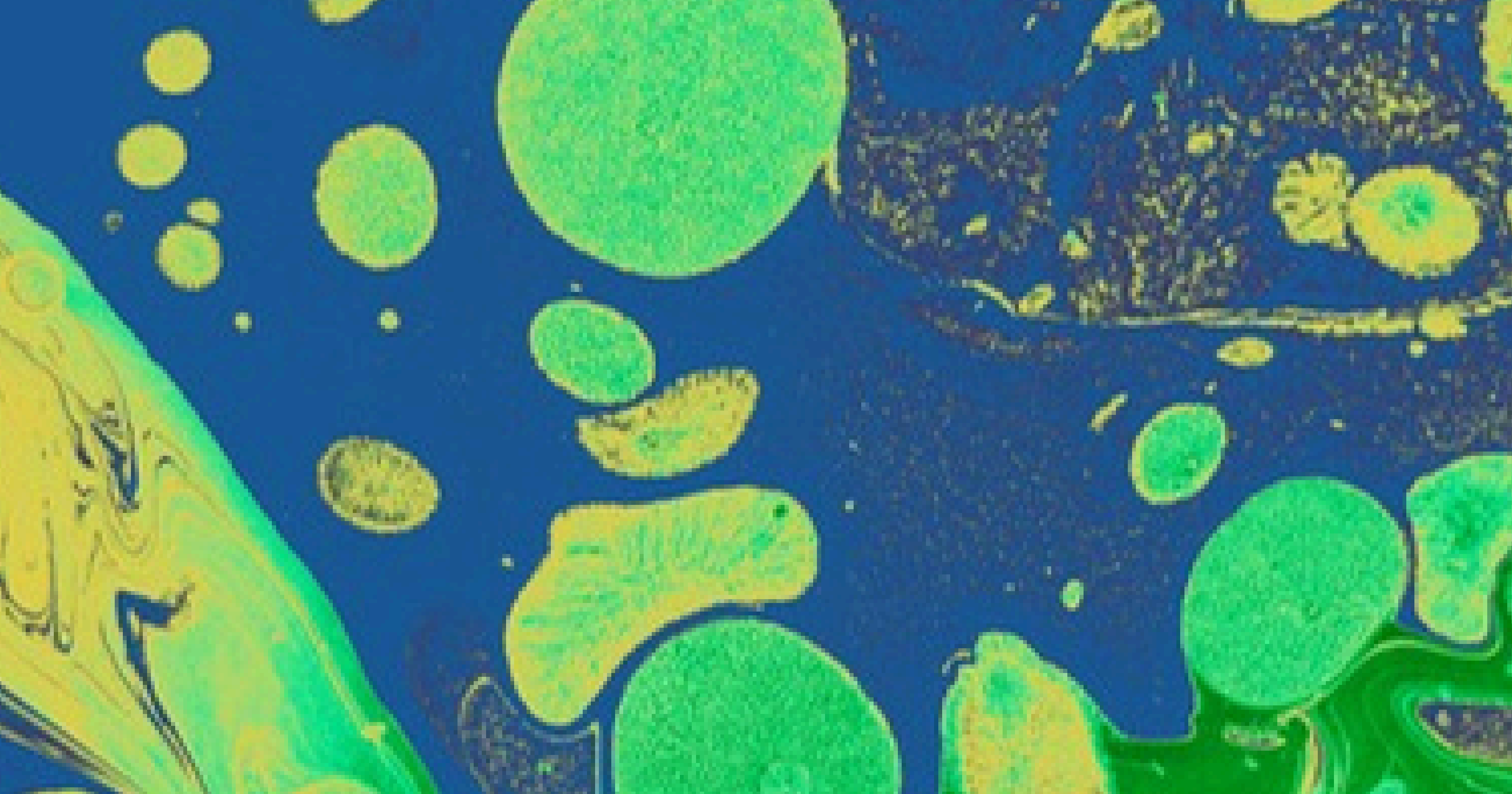


ENERGY EFFICIENCY FOR ENERGY SECURITY

Industry input to produce energy savings and system efficiency gains across the European Union

April 2026

INTRODUCTION

The European Union is entering an energy crisis of exceptional magnitude, driven by escalating geopolitical instability and rising energy prices. The scale of this crisis demands a response that is immediate and coordinated, finding solutions that Europe can rapidly deploy at scale, with its own mature industrial and technological capabilities.

Currently, the EU imports around 57% of its primary energy. Without post-2000 efficiency gains, this figure would have risen dramatically to approximately 73% dependency, making it far more vulnerable to global market shocks and supply disruptions.[1]

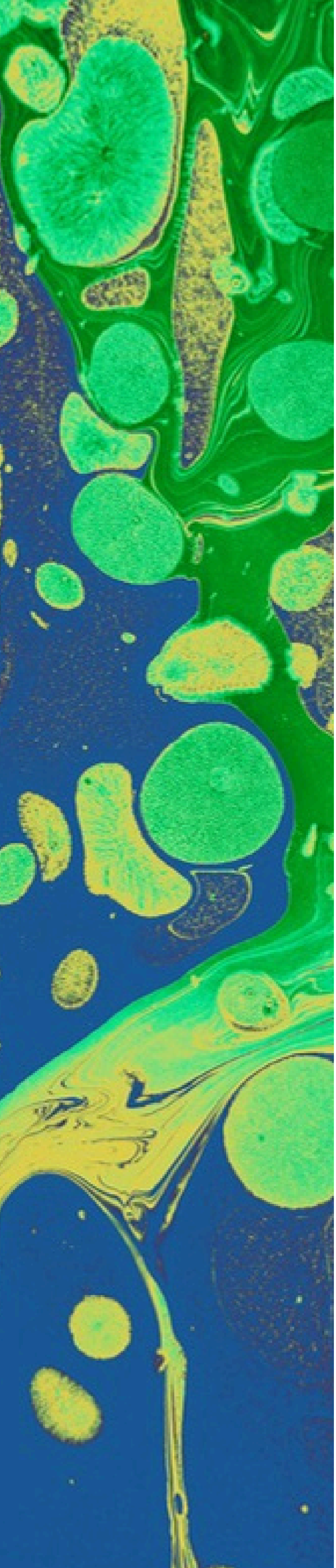
In a resource-constrained continent, the first step to address an energy crisis is to optimise what we have to reduce waste and improve performance. This is precisely what energy efficiency delivers. It corrects systemic inefficiencies and design flaws that cause Europe to consume more energy than necessary to produce, move, and live comfortably. Evidence shows that energy demand can fall while GDP continues to grow. According to the International Energy Agency the global economy today produces 36% more GDP per unit of energy than in 2000 and in manufacturing alone, the EU now produces 50% more added value with 25% less energy compared to 2000. Producing more with less is not theoretical; it is already happening. [2]

The technologies to improve energy efficiency are available and largely developed in Europe, with limited exposure to raw material shortages. They can be deployed across Member States and sectors - buildings, industry and transport - to deliver significant demand reduction, system optimisation, demand flexibility and cost relief, with short payback periods given the high cost of fossil fuel imports. Very importantly they are enablers of faster and more affordable electrification that is essential to reducing Europe's dependence on imported fossil fuels and strengthening energy security.

