. At the same time, the heat generated by the motor is recovered and can be used to provide warmth for domestic space and water. Increasingly, modern, fuel-cell based equivalents are also emerging.

In a conventional micro-CHP system, roughly 70-80% of the energy consumed (gross calorific value) is converted into heat, between 10-25% is used to generate electricity, and 5-15% is lost in the combustion process. While this compares favourably with an equivalent gas central heating boiler, the real advantage is that these systems produce electricity in addition to heat. It is the value of this electricity which covers the investment cost of the micro-CHP unit to provide a net saving, and which makes it a particularly energy-efficient technology. Micro-CHP technology allows for an optimal use of domestic energy resources, and permits:

- A reduction in annual $C0_2$ emissions of over one tonne per household.
- A decrease in a household's energy costs (as much as 75% in some cases)
- A relatively short investment pay-back period of 5-7 years

Gas Heat Pumps: Warmth by Other Means

Heat pumps are an innovative approach to the problem of meeting space heating demand. Instead of using a boiler to provide heat to the home, a heat pump recovers heat from natural sources in the air, water or underground, and transfers it using a refrigerant gas which exchanges heat during its compression/decompression phases. A heat pump works like an air conditioner in reverse. Indeed, heat pumps can be switched over to work as air conditioners during the summer months. This will be increasingly important, particularly in southern Europe, as cooling demand continues to rise.

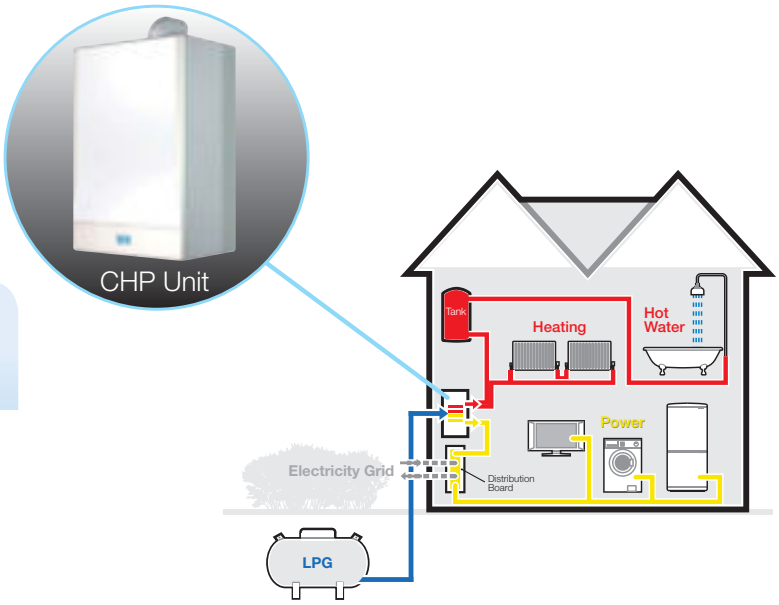
Until now electrical heat pumps (EHP) have been the norm, but gas heat pumps (GHP) are already available for industrial applications and residential versions are nearing market readiness.

Advantages of GHP:

- GHP are highly efficient appliances in the sense that they produce more energy than they consume. Indeed most GHP are considered as a renewable energy source under the EU's Renewable Energy Directive (2009/28/EC)
- GHP outperform EHP in cold temperatures, and are more flexible to operate thanks to their reduced ramp-up time.
- The use of clean-burning GHP, as opposed to their electrical counterparts, offsets part of the harmful emissions associated with the production of electricity.
- As is the case with solar thermal systems, the integration of an LPG supplementary burner to match the energy requirements of the house is easy and cost effective.

This technology is rapidly advancing, and efficiency gains and cost reductions are expected in the coming years.

A micro-CHP system provides electricity, space and water heating all from one energy source



From LPG to Bio-Propane: A Renewable Alternative

The use of LPG in increasingly clean and efficient appliances can and will make a meaningful contribution to enhancing the sustainability of OGE's energy system between today and 2030. However, with an eye on the longer term, the LPG sector is working towards a more fundamental change, namely the development and commercialization of a version of LPG derived exclusively from renewable sources.

Often referred to as 'bio-propane'[17], this emerging energy resource is entirely compatible with the EU's pursuit of a truly sustainable, secure and competitive energy model. As a $C0_2$-neutral fuel for the transport, industrial and residential sectors, bio-propane will allow European citizens to meet their energy needs without compromising the environment. As a derivative of domestically available, abundant and renewable feed stocks including glycerol, biomass-derived sugars and algae, which is identical to LPG on a molecular level, it will also help Europe and its constituent nations to reduce their dependence on imported fossil resources whose long-term availability and price are subject to uncertainty.

For the past three years, with support from the AEGPL, among others, Dr. Christian Hulteberg, and a research team at Biofuel Solution in Sweden have been working on using glycerol, a major by-product of the bio-fuel industry, as a feedstock for bio-propane. Although this work is at an early stage, the project has already yielded highly encouraging results. Having completed the "Proof-of-Concept" phase - wherein small amounts of bio-propane were produced - in 2010, researchers are now increasing the scale of production in order to verify preliminary results. Dr. Hulteberg is very optimistic in terms of both the science and the economics – "we know the process works, and we believe that as long as Europe continues on a path to bio-fuels, and consequently produces enough glycerol, that bio-propane can be produced on a significant scale at a price which is commercially feasible."

In light of the obvious benefits for the sector and for Europe as a whole, the European LPG sector is actively driving this process forward. Moreover, the industry looks forward to cooperating with the European institutions and other relevant stakeholders with a view to ensuring that bio-propane's contribution to meeting Europe's energy needs is understood and optimized in the coming years.

