Article | 23 July 2025 ENERGY MANUFACTURING, CONSTRUCTION AND RETAIL SUSTAINABILITY

The energy transition isn't just electric, it's molecular

The future of energy hinges on integrating sustainable molecules with electrification. We explore how sustainable biogas, heat, hydrogen, and hybrid solutions can pave the way to green, reliable and affordable energy systems

Electrification is key, but has its limitations

Electrification is essential for sustainability. Heat pumps and electric cars have lower energy losses compared to the fossil fuel-based alternatives. They increasingly use green electricity, which comes with low carbon emissions. Electricity also captures the imagination more than energy from molecules, such as gas or oil. Much-loved devices, such as mobile phones, laptops, tablets, and coffee machines all run on electricity. And this is increasingly true for our bikes and cars too.

Electrification is growing rapidly as a result, and this trend will continue. In many developed economies, about a fifth of the energy use comes from electricity. Scenario analyses show electricity's share needs to rise to 40-60% to achieve climate neutrality. Unfortunately, electrification faces limits; grids are overloaded, and on sunny and windy days, there is often too much green electricity generated, leading to negative prices and idle wind turbines. This complicates the business case for further electrification and investments in renewables.

Electrification is not the only solution, molecules remain important

However, electricity is not the only route to a zero-emission economy. Molecules such as low-carbon hydrogen, bio or synthetic gas, and the capturing and storing of CO2 play a significant role. They are especially important in production processes that require high temperatures, such as steel, plastic, cement, fuels, and glass. They are also crucial for transportation modes that require fuels with high energy density, including aeroplanes, ships, and heavy trucks.

Climate neutrality is impossible without sustainable molecules. The affordability of the transition also depends on the availability and use of these molecules. The transition is more affordable with a focus on cheap molecules (CO2 storage, biogas, recycling, residual heat and blue hydrogen) and fewer societal constraints, such as completely phasing out fossil molecules before sufficient sustainable alternatives are available. Climate neutrality can then be achieved with less profound and complex interventions in the energy system.

Not either-or, but both: how electrons and molecules can be integrated

The transition requires a mix of electrons (electricity) and molecules (such as gas from bio- and synthetic fuels, carbon recycling, the capturing and storage of CO2, and hydrogen). It is not an either-or story, but a both story.

The relevant question is how policymakers and corporate leaders can intelligently combine and integrate electrons and molecules into a sustainable, reliable, and affordable energy system. In technical terms, how should we shape system integration for our energy infrastructure?

Our vision, based on in-depth interviews with experts

For this analysis, we conducted in-depth interviews with various experts in the Dutch energy system from the worlds of electrons (TenneT), molecules (Gasunie, Energie Beheer Nederland, and HyCC), applied science (Netherlands Environmental Assessment Agency), and policy (Ministry of Climate and Green Growth). These conversations yielded a rich palette of opinions and advice on system integration, which often differed from each other, even among experts from the same organisation. We weighed these insights and formed our own vision based on them.

Note that our analyses focuses on the Dutch energy system, but could also be applied to other economies with similar fossil-based energy systems. Recommendations also apply to France and the Nordics, although this topic is less urgent due to large amounts of dispatchable power from nuclear and hydropower plants, respectively.

Also bear in mind that we focus on energy use, not electricity from molecules for feedstock use (sustainable C's and H's to make 'green' plastic, steel, and aluminium). Feedstock use could be another driver for infrastructure and system integration.

This analysis contains our findings from executives and policymakers.