The present document is the contribution of a broad industrial ecosystem to the European Commission's AccelerateEU [3] task to develop a catalogue of replicable measures to produce energy savings and system efficiency gains for the EU Energy Ministers that will gather in Cyprus on 13 May 2026.
The document builds on and updates a European Alliance to Save Energy's 2022 catalogue of technologies and solutions [4], originally developed in response to the energy crisis following Russia's invasion of Ukraine. While the context has evolved, the need for coordinated action remains. This updated catalogue presents cross-sectoral, readily deployable energy efficiency technologies and solutions that can strengthen energy security, alongside industry commitment to support the development of a concrete action plans for their large-scale implementation.

The technologies exist. The economic case is clear. The strategic necessity is undeniable. In the context of an unprecedented energy crisis, acting decisively on energy efficiency to strengthen Europe's energy security is an opportunity to lead with confidence and determination [5].

[1] Update of the governance of the Energy Union and climate action, DENEFF, 2026
[2] Economic growth, International Energy Agency, 2025
[3] AccelerateEU – Energy Union - affordable and secure energy through accelerated action,2026
[4] Short to mid-term measures in energy efficiency to reduce gas consumption in Europe, EU-ASE, 2022
[5] Energy Efficiency for Energy Security, Joint Letter, 2026



KEY FINDING

The catalogue identifies a broad non-exhaustive list of energy efficiency technologies and solutions. Their untapped energy savings and energy system efficiency potential could be a significant contribution to a structural reduction of fossil fuel imports and increase of EU energy security and independence.

METHODOLOGICAL NOTES

The estimated bcm of natural gas savings elaborated in relation to each energy efficiency measure listed have been conducted on the basis of industry estimations and data extracted from various documents and sources which apply different calculation methodologies and reference scenarios. The energy unit conversions to bcm of natural gas have been done using the conversion factor from BP [6] .Some figures related to the estimation of bcm of gas saved have been rounded down for the sake of simplicity. For units conversion we used the IEA's online unit conversion tool [7]. Gas price assumption is €40/Mwh.

[6] Approximate conversion factor by BP, BP website accessed on April 29, 2026
[7] IEA's online unit conversion tool, IEA website accessed on April 29, 2026

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BUILDING AUTOMATION AND ENERGY MANAGEMENT SYSTEMS

Building automation and control systems (BACS) monitor, analyse and continuously optimise the performance of technical systems in buildings. By connecting and coordinating heating, cooling, ventilation, lighting, shading and other building services, they reduce unnecessary energy use, improve operational performance and maintain comfort and indoor environmental quality.

Beyond direct energy savings, BACS and connected controls provide the digital backbone for flexible electrification, enabling buildings to integrate heat pumps, EV charging, on-site renewables, storage and demand response.

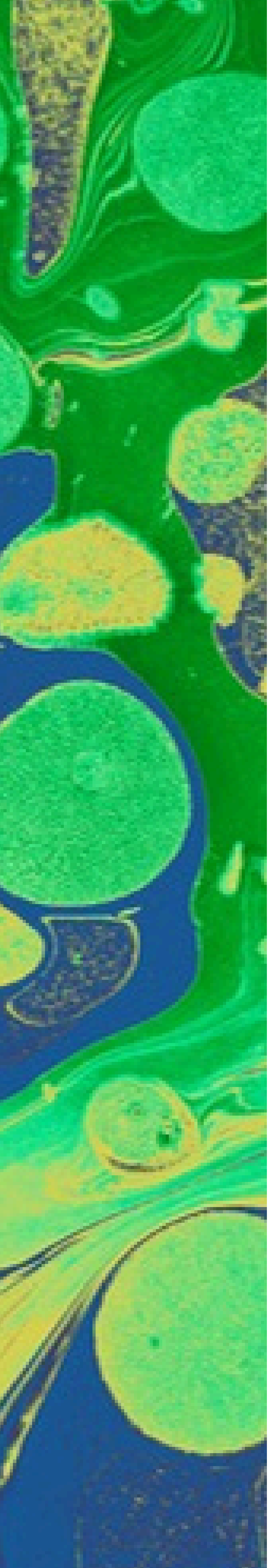
The energy savings potential of BACS is well established, and their deployment is now anchored in the revised Energy Performance of Buildings Directive (EPBD). The revised EPBD requires non-residential buildings with technical building systems above 290 kW to be equipped with BACS, and extends the requirement to buildings above 70 kW by 31 December 2029 [8]. The priority now is rapid and effective national implementation, including clear scope definitions, compliance verification and enforcement. National implementation should also promote interoperable and future-ready digital solutions, with access to real-time data and compatibility with smart meters, building management systems and other flexible assets.

In the framework of the EU's energy security and competitiveness objectives, the quick return on investment of BACS makes them an attractive short- to mid-term solution to improve the performance of the European building stock. BACS are fast to deploy, relatively low-disruption, highly scalable and cost-effective, while also creating the basis for deeper optimisation over time. Installing BACS is an essential part of any renovation project. It requires relatively small upfront costs, estimated at around €30/m^2 in non-residential buildings and €12/m^2 in residential buildings, while according to industry estimates, the value of savings generated exceeds the value of investments by a factor of 9.

An ambitious implementation of the BACS provisions in the revised EPBD could lead to savings corresponding to 14% of the total building stock final energy consumption by 2038. This would give rise to 450 TWh of annual final energy savings.

This level of annual final energy savings equals to 43 bcm of fossil gas saved per year, corresponding to approximately €19 billion worth of gas in today's market.