[17] 'Bio-propane' is a more appropriate appellation than Liquefied Petroleum Gas (LPG) since, despite possessing the same physical properties as LPG, it is in no way a derivative of fossil fuels.

PART 4. A MODEL FOR A MORE SUSTAINABLE OFF-GRID EUROPE

The heavy reliance of the OGE residential sector on heating oil and solid fuels is inconsistent with Europe's broader environmental and strategic imperatives, and must therefore be reduced as a matter of priority. Achieving this will require a concerted commitment on the part of both governments and consumers to (a) using better energy and (b) using energy better. More concretely, it will require the exploitation of an intelligent combination of gas, renewables and energy efficiency.

The LPG industry has long had an intuitive vision of how the transition to a more sustainable OGE energy model could be achieved. With a view to clarifying and quantifying this perceived potential, AEGPL commissioned a specific study by the Economic-Energy-Environment Modelling Laboratory (E3MLab) from the National Technical University of Athens (ICCS/NTUA). As the leading provider of energy scenarios to the European Commission and the creator of the PRIMES modeling tool, the E3MLab team is especially well-placed to carry out this type of analysis.

In order to identify the specific contribution that LPG could make to enhancing the sustainability of the European residential sector in general and of OGE in particular, an alternative to the reference case set out in the European Energy trends to 2030 study has been constructed by the E3M Lab. In this 'LPG Scenario', the role of LPG in meeting the residential energy demand of OGE doubles between 2010 and 2030, with less sustainable liquid and solid fuel alternatives being replaced in the process. This evolution, in tandem with the continued emergence of renewable energy and a more aggressive exploitation of potential efficiency gains, yields significant C02 savings and leads to the establishment of a more modern and environmentally friendly residential energy for both OGE and Europe as a whole.

About the PRIMES Model

E³M - Lab

The PRIMES model simulates the response of energy consumers and the energy supply systems to different pathways of economic development and exogenous constraints and drivers. It is a modelling system that simulates a market equilibrium solution in the European Union and its Member States. The model determines the equilibrium by finding the prices of each energy form in such a way that the quantity producers opt to supply matches the quantity consumers wish to use. The equilibrium is forward-looking and includes dynamic relationships for capital accumulation and technology vintages. The model is behavioural, formulating agents' decisions according to microeconomic theory, but it also represents, in an explicit and detailed manner, the available energy demand and supply technologies and pollution abatement technologies. The system reflects considerations about market competition, economics, industry structure, energy /environmental policies and regulations. These are conceived so as to influence market behaviour of energy system agents. The modular structure of PRIMES reflects a distribution of decision making among agents that decide individually about their supply, demand, combined supply and demand, and prices. Then the market integrating part of PRIMES simulates market clearing.

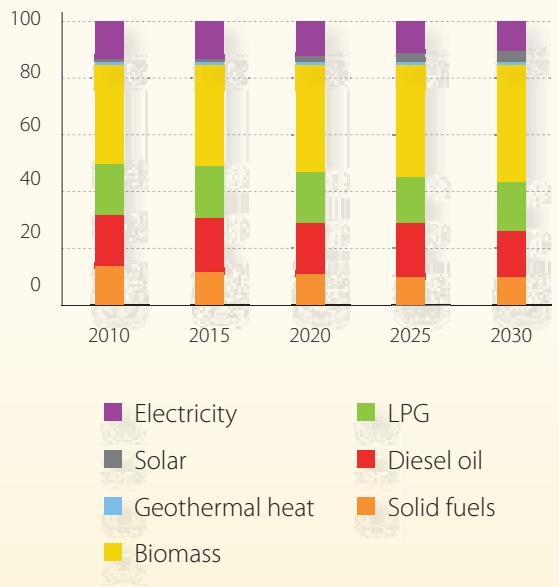
PRIMES has been used to create energy scenarios for a wide range of international organisations, most notably various departments of the European Commission, including DG Energy, DG Move and DG Climate Action. It is the basis for the 'Energy Trends to 2030' report, a document whose findings play a discreet but essential role in shaping the evolution of European energy policy. In addition to its role in the public sector, PRIMES has also provided modeling analysis for industry groups such as Eurelectric, the European association for electricity. To learn more about PRIMES, visit the E3M Lab website at: http://www.e3mlab.ntua.gr/e3mlab/

An LPG Scenario

As outlined previously, OGE's 2010 residential energy model is out of step with Europe's climate and energy ambitions. With natural gas, the leading residential fuel in Europe as a whole, unavailable by definition, heating oil and solid fuels combine to form the largest share of the energy mixes in 2010. In the reference case, these fuels continue to play a major role in meeting OGE's domestic energy needs through 2030.

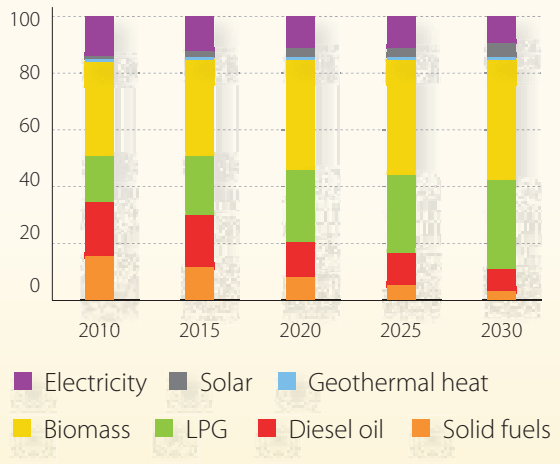
In the LPG scenario, a different, more sustainable picture begins to emerge. A greater role for LPG as a fuel for gas-powered heating and cooking equipment and for micro-cogeneration and renewable-gas hybrid systems leads to a sharp drop in the share of diesel and solid fuels, a decreased role for electricity, an increase in the share of renewables, and an improvement in the overall energy efficiency of Europe's residential energy sector.

