

**Note C** *At the request of the Committee on Housing and the Urban Agenda in the Congress of Deputies*

## Is there room for improvement in energy supply connectivity in new urban developments?

### At a glance

#### Strategic vision, planning and maintenance

Planning energy development and integrating it into urban design allows for more efficient neighbourhoods that make use of nearby energy resources and even generate energy. The expert community recommends:

- **Strengthening local governance**, on the basis of planning tools, making it possible to adapt energy solutions to territorial characteristics and to promote diverse energy options and synergies between them and at sectoral level (industrial, energy, transport). The exchange of experiences is also key.
- **Integrating the areas and sectors involved and coordinating competencies**. Coordinating electricity, air conditioning and mobility from the planning stage is key to the design of more diversified, flexible and efficient energy systems. This requires planning and roll-out of technologies for vector conversion, cogeneration, and electrical and thermal storage. Institutionally, it is necessary to establish mechanisms for cooperation and cross-cutting strategies that integrate the areas involved (transition – urban planning and housing – industry – energy).
- **Strengthening electricity** transmission and distribution infrastructures to facilitate the connection of renewable sources and promote the electrification of energy uses, which requires strategic planning and long-term investment.
- **Generating incentives and regulatory certainty** for self-consumption (individual and collective) and distributed energy consumption options is particularly important. Binding planning or economic instruments can signal regulatory progress and provide legal certainty to attract investment and secure the long-term commitment of users.
- **Streamlining administrative procedures** to adapt the deadlines and phases of energy development to urban development, thus facilitating decarbonisation and housing access.
- **Reducing energy demand** through measures that encourage changes in users' energy consumption habits is a direct, quick and cost-effective way to improve the resilience of the electricity system without compromising adequate comfort conditions.
- **Designing buildings that consume less and generate energy**, preferably integrating aesthetic and functional solutions. For example, passive design and insulation solutions, or distributed generation can be incorporated. These elements can also be integrated into the urban environment.
- **Planning maintenance** from the design stage can improve efficiency, reduce costs and facilitate technological adaptation. These solutions range from urban development, such as accessible galleries, to the digitisation of networks. The latter includes structural improvements necessary for technological adaptation and new advanced solutions.
- **Promoting inclusive solutions** to integrate demand needs, decarbonisation and participation in the energy transition of the most vulnerable groups. There is also a need to address the specific needs of rural areas and vulnerable suburban communities.

#### Promoting the flexibility of the energy system

With the penetration of renewables, the flexibility of the energy system is key to balancing energy supply and demand without the need for large infrastructure investments. The scientific community recommends a multi-level approach involving multiple technological and organisational levels.

- **Promoting demand response** as an approach to adjust users' consumption patterns to the time slots when renewable generation is most abundant. It also enables them to take on new functions, such as storing or producing energy.
- **Investing in innovation, modernisation and digitisation** of the energy system, through smart grids, cybersecurity and advanced data management, as this is key to integrating distributed resources, new stakeholders and emerging energy models.
- **Facilitating clear, real-time access to consumption data** enables the user to make informed decisions and actively participate in the energy transition.
- **Promoting the creation of flexibility markets** at local level and in distribution networks that integrate new stakeholders for better demand management. This can be facilitated by regulatory sandboxes that facilitate the expansion and scaling up of innovative solutions.

#### The future of heating, ventilation, and air conditioning

Planning air-conditioning taking into account the projected increase in cooling demand.

- **Prioritising alternatives for decarbonising heating, ventilation, and air conditioning** such as electric systems or district heating and cooling networks. The International Energy Agency recommends banning all fossil fuel boilers in new buildings as part of the *Net Zero by 2050* scenario.
- **Choosing the best alternative depends on the context**, the climate, the available resources and the interconnectedness of stakeholders. Heat pumps offer a quick and efficient solution, while district heating and cooling networks can be advantageous in densely populated areas, where they could lower peak electricity demand if the investment barrier is overcome. Both alternatives require overcoming users' resistance to change and their implementation implies mobilising the necessary investment.