[8]The impact of the revision of the EPBD on energy savings from the use of building automation and controls, Waide Strategic Efficiency Limited, 2021



GEARING UP HEATING CONTROLS

Installing smart heating controls is a simple process that can be scaled up quickly. According to IEA's forecasts, tripling the current installation rate of about one million homes per year would reduce gas demand for heating homes by an extra 200 mcm a year at a total cost of €1 billion. As highlighted by the Agency, existing programmes such as subsidies to households can help incentivising these devices.[9]

Industry estimates show that there are around 70 million homes in the EU that still only have manual radiator valves (MRVs) on their radiators. This effectively means that around 500 million radiators in the EU can be upgraded to thermostatic radiator valves (TRVs). If so, the annual EU energy saving would be 130 TWh of energy per year. In addition, if all the more than 20 years old TRVs would be upgraded, the amount of annual savings could be increased to 160 TWh [10].

This level of annual final energy savings equals to almost 15 bcm of fossil gas saved per year corresponding to approximately €6.5 billion worth of gas in today's market.

In addition to these technological upgrades, some behavioural changes such as lowering the thermostat in building heating systems would deliver immediate annual energy savings of around 10 bcm of gas for each degree of reduction, while also bringing down energy bills for households. At the scale of a city like Paris, with about a third of the building not yet equipped and an average of 2,35 mcm of gas to be saved per 10000 dwellings, this could represent 117 mcm of fossil gas saved in a year.

[9] A 10 point Plan to Reduce the European Union's Reliance on Russian Natural Gas, IEA, March 2022
[10] Room temperature controls : how the EU is missing an opportunity for substantial energy savings, eu.bac, 2021

DIGITAL OPTIMISATION OF HEATING SYSTEMS

Digital optimisation of heating systems improves how heating and cooling is generated, distributed and consumed from the central system to points of end-use. Currently, 5 to 10% of heating energy is wasted in distribution, affecting around 16 million residential buildings across Europe.

For example, in Germany, around 84% of the 18.9 million residential buildings are supplied by central heating systems.8 It is estimated that 85% of these buildings lack optimised hydronic balancing and operate with outdated system settings, leading to unnecessarily high supply temperatures and excessive energy use.

The potential for improvement is substantial. At building level, it can achieve savings of 2.5 to 16 kWh/m^2 annually, with payback periods of around 8 to 9 years for single-family dwellings and 3.5 to 4 years for multi-family buildings. Across the EU housing sector, hydronic balancing alone could deliver energy savings of up to 22.6 Mtoe per year. [11]

This level of annual energy savings equals to 24 bcm of fossil gas saved per year, corresponding to approximately €10 billion worth of gas in today's market.

The increasing availability of granular submetering data, driven by the rollout of remotely readable meters, now enables a shift towards continuous data-driven optimisation of heating systems. These solutions combine hydronic balancing with real-time monitoring of heating demand, allowing dynamic adjustment of system parameters such as supply temperature and control settings [12].

This approach not only improves heat distribution but also addresses system oversizing and inefficient operation, unlocking up to 30% additional energy savings while maintaining thermal comfort. By enabling buildings to operate at lower temperatures, it also facilitates the integration of renewable and decarbonised heating solutions such as heat pumps and renewable-based district heating.

[11] Energy Savings Across EU Domestic Building Stock by Optimizing Hydraulic Distribution in Domestic Space Heating Systems, Technological University of Dublin, 2015
[12] Smarter Heating, Lower Emissions, WE Data Europe, 2025

ENERGY EFFICIENCY PROGRAMMES COMBINING INTEGRATION OF RENEWABLE ENERGY, ELECTRIFIED HEAT AND ENVELOPE IMPROVEMENTS IN BUILDINGS

Higher renovation rates and deep renovations combining energy efficiency and renewable energy measures are crucial to achieve climate neutral buildings.

In alignment with the Energy Efficiency First principle, the deployment of heat pumps needs to be accompanied by energy efficiency measures reducing the overall energy demand of a building to achieve best-in-class efficiency results at a building and electricity grid level [13].

Heat Pumps deliver heat at 600% efficiency depending on overall building energy performance levels compared with a gas heater at 50% to 95% efficiency. Estimates show that replacing gas boilers with individual heat pumps can reduce household energy bills by up to 45% in Germany and up to 60% in France [14].

There were almost 2.4 million heat pumps installed in Europe in 2025. The European Commission's REPowerEU communication estimates 10 million heat pumps to be deployed by 2027 and a total of 30 million by 2030, bringing savings of 35 bcm of gas corresponding to approximately €15 billion worth of gas in today's market [15].

[13] Flattening the peak demand curve through energy efficient buildings: A holistic approach towards net-zero carbon, Akhmetov, Fedotova, Frysztacki, 2025
[14] Energy efficiency 2.0: Engineering the future energy system, Danfoss
[15] REPowerEU: Joint European Action for more affordable, secure and sustainable energy, European Commission, March 2022

BUILDING INSULATION IN ATTICS, ROOFS TOP-STOREY CEILINGS, FACADES AND WALLS

Installing or upgrading insulation reduces heat losses in buildings. The Buildings Performance Institute Europe (BPIE) estimated that by insulating attics and roofs in Europe, notably adding 20 cm of insulation, would save 254 TWh per year, representing up to 14% of heating energy demand in the EU's residential sector in 2020 [16]. As BPIE argues, this is a technically simple measure that can be scaled up quickly, by laymen guided by expert installers.

This level of annual energy savings equals to 23 bcm of fossil gas saved per year, corresponding to approximately €10 billion worth of gas in today's market.

External walls and façades also offer major savings potential. FIW Munich found that, depending on the country and the initial state of the wall, 24% to almost 40% of deep-renovation energy savings can come from external wall insulation. [17] Additionally, external thermal insulation composite systems (ETICS), installed from the outside, can also significantly reduce disruption for occupants [18].