Figure 13: **Projected Evolution of the OGE Residential Energy Mix - Reference Scenario**



Source: PRIMES

Figure 14: **Projected Evolution of the OGE Residential Energy Mix - LPG Scenario**

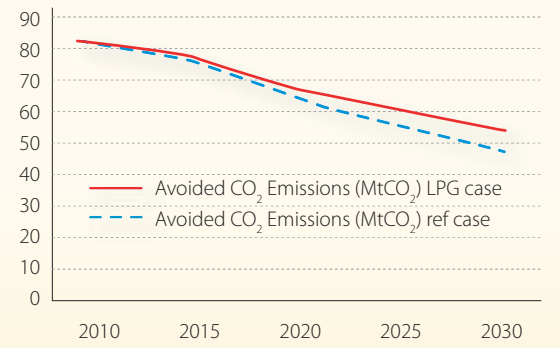


Source: PRIMES

Significant $C0_2$ Savings

The growth of gas (from 8.8 million Toe to 14.1 million Toe) within OGE leads to the removal from the energy mix of 18.5 million Toe of solid fuels and 20.9 million Toe of heating oil by 2030 as compared to the reference case. Predictably, this results in significant $C0_2$ savings that would make a meaningful contribution to the pursuit of the EU's climate change mitigation strategy. Indeed, in the LPG scenario, residential OGE produces 184 million fewer tonnes of $C0_2$ than in the reference case, an amount equivalent to the projected total emitted by the entire residential sectors of Germany, the UK, Poland and Spain in 2030.

Figure 15: **Comparison of avoided $C0_2$ Emissions in LPG and Reference Cases**



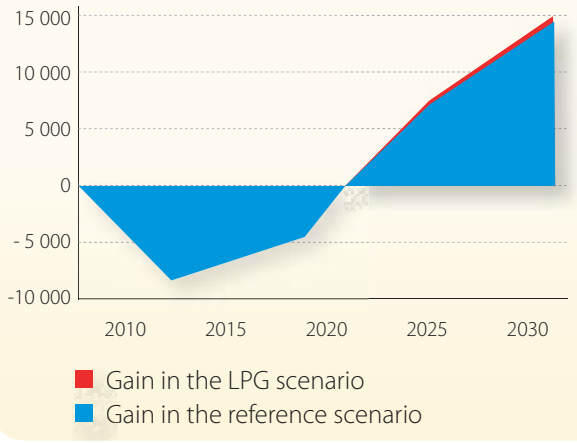
THE LPG SCENARIO LEADS TO 184 MILLION TONNES OF AVOIDED $C0_2$ EMISSIONS COMPARED TO THE REFERENCE CASE.

Source: PRIMES

A More Efficient Energy System

Increasing the share of LPG at the expense of diesel and solid fuels also yields efficiency gains for the residential system as a whole. Though the inherent inertia of the building sector means that progress in this area would likely be relatively modest between 2010 and 2020, the model demonstrates significant potential for improvements in the ensuing years, with the LPG scenario leading to a 7% improvement in the energy efficiency of Europe's residential energy sector over the reference case by 2030. According to the model, for every 6.7 tonnes of LPG entered into the residential mix in 2030 - as compared to the Reference case - 1 Toe of energy is saved[18]. This equates to 1 million Toe of avoided energy consumption for that year, making the LPG Scenario an ideal demonstration of how Europe can learn to do more with less.

Figure 16: **Anticipated Efficiency Gains for the European Residential Energy System - LPG and Reference Scenarios**



Source: PRIMES

A Boost for Renewable Energy

Under the LPG Scenario, renewable energy technologies experience more rapid growth than would otherwise be the case. Specifically, the solar and geothermal heat sectors account for 2%[19] more of the total residential energy consumption than they do in the Reference scenario. In a context where the EU is under pressure to meet its self-imposed target for the emergence of renewables, such potential advances are not to be ignored.

[18] PRIMES
[19] PRIMES

PART 5. FROM POTENTIAL TO REALITY - THE WAY FORWARD

The successful management of Europe's transition towards a lower carbon and more climate-friendly energy model will require a steady, incremental approach. Just as new, renewable-based technologies will gradually erode the position of conventional alternatives, cleaner fossil fuels can contribute by taking the place of their less environmentally friendly liquid and solid counterparts. As the above modeling exercise demonstrates, LPG, together with renewables and energy efficiency measures, can play a significant role in transforming OGE and residential Europe as a whole into a more sustainable proposition. Translating this vision from paper to practice will require a sustained commitment on the part of the LPG industry and public authorities

The 'LPG' scenario generated by the PRIMES model is an appealing vision of a more modern and sustainable OGE. With a view to helping transform potential into reality, the LPG industry proposes a win-win partnership with policy-makers wherein efforts on the part of the sector combine with the establishment of an appropriate regulatory framework to create an optimal situation for end-users and society as a whole. Given the high degree of inertia that characterises any large energy system, changes must begin to take place now if the full potential for progress by 2030 is to be exploited.