Overview of policy recommendations to integrate green electrons with green molecules

Our vision based on expert-interviews

Grids for	Purpose and application
Electrons	
Power	• Transport of (renewable) electricity • Enables electrification, which is often the logical choice for businesses and households to green activities
Molecules	
Heat	• Transport of residual and sustainable heat • Reduces total energy loss in the energy system • Relieves pressure on congested power grids in neighbourhoods
Gasses	• Transport of methane. • Currently fossil based, in the future bio- and synthetic gas • Backup for power production on days without wind and sun and over seasons
Hydrogen (carriers)	• Transport of hydrogen and derived products such as methanol, ammonia and synthetic fuels • Crucial for energy storage and sustainable production of chemicals, steel, plastics and fuels
CO_2	• Currently transport of captured CO_2. In the future biogenic and CO_2 from waste or recycled streams • Crucial for making chemicals, steel, plastics and fuels more sustainable and negative emissions

Recommendations for system integration

- Build the infrastructure to solve the '**chicken egg problem**'. Accept that society has to go through this phase.
- **Reuse and repurpose** the existing infrastructure / pipelines for natural gas as much as possible for green molecules.
- Use **hybrid solutions** as much as possible, such as hybrid heat pumps and cars instead of fully electric solutions.
- Preferably **transport** large amounts of energy via molecules instead of electrons.
- Put generation and demand **close together**, that saves infrastructure. So electrolyzers at sea or in clusters where electricity from the sea landed. And data centers in places with surpluses of generation.
- Invest not only in generation and demand, but also in **interconnection, storage, backup capacity and integration**. Think and work outside the existing **silos** of gas and electricity.
- **Perfection is the enemy of good**: use sustainable molecules in this start-up phase where it is easiest instead of for the ultimate solution. Let **CO2 reduction** be leading, not the dream solution.
- Make **the public sector** part of the policy mix (in addition to pricing and standardisation). Use public enterprises not only to build infrastructure, but also for system integration and demand creation, for example by reducing offtake risks.
- Don't expect miracles from **flex solutions**. Energy-intensive manufacturers often have to produce continuously. Forced flexibilization may also affect their competitiveness.

Source: ING research

The basic insights: what we know but easily forget

1. In all cases: significantly expand the power grid

Electrification requires large investments in power grids. According to the most recent data for the Netherlands, network operators invested more than €6bn in their networks in 2023. Of this, a significant 90% goes to the electricity grid. And it doesn't stop there. Investments in the power grid could gain pace and reach nearly €200bn by 2040. Politicians realise that a lot of money is needed and want to get the most value for taxpayers' money. Intelligent integration of sustainable electrons with sustainable molecules provides a framework for them.

2. Simultaneously invest in infrastructure for sustainable molecules

There is a simultaneous transition of infrastructure for electricity and molecules. Even though currently 'only' 10% of investments concern gas, hydrogen, heat, and CO2, ambitions are high and the challenges are complex. As a result, parties often focus on their own discipline, and system integration receives too little attention.

3. Invest not only in infrastructure but also in interconnection, storage, and backup capacity

A reliable and affordable power grid requires strong connections with foreign grids and the ability to store electricity, for example, in batteries, heat, or green hydrogen. The recent blackout in Spain and Portugal shows that the reliability of a weather-dependent power grid (from the sun and wind) can come under pressure if there are insufficient possibilities to store or exchange power with foreign countries.

The opposite also applies: there must be sufficient dispatchable capacity in the system for prolonged periods with little wind and sun. In the Netherlands, this is still manageable until 2030. Between 2030 and 2040, a major problem arises when coal-fired power plants are closed and there are no new nuclear power plants yet. Gas-fired power plants will have to fill that gap, preferably with a mix of sustainable molecules such as biogas and blue and green hydrogen to reduce CO2 emissions. However, the business case for (new) gas-fired power plants is under significant pressure if the investment can only be recouped during the hours when a gas-fired power plant is operating. Capacity payments also provide income when the gas-fired power plant is not operating, and seem necessary to have sufficient backup capacity from gas-fired power plants during times of little wind and sun. Surrounding countries such as Belgium, and the United Kingdom have already introduced capacity payments to guarantee security of supply, but this is not the case yet for the Netherlands.