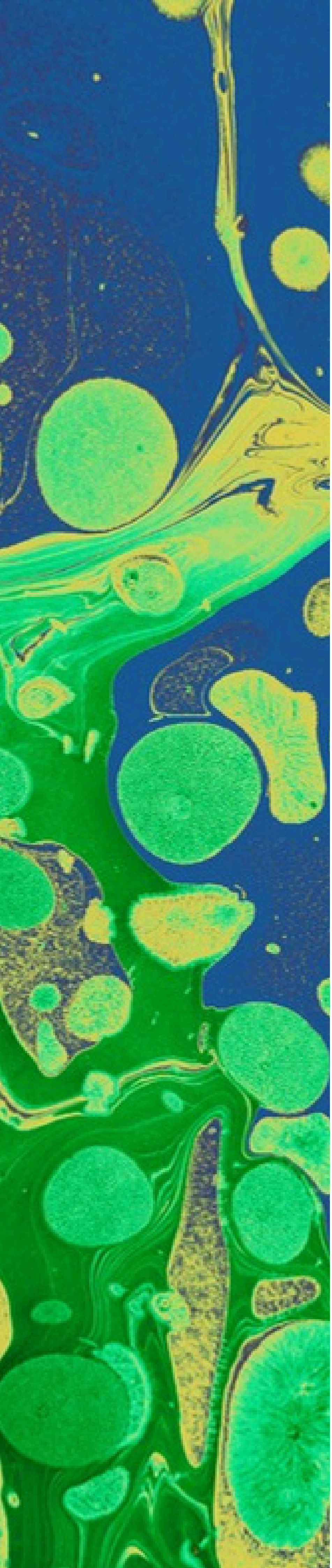
Better insulated homes could cut space heating demand by 777 TWh by 2050, or 44% of final energy used for residential space heating [19]. This would reduce natural gas use for residential space heating by 309 TWh, equal to 46% of current residential gas use and corresponding to approximately 12 billion worth of gas in today's market.

By 2030, renovating only roofs and walls could already save 8% to 11% of residential space heating demand in around 60% of EU countries.

Industrialised and prefabricated envelope renovation kits can further help accelerating deployment at scale. EU-funded projects already point to meaningful gains: DigiFab estimates installation times of 2 days per 200 m^2 unit and 30% lower cost than conventional renovation, while RenoZEB reported at least 30% lower installation time, more than 65% lower total renovation process time, 16% lower cost, and demonstrated energy-saving potential of 64.4%. Already with good planning and execution coordination deep retrofits can be done within just 22 days - a specific training scheme and certification system has been rolled out[20].

With an increasing importance, thermal insulation also helps reduce cooling demand, especially in southern European climates. Ecofys found that, in residential buildings with reasonable passive cooling strategies already in place, a sound package of insulation measures reduced cooling demand from 31 to 17 kWh/m^2a in a single-family house and from 18 to 12 kWh/m^2a in a multifamily house in Seville[21].

[16] Solidarity and Resilience: An Action Plan to Save Energy Now!, BPIE, March 2022
[17] European Energy Saving Guide 2024: A true Renovation Wave for a Sustainable Future, FIW München on behalf of European Association for External Thermal Insulation Composite Systems (EAE), June 2024.
[18] For example see EAE Awards 2023/2024
[19] How to stay warm and save energy: Insulation opportunities in European homes, BPIE, January 2023
[20] For more information see https://modernisierungsoffensive.com/.
[21] The Risk of Overheating in Multifamily NZEBs: Evaluation of thermal comfort in multi-family NZEBs in Mediterranean-continental climate, zone D3 Madrid (LCCE / Basque Government Building Quality Control Laboratory)



HIGH-PERFORMANCE WINDOWS AND DOUBLE-GLAZING

The European building stock is generally equipped with very inefficient windows. Most of them are single glazed, which is partly responsible of significant thermal losses from buildings, given that inefficient windows account for up to 30% of energy loss.
A 2019 study finds that doubling the window replacement rate, from 2% annually to 4% with high energy performance glazing on both existing buildings and new buildings could save 75.5 Mtoe a year by 2030 in the EU27 + UK. This is equivalent to a reduction of energy consumption for heating and cooling of more than 29% if all of Europe's buildings were equipped with high-performance glazing. [22]

This level of annual energy savings equals to 75.5 bcm of fossil gas saved per year, corresponding to approximately 35 billion worth of gas in today's market.

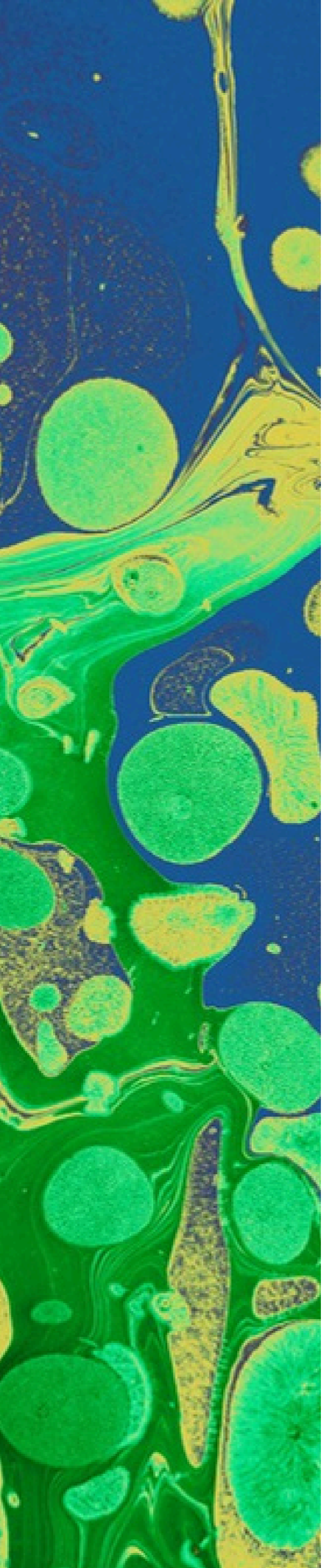
In addition to its insulating properties, high performance glazing such as solar control glass serves as a robust enabler of passive coolingx. [23] High performance glazed surfaces can filter and reduce unwanted solar heat gain while still allowing natural daylight in. According to the UN report, the Global Cooling Watch 2025, solar control glazing can deliver an average energy savings of ~20% and indoor temperature reductions of ~3°C [24]. This improves summer comfort and occupant wellbeing, directly reducing the need for active cooling in buildings and the associated energy bills [25].

BLINDS AND SHUTTERS FOR ENERGY EFFICIENCY AND SUMMER COMFORT

Blinds and shutters are a high-potential, low-disruption solution to improve energy efficiency and summer comfort in EU buildings. By controlling solar gains before they overheat interiors, especially when external or automated, they can reduce reliance on air conditioning while also improving winter insulation around windows.

Guidehouse [26] estimates that smart solar shading could cut space-cooling energy use in European buildings by up to 60% by 2050, avoid around 100 Mt of CO_2, and save up to €285 billion in cumulative energy and investment costs—making blinds and shutters a practical "first line of defence" for resilient, comfortable, low-energy homes and workplaces.