Commitments from the LPG Industry:

The European LPG sector and its thousands of constituent operators are committed to optimizing LPG's contribution to meeting the energy and environmental challenges facing Europe and its citizens. This commitment is particularly important in the residential sector where LPG's status as the only gaseous fuel alternative in OGE gives it a clear and specific vocation. With this in mind, the European LPG industry is prepared to mobilise significant resources in order to:

- Ensure that every residential LPG-user is provided with not only energy but thoughtful and practical advice on how to use this energy to optimal effect. Given its inherently close and direct contacts with its customers, the European LPG industry believes it can serve as a leading example of how energy companies can make the vital transition from suppliers to advisors.

- Pursue continuous year-on-year increases in the installation of LPG-powered residential energy systems paired with a renewable element.

- Support the emergence of LPG-fuelled micro-cogeneration systems for European homes through cooperation with equipment manufacturers, installers and energy advisors.

- Pursue, ideally in cooperation with interested partners from across the public and private sectors, the development of bio-propane in order to provide Europe and Europeans with a carbon neutral, domestically produced gaseous fuel for use in OGE and a range of other applications.

Public Policy for a more Sustainable Residential OGE

As outlined above, moving any given energy system on to a more sustainable track requires leadership, vision and commitment on the part of policy-makers. In light of Europe's complex and multi-layered governance structure, these traits will need to be exhibited at European, national and local level. As this Roadmap covers a twenty-year period between 2010 and 2030, it would be unhelpful and inappropriate for the LPG sector to make unduly prescriptive proposals for specific legislative initiatives. Instead, it is preferable to set out general principles which can serve as the basis for the establishment of a genuinely effective energy policy framework for OGE and the European energy system as a whole.

In this spirit, AEGPL calls on public policy-makers to consider the following precepts:

• Promote a rational allocation of energy resources
Given the scale and scope of Europe's energy challenges, it is safe to assume that all available resources will have a role to play in the energy mix up to 2030 and beyond. Therefore, rather than devising a regulatory framework designed to eliminate certain 'undesirable' fuels from the market, policy-makers should focus on (a) diversifying the energy system and (b) promoting the allocation of energy resources to the specific application (e.g. residential, transport, power generation) for which they are best suited.

• Avoid an all or nothing approach
As governments and individual policy-makers come under increasing pressure to reconcile strategic, environmental and economic priorities, it is tempting to seek out "silver bullet solutions", casting aside other, more pragmatic alternatives with the potential to yield modest but immediate benefits in the process. The perfect must not become the enemy of the good. Europe's transition to a more sustainable, secure and competitive environment will be a lengthy process composed of incremental steps. The desire to pursue the large-scale, revolutionary advances of tomorrow must not obscure opportunities to make small but genuine steps forward today.

• Acknowledge the existence of competing imperatives
Regrettably, Europe is facing such a wide range of energy, environmental, social and economic challenges that compromises will need to be made, at least in the short to medium term. An approach wherein one such challenge is tackled without due regard for the impact of the policy in other domains will inevitably lead to frustration and social tensions. Policy-makers must therefore take a concerted approach to governing with a view to achieving balanced and optimal results.

• See the world as it will be, not as it could be
When making assumptions regarding the energy system of the future (i.e.; 2030 or 2050), it is understandably easy for policy-makers to fall into the trap of seeing the world as it might be in an absolute best case scenario rather than as it is actually likely to be. This blurring of the line between genuine projections and wishful thinking about tomorrow is potentially dangerous since the associated conclusions can become the basis for concrete policy decisions taken today. If they are to lead to effective policy, assumptions about the environment for which the regulatory framework of the future will be constructed must be grounded in a sober, independent analysis of technical and economic realities.

• Make energy efficiency a priority

The European Commission's 2011 Energy Efficiency Action Plan makes it clear that Europe as a whole is not currently on track to meet the EU objective of a twenty percent energy savings by 2020. In light of its status as the best means of simultaneously addressing sustainability, supply security and economic competitiveness, energy efficiency must figure increasingly prominently in European, national and regional energy strategies. As Europe and Europeans come under increasing environmental and economic pressures in the coming decades, learning to do more with less will become more essential than ever.

From Principle To Practice: Translating Concepts Into Specific Policies.

Precept	Examples of Corresponding Policy Paths
Promote a rational allocation of energy resources	• Diversion of heating oil/diesel from residential to transport sector • Restricting the use of coal to the power sector where pollution controls and, eventually, CCS technology should be able to limit harmful emissions
Avoid an all or nothing approach	• In parallel to the promotion of renewables, take advantage of emissions savings offered by gaseous fossil fuels over liquid and solid alternatives as part of the broader decarbonisation process. This could be achieved by continuing to support favourable taxation rates for gaseous fuels at EU and national level • Establish interim objectives and corresponding means in parallel to long-term emission reduction strategies
Acknowledge the existence of competing imperatives	• Balance ecological and social priorities when - for example - revising energy taxation legislation • Ensure that $C0_2$ reductions resulting from the switch to biomass are not negated by the associated black carbon emissions
See the world as it will be, not as it could be	• Take a prudent approach to promoting increased reliance on electricity until there is greater certainty as regards prospects for establishing a low carbon power generation model • Strike an appropriate balance between encouraging the emergence of new energy solutions and overestimating their capacity to replace more conventional technology
Make energy efficiency a priority	• Continue efforts to encourage the uptake of more efficient fuels and appliances • Encourage energy suppliers to play an active role in optimising the performance of household energy systems

CONCLUDING REMARKS

Europe and Europeans will have to significantly adjust the way they produce, use and think about energy over the coming decades. Whether seen from a strategic, environmental, social or economic perspective, the existing system is demonstrably unsustainable. Business as usual is simply not an option. Every sector of the economy will need to take steps towards the establishment of a more sustainable, secure and competitive energy model.