Recommendations to further integrate sustainable electrons and molecules

1. The ultimate goal of the large-scale application of green hydrogen is not yet achievable; focus on the intermediate steps and embrace hybrid solutions

Many of the experts we interviewed indicate that system integration is hampered by wishful thinking. The transition to a large-scale hydrogen economy is a striking example. For many, this transition should immediately focus on green hydrogen, based on renewable electricity, while that business case is still not viable and will not happen for a while. The desire for large-scale production of steel, plastic, and fuels based on green hydrogen is a utopia for now. This leads to 'the drama of good intentions'; by only looking at the ultimate final solution, too little progress is made with intermediate steps that seem more feasible in the medium term.

A solution could be to use the available blue and green hydrogen where it is easiest, for example, in refineries, so that the production of gasoline and diesel is accompanied by fewer emissions. Hydrogen can also be mixed with methane (natural gas and LNG) in the existing gas network, reducing the CO2 emissions from the gas consumption of households and SMEs. These are quick wins with blue and green hydrogen scaled up more easily. Scaling up is necessary to make hydrogen applications affordable. But these 'easy forms' of scaling up face a lot of resistance because they do not correspond to the desired use from the final picture (the greening of steel and plastic and phasing out coal, oil, and gas). As one interviewee aptly put it: "Perfection is the enemy of good here."

System integration can be further strengthened by promoting hybrid solutions instead of all-electric solutions. The latter solutions place a disproportionately large burden on the power grid. This is because power cables can transport less energy than gas pipelines and can also provide less for the peak demand for energy, for example, on cold days (see graphs below).

Hybrid heat pumps use electricity for most of the year, but switch to (bio)gas when it is too cold and the grid is too heavily loaded. This way, more homes can be (to a large extent) electrified than when homes are fully electrified and disconnected from the gas grid completely.

The same applies to district heating networks. These offer society as a whole a relatively inexpensive way to green homes in densely built-up areas near heat sources. A successful rollout of district heating grids then creates more space on the power grid, creating more opportunities for the electrification of cars (more charging points) and the densification of neighbourhoods (building more homes and electricity-intensive facilities such as supermarkets, schools, and swimming pools).

2. The greening of energy-intensive industries and bunker fuels is an uncertain factor; develop a vision on reorganising production chains

There are many uncertainties that affect the energy system of the future. This also makes the many options for smart integration of different energy carriers and infrastructure uncertain. Two factors stand out for countries with large industrial clusters, ports and airports like the Netherlands, Germany, Belgium and the UK. First, the scale and pace of the transition in the energy-intensive industry (chemicals, plastics, steel and cement production). Second, the scale and pace of the transition of fuels for aviation and shipping – the so-called bunker fuels.

Uncertainties in the pathways to climate neutrality

Key uncertainties for the future energy system from expert interviews

Industry	Europe's energy-intensive industries are finding it challenging to remain competitive in the global marketplace due to significantly higher energy costs compared to those in China and the U.S. What implications does this have for the industry's scale, and how will it evolve in a climate-neutral economy? To what degree does a reduction in size correlate with the substantial investments required for sustainability?
Bunker fuels	Northwest Europe serves as a central point for fuels used in aviation and shipping. While these fuels are all derived from fossil sources, their emissions are not included in national emission statistics according to international standards. Consequently, they are often overlooked. What role do these fuels play in a climate-neutral economy? How are efforts underway to enhance their sustainability? Additionally, will the production occur mainly within Europe or through imports?
Fossil fuels	Will fossil fuels still have a place in a climate-neutral economy? Essentially, is there a potential for a revolutionary shift where fossil fuels are entirely supplanted by electricity, biofuels, and hydrogen-based fuels? Or will the transition be gradual, allowing fossil fuels to remain part of a climate-neutral economy while significantly reducing their emissions through methods like carbon capture and storage (CCS)?
Nuclear energy	Will nuclear energy expand and provide a substantial base load of CO2-free electricity, even during times when the sun isn't shining and the wind isn't blowing? Will advancements occur in smaller modular reactors that can, for instance, deliver power to major energy users like data centres or manufacturers of steel, plastic, and aluminum? Additionally, what is the future of nuclear fusion?
Supply of green molecules	What is the accessibility of sustainable molecules in a climate-neutral economy, such as biogas, hydrogen, synthetic fuels, and pyrolysis oil derived from plastic waste? Are these resources generally abundant, or do they remain quite limited? Additionally, are they predominantly produced locally, or are they mostly imported?
Energy saving	How successful will Europe be in saving energy? After all, saved energy does not have to be made sustainable by green electricity of green molecules. In recent years, energy savings have been at a steady pace. However, it is proving difficult to achieve an acceleration, especially in a world where new developments require a lot of energy, such as data centres, GenAI, cryptocurrencies, a growing population and more but smaller households.
Additional goals	How significantly will goals beyond CO2 reduction influence the future energy landscape? Consider elements like affordability, energy security, strategic independence, circular economy, phasing out fossil fuels, air and water quality, spatial integration, nitrogen emissions, and biodiversity. While we examine system integration primarily through the lens of emission reductions, other factors also contribute to shaping the future energy framework.