[22] Potential Impact of High Performance Glazing on Energy and C02 Savings in Europe, TNO, 2019
[23] General framework for the calculation of the energy performance of buildings, Section 5 Guidance on transparent building elements, European Commission, 2025
[24] Global Cooling Watch 2025: The free degrees: How sustainable, passive first-cooling can save lives, money and food, United Nations Environment Programme, 11 November 2025
[25] The role of solar control glazing in passive cooling of buildings, Glass for Europe, 2026
[26] Guidehouse, Solar shading – Synergising mitigation of GHG emissions and adaptation to climate change, 2021



TECHNICAL INSULATION IN INDUSTRY

Technical insulation improves the energy efficiency of industrial equipment like valves, tanks, air ductworks, pipe networks, or heating systems that need to function at high and low temperatures.

According to the European Industrial Insulation Foundation (EiiF), improving the technical insultation of pipes, vessels, tanks and boilers in industry across the EU27 could bring annual saving of about 160 TWh [27]. This level of annual energy savings equals to 14 bcm of fossil gas saved per year, corresponding to approximately 6 billion worth of gas in today's market.

This potential can be achieved by applying class C systems (based on EN 17956) and it is equivalent to the annual energy consumption of more than 10 million households.

To put this scale into perspective, consider a single industrial valve (DN 150/6 inch) operating at 150 °C. By simply insulating this one component, 10.000 kWh will be saved annually. This means the energy recovered from insulating just one valve is enough to match the total annual gas consumption of a typical European single-family household.

The best part? At least 50% of this potential can be realized immediately, without shutting down industrial plants. With a typical payback period of just 2 years, these investments are highly profitable. At a reference gas price of 45 €/MWh, these savings would reduce the European industrial gas bill by €3.6 billion, significantly boosting global competitiveness and decarbonisation whilst generating jobs in Europe.

[27] Data retrieved from the European Industrial Insulation Foundation, EIIF

INSULATED PIPES IN DISTRICT HEATING

Throughout Europe, an average loss of approximately 18% of heat happens because of an ineffective heat distribution structure. By installing new pre- insulated pipes, redesigning and digitalising the distribution system, it is possible to halve thermal losses and reduce energy consumption. Thanks to industry estimations [28], using today's design principles and pre-insulated pipes, it is possible to reduce the heat loss of heating systems of about 70%.

Furthermore, current design principles and pre-insulated pipes enables the transportation of industrial surplus heat and hot water (86 C) over 20 kilometres with a temperature drop of less than 1 degree C. This makes it possible to tap into the potential of excess heat from industrial sites, data centres and commercial activities to use on the industrial site or to inject into district heating to meet Europe's building heat demand. This infrastructure is critical to tapping into the great potential of excess heat. [29]

In the EU alone, accessible excess heat amounts to 2,860 TWh/y, which almost corresponds to the EU's total energy demand for heat and hot water in residential and service sector buildings. By using district energy systems to capture this heat from industrial sites (providing over 267 TWh/y), wastewater facilities (318 TWh/y), and data centres (95 TWh/y) would equal to energy savings of 63 bcm of fossil gas saved per year, corresponding to approximately 27 billion worth of gas in today's market.

[28] LOGSTOR calculator, Kingspan
[29] Excess heat is the world's largest untapped source of energy, Danfoss Impact Issue No.2

LED AND SMART LIGHTING

According to industry estimates, there are still more than three billion conventional light points in the European Union Member States in professional and residential segments. Moreover, the first generation of already-installed LEDs is approaching end-of-life, creating an opportunity for the next phase of LED adoption – one that is focused on higher performance, longer lifetimes and smarter systems [30]. Upgrading conventional light points and the old generation of LED with efficient LED light sources and smart lighting systems could save 185 TWh every year. The upgrade would deliver monetary savings of a scale of €43 billion. The installation costs would be offset within 2 years, while creating thousands of new jobs and reducing the carbon footprint by 50.4 million tons of CO_2, the equivalent to the annual electricity demand of Poland [31] or two times the energy consumptions of the data centres in the EU27 [32].

The savings for the entire residential sector would be 18 TWh and 4.9 billion euro, meaning 24.65 euro per household or 11.00 euro per capita.

Moreover, upfront installation costs could be further reduced by lighting-as-a-service offers, which could produce immediate cost savings and a reduction of energy consumption.

This level of annual energy savings equals to 2.9 bcm of fossil gas saved per year, corresponding to € 1.3 billion worth of gas in today's market.

Lighting is an easy, fast solution to reduce energy consumption. The upgrade of the installation is in most cases as easy as changing a bulb or replacing the luminaire without any modification to the existing electrical system or building construction. Smart lighting can further bring savings to an already efficient lighting system by automatically adjusting the lighting to factors, such as building occupancy or the availability of daylight, switching it off when not needed or dimming to the right light levels. The adequate zoning of lighting can contribute to even further energy savings. Subdividing large areas into smaller zones enables lighting systems to dim or switch off portions of space that are not in use within a broader zone.

Cities alone spend up to 20% of their electricity bill for roads and streets lighting. The impact on their balance sheet by upgrading their lighting system is huge as LED lighting can save up to 80% of electricity. Indeed, the upgrade of the existing 34 million conventional street light points to LED and 5 million old LEDs could effectively generate electricity savings of 22 TWh. A medium sized city of 200.000 people could annually save 9 GWh in street lighting equivalent to €3.0 million and 23 GWh in public buildings equivalent to €7.5 million.

It is worth to note that any immediate saving of electricity by lighting could compensate for the growing additional demand of 49 million of electric cars, enabling cities to contribute to the transition to electric mobility.
One further step could be the adoption of solar and hybrid solar-powered streetlights: it is estimated that 31.5 TWh of electricity consumption from the grid could be saved [33].

[30] The next wave of LED lighting: Smarter, circular and more efficient, IEA, 2026
[31] EU data retrieved by Signify based on a simulation presented as illustrative and on forecast and assumptions
[32] According to Our World in Data: Electricity Demand, Ember, 2025, the electricity demand of Poland is 173 TWh
[33] According to ICIS (Independent Commodity Intelligence Services), Data centres: Hungry for power, the European power demand from data centers in 2024 is 96TWh

UPGRADING TO HIGH EFFICIENT MOTOR-DRIVEN SYSTEMS

Electric motors are the backbone of industrial energy consumption. They drive pumps, fans, compressors, conveyors, and a wide range of production processes. In the EU27, 380 million electric motors consume approximately 1,326 TWh of electricity per year — equivalent to 53% of total EU electricity consumption [34]. Accoridng to CEMEP, the European Committee of Manufacturers of Electrical Machines and Power Electronics, in industry specifically, electric motor systems account for around 70% of all industrial electricity use In industry specifically, electric motor systems account for around 70% of all industrial electricity use.