Europe's millions of households, and - by extension - the millions of citizens who inhabit them, have an essential role to play in this transition. The way forward is clear. Through an intelligent mobilisation of renewable energies, energy efficiency measures and an increased uptake of immediately available and lower carbon gaseous fuels, at the expense of liquid and solid fuel alternatives, the European residential energy system can become a considerably more sustainable proposition by 2030. As the 'LPG Scenario' set out by the PRIMES model has demonstrated, LPG, as part of a broader strategy to increase the share of renewables and promote energy efficiency, can make a difference. Under this alternative scenario, residential Europe becomes 7% more energy efficient, emits 184 million fewer tonnes of $C0_2$ and sees an additional 2% share for solar and geothermal energy as compared to the Reference case.

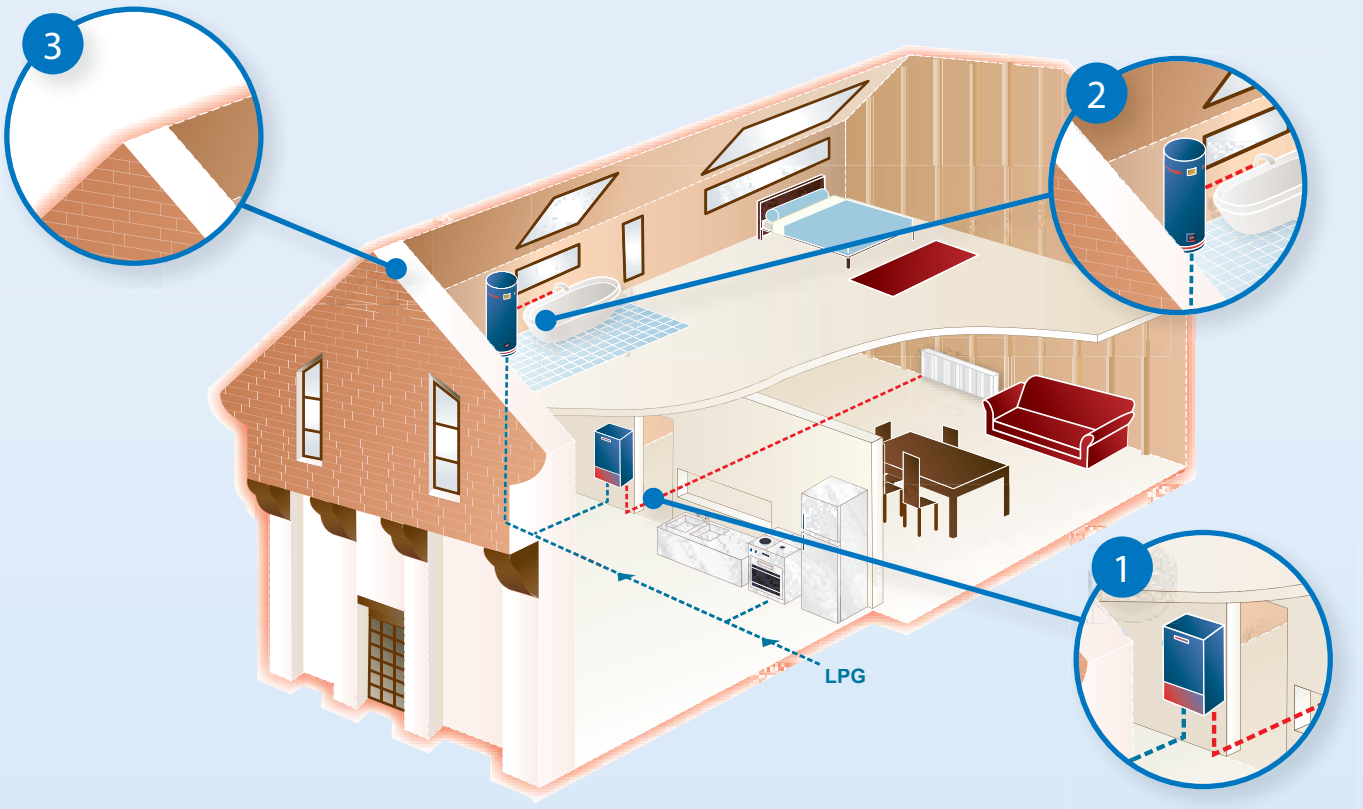
For OGE, where higher carbon fossil fuels continue to play a disproportionate role in the energy mix, the degree of urgency and the scale of the opportunity are particularly high. Doubling the share of gas in the OGE residential fuel mix would effectively displace a combined total of nearly 40 million Toe of liquid and solid fuels. This, in combination with the associated benefits of avoided emissions of various pollutants, including climate forcers such as black carbon, makes the LPG scenario synonymous with a more sustainable OGE and an improved European energy system in general.

The European LPG industry is committed to working together with policy-makers, end-users and all interested stakeholders at EU and national level to help ensure that this potential is exploited to optimal effect over the coming two decades and beyond.

With the adoption of the revised Energy Performance of Buildings Directive (EPBD) in 2010 came the emergence of the "nearly zero-energy" building as a policy concept. According to the new Directive, which defines nearly zero-energy buildings as those exhibiting "a very high energy performance", all new buildings must meet this performance level as of 31 December, 2020 at the latest.