Source: ING research

In scenario analyses for the future energy system, there are various ways to deal with these uncertainties about the future of industry and bunker fuels.

- **Green current activities in their current size.** This was common practice in the years before the energy crisis, but is no longer realistic now that Northwestern Europe is at a structural disadvantage due to high energy prices.
- **Green current activities while they are reduced in size.** More recent scenarios therefore reduce the future size of energy-intensive industries and bunker fuels.
- **Towards new sustainable production chains.** The question is whether these sectors can simply be made more sustainable if they are smaller in size. Europe's structural competitive disadvantage due to high energy costs may require more drastic changes in the value chain. Steel companies, for example, can have their most energy-intensive activities take place where energy is cheapest (think of Scandinavia, Southern Europe, or elsewhere in the world). They can then import raw steel and locally finish it into high-

quality steel. The same applies to plastic producers. In the chemical industry, the refining of raw materials such as naphtha and ethylene can take place in low energy cost regions in or outside Europe, while the processing into plastic happens locally via the import of raw materials or locally sourced recyclate.

Develop a vision for energy-intensive industries and bunker fuels

Reorganising production chains can have a significant impact, as it involves process steps that account for up to 80% of the energy demand of the activity, such as in the production of steel or plastic. Despite this, the consequences of reorganising production chains are still insufficiently known. This applies both to the impact on the energy system (demand and supply of energy) and the availability of sustainable raw materials (green hydrogen and sustainable carbon as feedstock for sustainable products). This complicates the design of energy infrastructure and the system integration between sustainable electrons and molecules. More vision and policy need to be developed on this.

In the absence of this, it is difficult for politicians to implement strong guiding policies, and uncertainty remains high for businesses when allocating their investment space, especially in energy-intensive industries struggling with a loss of competitiveness and an uncertain investment climate. Such a vision can also incorporate non-energy considerations, such as strategic autonomy regarding crucial energy carriers and (intermediate) products.

Do not overestimate the potential for demand-side flexibility

Although there is limited out-of-the-box thinking on the supply side, this type of thinking is occurring regarding the flexibilisation of electricity demand. In the future energy system, it is assumed that major energy consumers will adjust their electricity needs according to the weather-dependent supply of renewable electricity. While this has been stressed in recent years, many experts indicate that little progress has been made in practice. Of course there are a few exceptions, but in general, energy-intensive companies are reluctant to flexibilise their electricity demand. When it does happen, it is more of a necessary evil to obtain a grid connection than a desired option. Companies express concerns that forced flexibilisation will impair their competitiveness. Moreover, households without an electric car, a hybrid heat pump or a home battery have few devices to make a real difference in shifting electricity demand throughout the day. On the demand side, it is therefore wise not to expect miracles from flexibility options. The potential is probably greater on the supply side, for example, through flexible production of sustainable molecules at times when renewables are abundant and power prices are low.