Two complementary technologies can dramatically cut this consumption: high-efficiency motors (IE4/IE5 class) and variable speed drives (VSDs), which adjust motor speed to match real-time load demand. Together, they represent the largest single untapped industrial energy efficiency opportunity available to the EU today.

The International Energy Efficiency (IE) classification runs from IE1 (lowest) to IE5 (highest). Modern motor technologies can reach IE4 and IE5 ratings, offering measurably lower losses than the IE3 motors that dominate current sales. Upgrading the existing installed stock of old, sub-IE3 motors to IE3 or above could deliver an additional 25 TWh/year of electricity savings across the EU27 — based on conservative estimates and an average efficiency gain of ~4% per replacement [35].

Where replacement is combined with full system optimisation (right-sizing, VSD deployment, digitalisation), savings per motor system can reach up to 30% compared to legacy equipment.

Industrial motors tend to remain in service for 30–40 years, far beyond their intended lifetime, meaning that the efficiency gap between the installed stock and modern standards is large. Accelerated replacement turns this gap into a near-term opportunity.

DEPLOYING VARIABLE SPEED DRIVES(VSDs)

Variable Speed Drives (VSDs) enable electric motors to adjust speed to actual load requirements, significantly reducing unnecessary electricity consumption in industrial applications such as pumps, fans and compressors. Expanding VSD deployment across EU industry could save up to 121 TWh of electricity annually, equivalent to 10.3% of the EU's 2030 energy efficiency reduction goal, while avoiding 25.4 million tonnes of CO_2 emissions [36][37]. Full implementation of VSDs could save up to 6% of the EU's electricity – more than the electricity use of Denmark and the Netherlands combined in a year [38] and deliver approximately EUR 22.6 billion in annual electricity cost savings, with typical payback periods as short as six months. In addition, when combined with digital controls, VSDs can support demand-side flexibility by reducing peak power demand and improving overall system operation.

The cumulated level of annualenergy savings equalsto 13 bcmof fossil gas saved per year, corresponding to € 6 billion worth of gas in today's market.

[34] Electric Motors and variable speed drives, European Commission
[35] EU-MORE Project
[36] Blueprint for competitive decarbonization of European industry, Danfoss 2025
[37] Competitive decarbonization, Danfoss, 2024
[38] Study on the energy-saving potential of electric motors with variable-speed drives in the european union, Fraunhofer institute, 2023

ACTIVATING DEMAND-SIDE FLEXIBILITY

13

Europe energy system is too dependent on fossil fuels while it requires a system that is efficient, flexible and adapted for the smart integration of renewables.

Demand-side flexibility (DSF) is the capacity of energy consumers to react to external signals and adjust their energy generation and consumption in a dynamic time-dependent way, individually as well as through aggregation. This can be provided by smart decentralised energy sources, including demand management, energy storage and distributed renewable generation to support a more reliable and efficient energy system.

Maximising the potential of demand-side flexibility in the EU can drastically reduce reliance on fossil fuels. By 2030, DSF can reduce annual electricity generation from natural gas by 106 TWh, which represents approximately 20% of the EU's total natural gas consumption for electricity in 2022. Beyond gas reduction, these measures can save 40 million tons of CO_2 emissions annually by 2030 [39].

The economic benefits of DSF are significant for both society and individual households. Annual societal cost savings are estimated at €10.5 billion by 2030, rising to €15.5 billion by 2050. Highlighting the scale of this opportunity, the EU's Action Plan for Affordable Energy estimates that widespread activation of demand-side flexibility could deliver up to €29 billion in societal savings. For consumers, these efficiencies are projected to lower average household energy bills by 7% in 2030.

This level of annual energy savings equals to 9.5 bcm of fossil gas saved per year, corresponding to € 4 billion worth of gas in today's market.

[39] Danfoss Impact No. 4 EE2.0 - Engineering the future energy system

INTEGRATING EXCESS HEAT INTO THE ENERGY SYSTEM

14

Excess heat, also called waste heat, is produced by an engine due to fuel combustion or chemical reaction and is generally released to the environment while it can be reused. Reusing excess heat is much cheaper than buying or producing energy for heating and it will lower overall energy demand and costs for consumers. Adding to this, excess heat can replace significant amounts of electricity or gas otherwise needed to produce heat, thus helping stabilize the future electricity grid and easing the transition to a green energy system.

In total, there is about 2,860 TWh/year of waste heat accessible in the EU. This corresponds almost to the EU's total energy demand for heat and hot water in residential and service sector buildings, which is approximately 3,180 TWh per year in the EU27+UK.

In the EU, industrial sites constitute the largest source of excess heat, with heavy industrial sites amounting to over 267 TWh a year. This is more than the combined heat generation of Germany, Poland and Sweden in 2021. Especially cement, chemicals and steel industries have big potential since they produce waste heat in high temperatures and account for a significant proportion of industrial energy demand.

This level of annual energy savings equals to 24 bcm of fossil gas saved per year, corresponding to € 10 billion worth of gas in today's market.

The excess heat produced by the industry can be reused to supply a factory with heat and warm water, but it also can be exported to neighboring households and industries through a district energy system. Estimates indicates that industrial excess heat alone could cover around 13% of industrial heat demand and abate up to 66 million tonnes of CO_2e. Around 23% of industrial excess heat is available below 100°C, making it immediately suitable for integration into district heating networks. Heat recovery technologies are mature and typically feature investment payback times of 1–3 years [40].

Although their amount of waste heat is not as much as in the industry, data centres, subway stations, supermarkets, wastewater treatment plants and food production facilities also produce significant amounts of excess heat that is not reused today although the technologies to do so exist. The excess heat can be re-used for heating the space and providing hot water in the same unit or together these sectors can cover a considerable amount of energy consumption in urban areas. A study shows that the amount of excess heat from these sources in the Greater London adds up to 9.5 TWh per year, which meets the amount of heat required for around 790,000 households [41]

Beyond this, in the future new excess heat sources will emerge and generate large amounts of excess heat. Projections show that a full implementation of excess heat has the potential to save EUR 67,4 bn a year in 2050 [42] These savings result from large fuel savings leveraged by interconnecting the heating and cooling sector with other parts of the energy system and more flexibility resulting in the better integration of renewable electricity sources in the wider system [43].