Even in these low-consumption structures of the future, LPG can play a role by helping to transform buildings into individual power plants as part of a hybrid, renewable-based systems or as a feedstock for fuel cell powered micro-cogeneration units. Moreover, the emergence of bio-propane is consistent with the Directive's provision that "the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources".

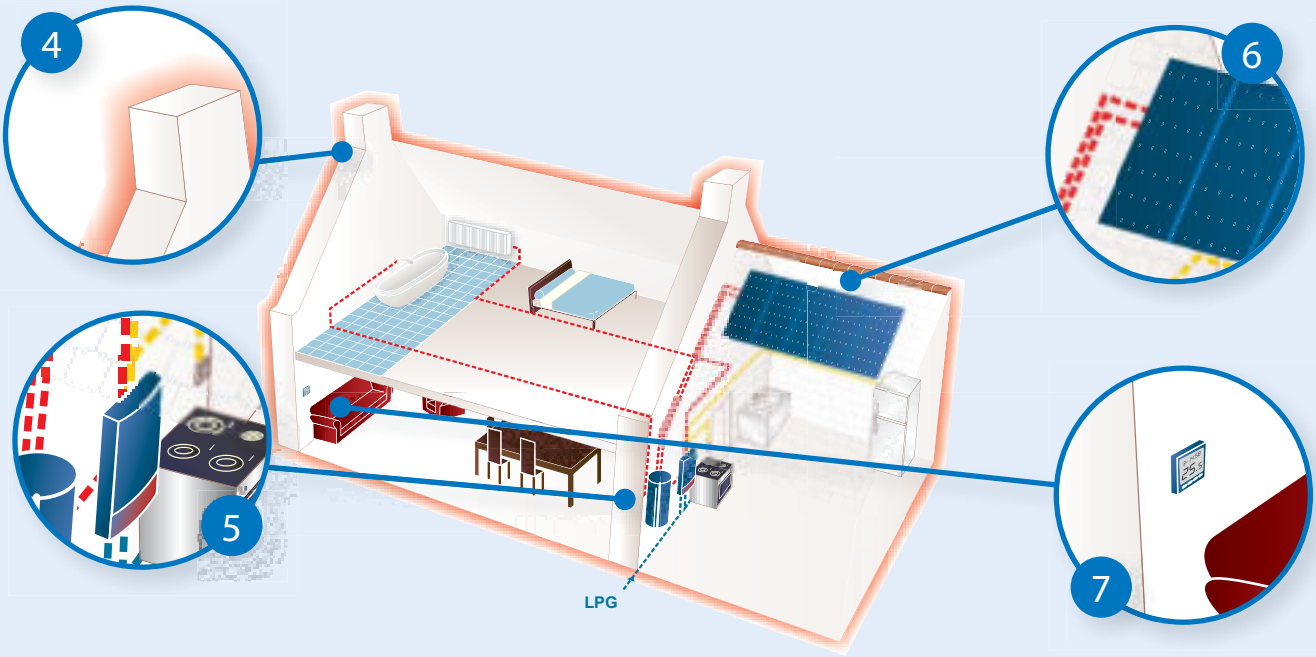
A Conventional House in **2000**



1. **Conventional boiler**
2. **Conventional water heater**
3. **Conventional insulation**

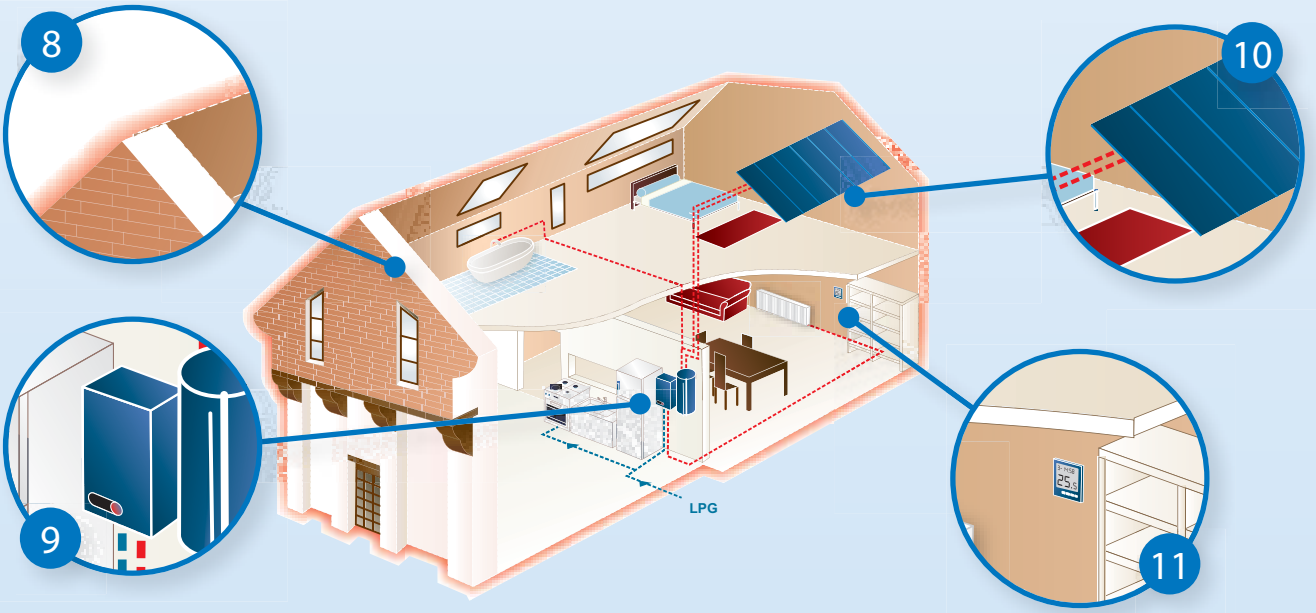
LPG — Bio-Propane — Hot water — Electricity