Enhance the public sector’s role in scaling up infrastructure

The renewable energy market sees a stark contrast between electrons and molecules. While the electricity grid struggles to keep up with green electrons' supply and demand, the molecules market faces a chicken-and-egg problem: limited infrastructure exists because demand is low, and demand is low due to limited infrastructure. Economically, this is a coordination issue where leadership is needed to break the cycle.

Market coordination, for instance through CO2 pricing or subsidies, is the preferred solution for many experts. However, they note that pricing alone may not suffice. For individual companies, the costs of organising new infrastructure or system integration often outweigh the benefits (better energy efficiency and/or lower emission costs), particularly for international companies competing in global markets where they cannot pass on extra costs. They stress that the government can enforce coordination in several ways.

Blend mandates help solve the chicken-and-egg problem by simultaneously stimulating supply and demand. They also make price premiums for sustainable molecules manageable; mixing 5% spreads the significant cost difference over the other 95%.

However, economic issues are not fully resolved. Green molecule producers need 10 to 15-year supply contracts to recoup investments, but buyers are reluctant to commit for more than a few years due to the high current costs and the potential for future price drops from scaling up. Even with existing infrastructure, producers and buyers hesitate to make Final Investment Decisions due to misaligned risk profiles.

The public sector can bridge this gap. For example, by bundling demand for green molecules from multiple buyers or guaranteeing demand over a longer period (acting as a 'market maker and aggregator'), or by ensuring purchase if market players cannot (buyer of last resort). This reduces the risk profile of the business case, aligning it with the risk profiles of suppliers and buyers. Germany's system already supports green hydrogen investments. Such a role need not be permanent, but should cover the transitional period of say 15 to 20 years until solutions are scaled up and risks are manageable for market parties.

Companies and policymakers: take advantage of the benefits of system integration

Smart integration of electrons and molecules has many benefits.

1. **Sustainability**: Smart system integration allows us to make optimal use of the immense potential of cheap renewable energy from wind turbines and solar panels. Literature research by Frontier Economics shows that offshore wind capacity in the North Sea can increase by 88-121 GW if hydrogen production takes place at sea and wind farms, electrolysers, and grid infrastructure are clustered. Hydrogen production prevents wind farms from being shut down when too much electricity is generated (curtailment). System integration can, therefore, make a significant contribution to achieving the joint goal of the North Sea countries to realise an offshore wind energy capacity of 300 GW by 2050.

2. **Reliability**: Integration of molecules in a future energy system dominated by electricity can provide backup capacity when sun and wind are not available for long periods. Additionally, it can meet the peak demand for energy which is impossible to fully electrify.
3. **Affordability**: An integrated approach reduces the costs of the transition to a climate-neutral economy. The aforementioned literature shows that offshore hydrogen production saves €5-11bn per year until 2050, compared to an electricity configuration that transports power directly to the coast from wind farms. International interconnection of offshore wind farms provides additional annual cost savings of €1-4bn. These savings result from lower transport costs, operational and economic flexibility (choice between electricity or hydrogen production based on market prices), sales to markets where prices are highest, optimal energy storage, and less import of electricity and hydrogen. Another example is district heating networks. Numerous studies have shown that district heating networks are, for society as a whole, a good option for making densely built-up areas near heat sources more sustainable. These district heating networks utilise heat that would otherwise be wasted and can be made sustainable in the long run through green electrons and molecules (geothermal energy, electric boilers, industrial heat pumps, biogas, blue and green hydrogen). System integration, therefore, contributes to an affordable transition.
4. **Space**: An energy system in which electricity is the primary form of energy requires significantly more space than an integrated energy system. For example, solar farms need two hundred times as much space for the same amount of capacity as a gas-fired power plant, which can run on bio-gas or low-carbon hydrogen in the future. When considering the actual electricity generation, a solar farm requires approximately 800 times more space. This is because solar panels do not generate power at night, and output in winter is only a fraction of summer output. By using more molecules in addition to dual space usage (solar panels on rooftops), you reduce the extra space demand of the future energy system. By placing generation and consumption as close together as possible, the need for energy infrastructure is reduced. Moreover, pipelines for molecules can be more easily laid underground, making the infrastructure less visible. System integration, therefore, can provide spatial benefits, which is not to be underestimated in densely populated areas where many functions compete for scarce space.