[40] The world's largest untapped resource: Excess heat, Danfoss, 2023
[41] Heat Roadmap Europe 4: Quantifying the Impact of Low-Carbon Heating and Cooling Roadmaps, Aalborg University, 2018
[42] Heat Roadmap Europe 4: Quantifying the Impact of Low-Carbon Heating and Cooling Roadmaps, Aalborg University, 2018
[43] Blueprint for competitive decarbonization of European industry, Danfoss, 2025

TECHNOLOGIES TO REALISE THE WATER-ENERGY NEXUS IN PUBLIC UTILITIES

15

Strong interdependencies exist between water and energy (water-energy nexus). A smarter management of water would reduce the consumption of energy required for the abstraction, transportation, heating, cooling and treatment of water across sectors.

A wide spectrum of readily available technologies could deliver significant energy and water savings in manufacturing; municipalities and water management plans, as well as across European households, thus contributing to significantly reducing gas consumption.

In public utilities, examples of water and energy saving technologies and solutions include:

- Intelligent pumps for wastewater management can save up to 70% energy per utility with 80% inventory reduction, e.g. lowering costs for utilities.. In addition, estimates show that variable speed drives on motors driving water pumps have the potential to reduce energy consumption by 20% to 50% [44].

- High-efficiency blowers, pumps and mixers. Adaptive mixers automatically match output to demand and can achieve 47% energy savings by applying variable thrust based on aeration conditions.

- Hydraulic optimisation, diffuser layout, tank geometry, and pipe sizing support system design and can provide savings of up to 20–30%.

- Properly maintained sensors and calibrated controls to prevent over-aeration and unnecessary pumping.

- Digital optimisation including analytics, modelling, and real-time optimisation provide an additional 10–30% energy reduction. With existing digital technologies, wastewater treatment plants of 400,000 p.e. size can reduce 26.3% of their energy use per year that is equivalent to savings of 1.1 million kWh per year and equivalent to in costs savings 330.000/a. For instance, The Marselisborg Wastewater treatment plant in Denmark achieved 100% energy surplus through strategic digitalization and the use of 125 variable speed drives.

- Digital twins have major impact in supporting the optimisation of wastewater networks and treatment processes and hence on energy efficiency. A digital twin is a digital replica of a device or product that can be modelled to use in simulation or prediction of behaviour. Digital twins can represent assets from the physical world and the digital world. On wastewater treatment they enable an optimisation of wastewater treatment processes with machine learning and reduce the energy consumption by up to 30% for 350.000 p.e. plant. This is obtained without the need for building new treatment infrastructure and allows to stay at low capital investment.

- Efficient aeration systems represent 30-70% energy costs in wastewater treatment. Turbo Blowers provide for 30-40% lower energy losses and efficient bubble aeration systems.

- Biogas mixers can be deployed at wastewater treatment plants for biogas production from sewage sludge. They provide for minimum energy consumption due to high efficiency in biogas media and the produced biogas can be reintroduced as renewable energy source to the utility with excess energy exported back into the grid. This allows for energy positive utilities.

TECHNOLOGIES TO REALISE THE WATER-ENERGY NEXUS IN ENERGY GENERATION AND INDUSTRY

Examples of water and energy saving technologies and solutions include:

- Advanced water treatment technologies in conventional thermal power plants can typically increase their energy efficiency performance by 1 to 2%. The on-site monitoring, evaluation and quantification of improvement for the cleanliness of water condensers and cooling towers reduces energy consumption needed to produce electricity. For a 550MW plants, this represents annual energy savings as high as 178.4 million kWh. The technology has a high return on investment with a ratio of 420% and a payback period of less than 3 months.
- Opportunities for efficient operation are inextricably linked to good water management practices. Production of steam requires a very high energy intensity. Reducing blowdown, returning more condensate, boiler tube cleanliness, eliminating steam leaks and steam trap maintenance are all associated with significant energy saving potentials (individually often 2 – 8% energy savings).

TECHNOLOGIES TO REALISE THE WATER-ENERGY SAVINGS IN RESIDENTIAL BUILDINGS

Water use is a significant driver of energy consumptions in buildings, with water heating accounting for around 15% of residential energy use. The less water used in the built environment, the lower the energy demand and the associated CO_2 emissions. In this context, water-saving technologies, such as efficient taps, showers and sanitaryware, provide a cost-effective and impactful means of saving water while also decreasing energy consumption and carbon emissions. A recent study, commissioned by the German Energy Agency (dena) found that modern water-saving technologies can reduce total household energy consumption by up to 6%. Investment incentives for water efficiency in buildings should therefore be strengthened, hot water efficiency recognized as a crucial component of overall energy performance and the Energy Performance of Buildings Directive (EPBD) should be implemented in a way that systematically promotes water-efficient technologies. To accelerate their adoption, the benefits of water-efficient solutions for buildings should be accounted for in Energy Performance Certificates (EPCs) and National Building Renovation Plans (NBRPs), following the European Commission's recommendation.

Another example of water-energy saving technology in residential building is a Wastewater Heat Recovery System (WWHR), a simple and cost effective technology that captures heat from warm water going down the drain (like from a shower) and uses it to preheat the incoming cold water supply. Instead of letting that heat literally go down the drain, it gets reused immediately. The process can raise the temperature of freshwater from 10 to 30 C. If between 2022 and 2030 every second renovated or newly constructed building in Europe were equipped with a WWHR system, 35.7 TWh less energy would have to be generated. In theory, installing the system in all current buildings could triple that amount. [45]

[44] Danfoss Impact Issue No. 7, "The potential of the water-energy nexus
[45] The Potential of Wastewater Heat Recovery Systems in reducing the energy need for water heating in the EU in a cost efficient way. Study, University of Innsbruck, Passive House Institute, March 2022.

REPLACING OLD ENERGY-INTENSIVE APPLIANCES AND IMPROVING ENERGY EFFICIENCY AT HOME

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Thanks to ecodesign and energy labelling requirements, on average, every EU household is estimated to have saved €290 in 2022 [46]. By 2030, this figure is set to increase to €475 per household compared to a scenario without ecodesign and energy labelling measures. Overall, by making products more efficient and longer-lasting, consumers reduced annual spending by nearly €90 billion in 2022. By 2030, this figure could reach €150. In addition, according to the European Consumer Organisation (BEUC), a household equipped with appliances in the highest available class during the height of the 2022 energy crisis would have saved up to €2,450 [47]. In the following year, energy savings in households amounted to 92 Mtoe (million tonnes of oil equivalent), showcasing the enormous potential for energy efficiency improvements [48].