New House **2015**



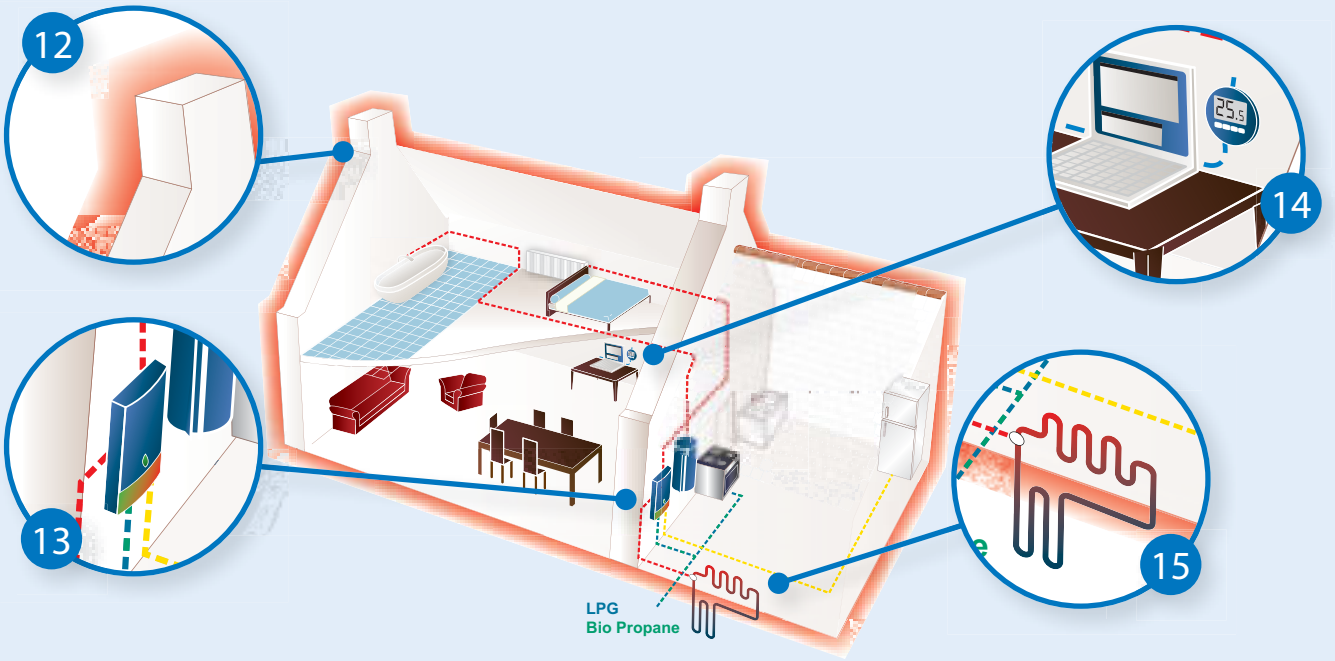
4. **Envelope approach to insulation (including advanced air recycling system)**
5. **Internal combustion or Sterling micro-CHP unit for space and water heating and electricity**
6. **Solar thermal system for hot water**
7. **Thermal management system or smart meter**

Renovated House **2015**



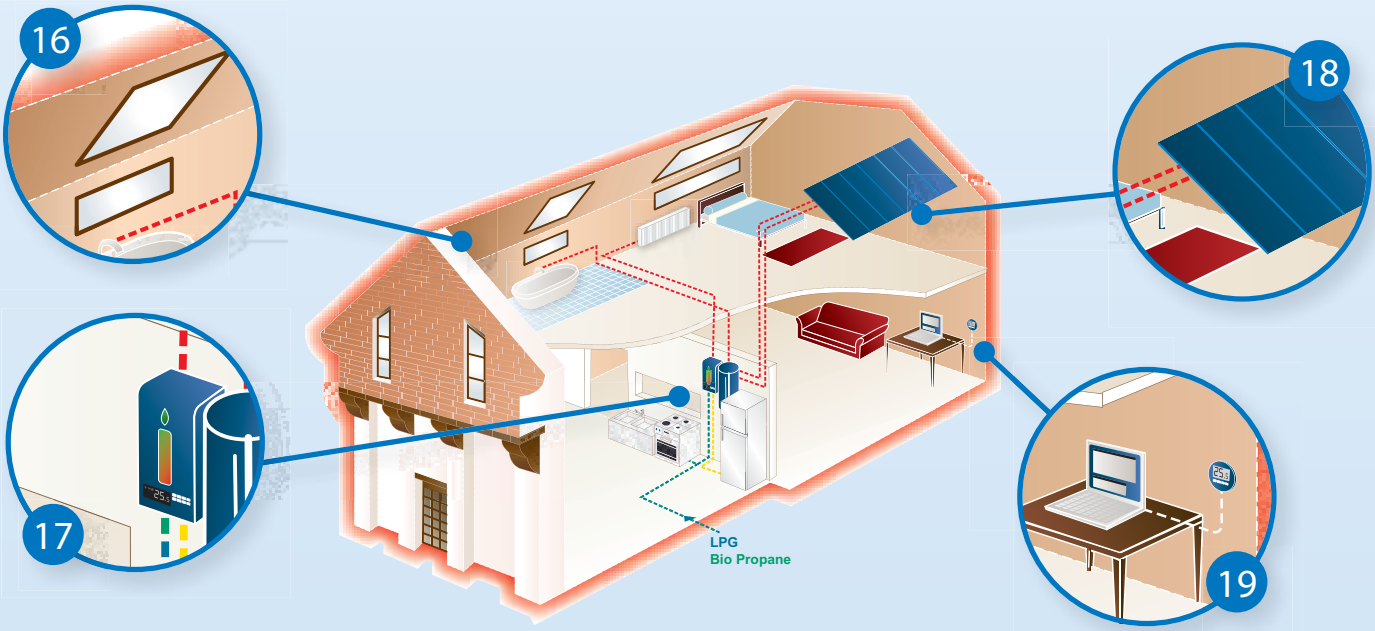
8. **Improved insulation to roof and walls**
9. **Condensing boiler for space and water heating**
10. **Solar thermal system for hot water**
11. **Thermal management system**