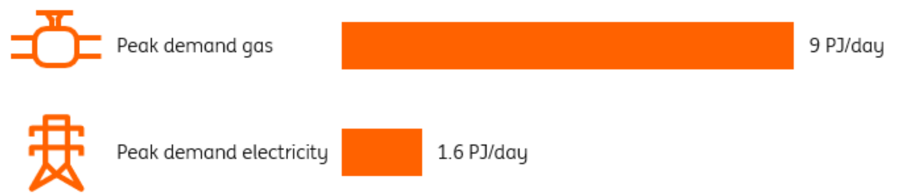
It is imperative for companies and policymakers to seize the myriad benefits offered by smart integration of green electrons and molecules. Embracing this integrated approach will not only drive sustainability but also ensure affordability, reliability, and spatial efficiency in our energy systems.

Appendix: Key differences between electrons and molecules

The extremes of electricity and gas (molecules of natural gas, biogas, and synthetic gas) are depicted. Based on chemical properties, hydrogen occupies an intermediate position.

Gas infrastructure can meet higher peak demand

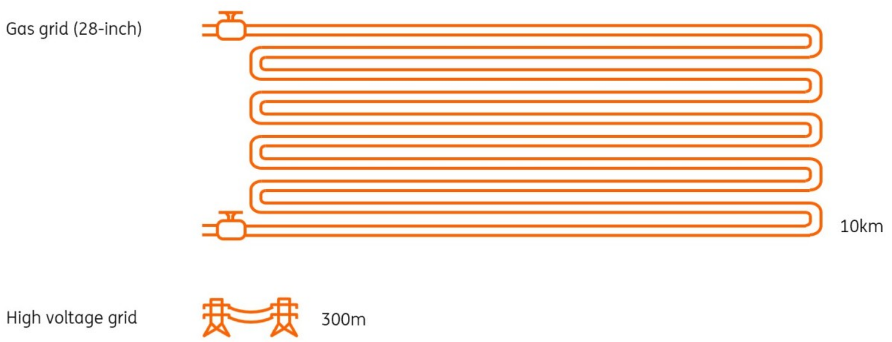
Peak demand on a cold winter day in the Netherlands



Source: ING research

Infrastructure for gas is cheaper

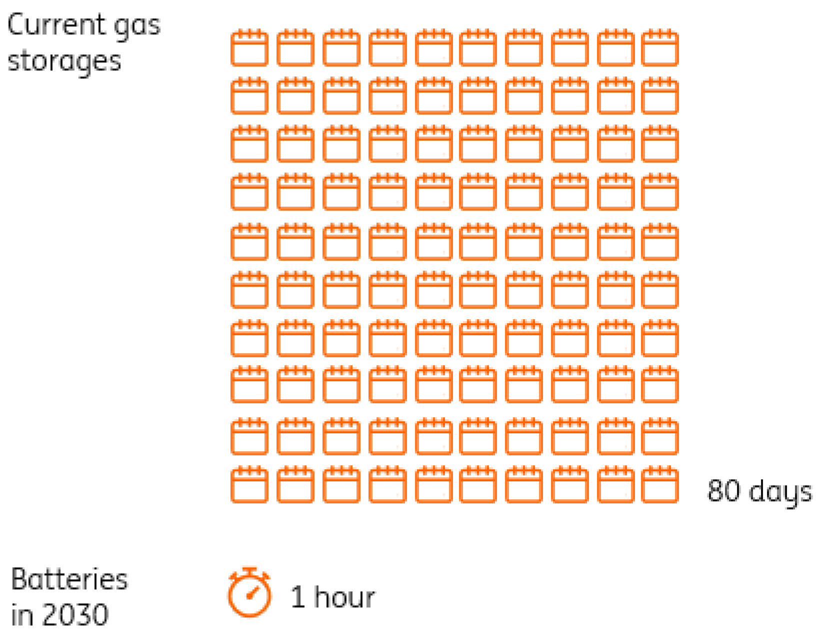
Infrastructure length for 1 GW capacity that can be constructed with €1m in the Netherlands