More than 188 million home appliances across Europe are over 10 years old, despite these energy efficiency improvements. EU citizens and especially vulnerable and energy-poor households should be able to replace older, more energy-intensive household appliances with newer, more efficient ones, which may not be readily affordable. Therefore, consumers need to be incentivised to purchase top-grade energy-efficient appliances and for this reason, a European coordination scheme to support low-income households in installing energy-efficient appliances should be established, potentially using additional EU funding beyond national initiatives [49].

In this areas, behavioral changes can deliver important savings. For example using a dishwasher consumes 10 times less water than washing tableware by hand and consumers tend to ignore the potential of using the ECO setting on their washing machines and dishwashers. Although the average duration of the ECO programme is about 39 minutes longer than any other setting, it substantially reduces energy and water consumption. Another simple, easily implementable tip is cooking with a lid on. It can save up to 25% of energy and thus contribute to reducing a household's daily energy consumption [50]

[46] Ecodesign Impact Accounting Overview Report 2023
[47] Energy-savings appliances: the silent money makers in consumers' homes, BEUC, 2023
[48] APPLiA Statistical Report 2024
[49] National examples of incentive schems already include Italy's "Bonus Mobili ed Elettrodomestici", Spain's "Plan Renove", France's "MaPrimeRénov", Belgium's "Mijn VerbouwPremie" (Flanders) and Germany's KfW (Kreditanstalt für Wiederaufbau) bank
[50] MyAPPLiA provides similar useful tips, insights and information to consumers

URBAN GREEN INFRASTRUCTURE FOR ENERGY DEMAND REDUCTION

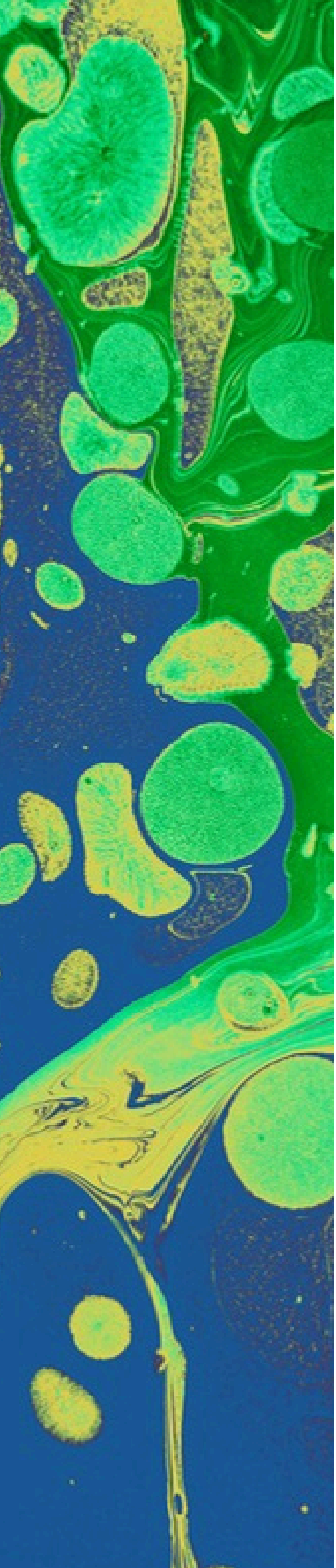
The Energy Efficiency Directive (EED) and Energy Performance of Buildings Directive (EPBD) recognize building-integrated vegetation as an effective measure to reduce energy demand. Green roofs and walls lower heat gains in summer and heat losses in winter, with studies reporting 2–10 kWh/m^2/year energy savings and up to 30% cooling demand reduction in Southern Europe. At EU scale, a conservative deployment (25% of roofs i.e. 20 billion m^2 of EU roofs) could deliver ≈30 TWh/year in energy savings, equivalent to ~3 bcm of natural gas imports avoided annually [51] [52].

In addition to its direct energy-saving potential, green roofs can enhance the performance of integrated photovoltaic systems by reducing both ambient and surface temperatures. Since solar PV efficiency declines above ~25°C due to temperature-related losses, the cooling effect of vegetation helps keep panel operating temperatures closer to optimal conditions. Reported studies indicate that this synergistic effect can increase annual electricity generation by approximately 2–8% on average, with peak output gains of up to ~20% under high irradiance and heat conditions, depending on system design and local climate [53].

Beyond buildings, green roofs contribute to energy system efficiency by reducing stormwater inflows to water treatment plants. With typical treatment energy intensities of 0.3–1.5 kWh/m^3, and conservative water retention (~0.3 m^3/m^2/year), EU-wide uptake could save ≈1–2 TWh/year, equivalent to ~0.1–0.2 bcm of gas imports avoided [54].

As Member States and local authorities implement EED obligations – namely Energy Efficiency Directive's Energy Efficiency Obligation Schemes (Art. 8) and the requirements for public bodies to reduce their total annual final energy consumption by 1.9% (Art. 5) - urban green infrastructure offers a cost-effective, scalable solution to simultaneously address energy security, climate adaptation, and infrastructure resilience.

[51] Implementing green roofs and walls: lessons from European experiences, JRC, 2026
[52] Making European Cities healthier, more resilient and beautiful, WGIN, 2026
[53] Solar Green Roofs Resource Guide, WGIN, EFB, SolarPowerEurope
[54] Meet the Water Energy Nexus, EU-ASE, 2023



CLOSING REMARKS

The aggregation of the energy savings potential of the technologies and solutions included in this document shows that accelerating energy efficiency measures would be a turbocharger for the EU to strengthen its energy security and independence.

In order to support the large-scale implementation of the solutions listed in the document, we would recommend establishing sectoral working groups and develop concrete action plans for their implementation. In parallel we would recommend to:

1. Accelerate the full implementation of all the existing EU energy efficiency policy and regulatory framework.

2. Refocus unspent Recovery and Resilience and cohesion policy funds and steer future Cohesion Policy programming and National and Regional Partnership Planning to incentivize energy efficiency programmes.

3. Allocate sufficient resources (for example 10% of building renovation programmes) to technical assistance, capacity building, reskilling and upskilling.

4. Provide adequate cushioning for increased energy prices starting from the reduction of VAT on energy-efficiency products and installation services.

5. Ensure adequate representation of the energy efficiency industrial ecosystem in the EU Energy Union Task Force.

6. Support energy audits, especially for SMEs, and mandate the implementation of the measures with short payback included in the audits reports.

7. Support raising awareness campaign and engagement programmes for businesses and citizens to invest in energy efficiency measures for process innovation and collective behavioral change.

For more information and to add more technologies and solutions please contact info@euase.eu

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