New House **2030**



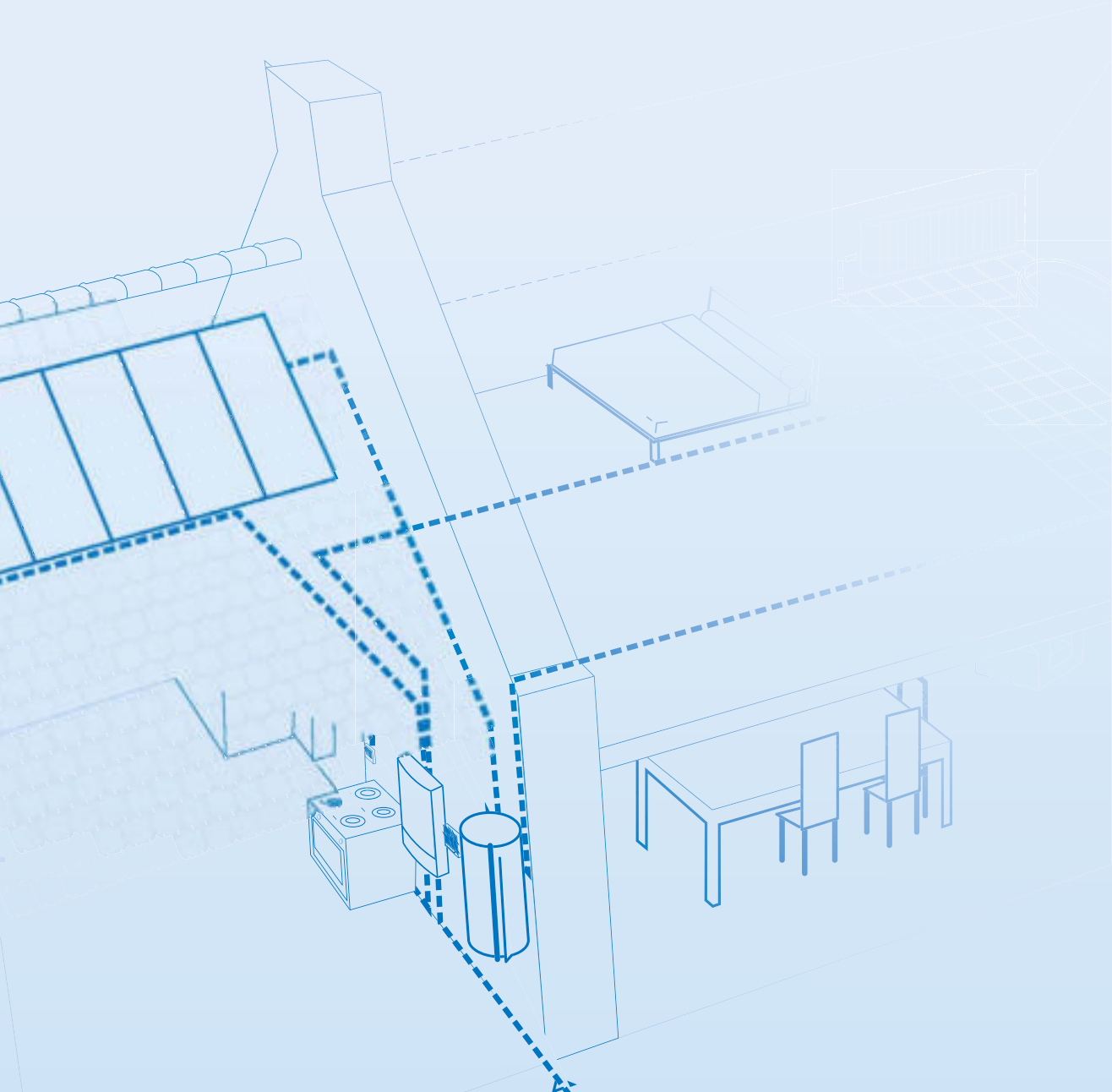
12. **"Nearly-zero energy building" insulation (including advanced air recycling system)**
13. **Fuel cell micro-CHP unit for space and water heating and electricity**
14. **Smart meter**
15. **Gas heat pump for space heating**

Renovated House **2030**



16. **Further improved insulation to windows**
17. **Internal combustion or Sterling Micro-CHP unit for space and water heating and electricity**
18. **Solar thermal system for hot water**
19. **Smart meter**

LPG IN THE HIGH PERFORMANCE BUILDINGS OF TOMORROW



design by **inextremis.be**

EUROPEAN LPG ASSOCIATION
Rue Belliard 15-17,
B - 1040 Brussels
Belgium

aegpl@aegpl.be
www.aegpl.eu