Source: ING Research

Gas can store a lot more energy

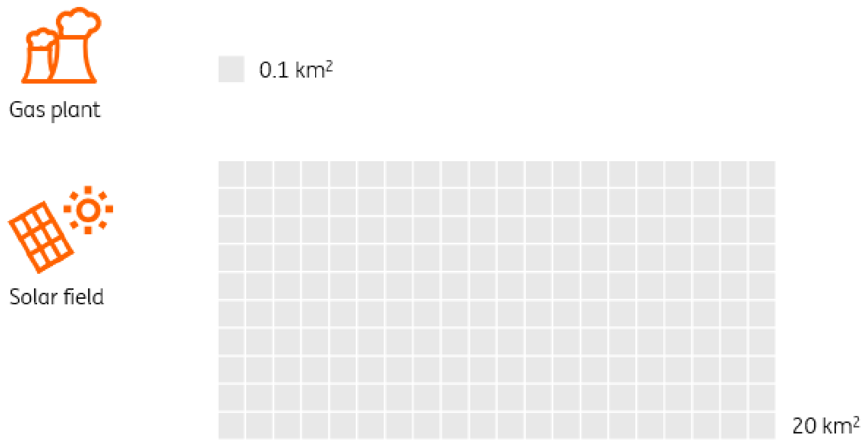
Time before average demand depletes the storage facilities during a cold winter in the Netherlands*



Source: ING research

Gas plants require less space

Required space for 1 gigawatt capacity in the Netherlands



Source: ING research

Author

Gerben Hieminga
Senior Sector Economist, Energy
gerben.hieminga@ing.com

Disclaimer

This publication has been prepared by the Economic and Financial Analysis Division of ING Bank N.V. ("**ING**") solely for information purposes without regard to any particular user's investment objectives, financial situation, or means. *ING forms part of ING Group (being for this purpose ING Group N.V. and its subsidiary and affiliated companies).* The information in the publication is not an investment recommendation and it is not investment, legal or tax advice or an offer or solicitation to purchase or sell any financial instrument. Reasonable care has been taken to ensure that this publication is not untrue or misleading when published, but ING does not represent that it is accurate or complete. ING does not accept any liability for any direct, indirect or consequential loss arising from any use of this publication. Unless otherwise stated, any views, forecasts, or estimates are solely those of the author(s), as of the date of the publication and are subject to change without notice.

The distribution of this publication may be restricted by law or regulation in different jurisdictions and persons into whose possession this publication comes should inform themselves about, and observe, such restrictions.

Copyright and database rights protection exists in this report and it may not be reproduced, distributed or published by any person for any purpose without the prior express consent of ING. All rights are reserved. ING Bank N.V. is authorised by the Dutch Central Bank and supervised by the European Central Bank (ECB), the Dutch Central Bank (DNB) and the Dutch Authority for the Financial Markets (AFM). ING Bank N.V. is incorporated in the Netherlands (Trade Register no. 33031431 Amsterdam). In the United Kingdom this information is approved and/or communicated by ING Bank N.V., London Branch. ING Bank N.V., London Branch is authorised by the Prudential Regulation Authority and is subject to regulation by the Financial Conduct Authority and limited regulation by the Prudential Regulation Authority. ING Bank N.V., London branch is registered in England (Registration number BR000341) at 8-10 Moorgate, London EC2 6DA. For US Investors: Any person wishing to discuss this report or effect transactions in any security discussed herein should contact ING Financial Markets LLC, which is a member of the NYSE, FINRA and SIPC and part of ING, and which has accepted responsibility for the distribution of this report in the United States under applicable requirements.

Additional information is available on request. For more information about ING Group, please visit www.ing.com.