#### Integrating the electric vehicle

Planning new urban developments taking into account the increase in electricity demand due to the projected growth of electric vehicles, as well as their function of storing and injecting energy into the grid. It is necessary to guarantee the right to charge in buildings or in the public realm, enhancing smart charging and the safety of installations.

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## Method of preparation

Notes C are brief documents drafted by Oficina C on subjects commissioned directly by the Bureau of the Congress of Deputies, at the request of parliamentary committees. Their purpose is to provide an timely, rigorous and accessible synthesis of the scientific and technological evidence available on a specific question of legislative interest. They provide insights into areas of agreement, disagreement, uncertainties, and ongoing discussions.

Notes C are prepared based on expert consultation through focus groups and interviews, supported by specialised literature. The document is subsequently reviewed by the experts consulted.

For the drafting of this Note C, a total of 115 documents were consulted and 10 experts were interviewed. The expert community is a multidisciplinary group: 80% have a background in the fields of engineering and energy and 20% are from a social sciences background. 80% of the experts work in Spanish institutions, while 20% work in at least one foreign institution.

Oficina C is responsible for the content of the note and acts as editorial supervisor of the document.

## Introduction

Energy connectivity in urban developments has a direct social and environmental impact and is relevant for the energy transition<sup>1</sup>. It is estimated that buildings generate 8% of greenhouse gas emissions in Spain (without taking into account those from electricity production which account for between 12% and 19% of the energy sector's emissions)<sup>2</sup> and consume 32% of final energy<sup>3</sup>. Of this final consumption, it is estimated that 60% is for heating, ventilation and air conditioning (HVAC) and hot water<sup>4</sup>. In the context of the climate objectives of decarbonisation<sup>5-8</sup>, the European Union is committed to the direct electrification of energy end-uses and to reducing dependence on fossil fuels in favour of renewable energy<sup>9</sup>. Urban developments are expected to reach a zero-emission environment by 2050<sup>6</sup>. The urban energy grid, both electrical and thermal, is essential infrastructure to achieve the target of zero-emission new buildings by 2030<sup>10</sup>. It is also essential for the development of neighbourhoods connected to renewable sources or new **district heating and cooling networks**, among other key aspects<sup>1,11</sup>.



**Illustration.** Energy supply in new urban developments. Energy connectivity requires a systemic approach that encompasses technical, social, economic and community aspects.

Improving energy supply in new urban developments requires a systemic view<sup>12</sup> to integrate the multiple aspects<sup>11</sup> that can otherwise act as barriers<sup>13</sup>. Connectivity is not only a technical issue, but also incorporates a socio-economic and community vision that, beyond comfort and functionality, affects the viability of urban developments<sup>12,14</sup>. This integrates aspects such as energy consumption habits and social acceptance<sup>15</sup>, affordability, energy poverty or security<sup>12,16</sup>.

At the grid level, the systemic approach requires effective integration between generation, distribution and consumption i.e. energy demand management, as well as coupling between the electricity, thermal and mobility sectors, especially since the advent of the electric vehicle<sup>12</sup>. This means a real paradigm shift for the electricity grid: from a unidirectional model to one of bidirectional flows of energy and information between consumers and producers, which increases the complexity of the system and incorporates new stakeholders. In this new model, grid and demand-side flexibility, energy storage

<sup>1</sup> **District heating and cooling networks:** Centralised production of heating and cooling using renewable (biomass, geothermal, solar etc.) or waste energy distributed via underground pipes to multiple buildings. In this document we use this term or district heating and cooling networks interchangeably.

options, efficiency and thus smart design become key aspects<sup>12,17</sup>. This systemic approach also has a social and community dimension, requiring adaptation of services, designs and infrastructures<sup>14,17</sup>, as new models of collective consumption emerge (**energy communities**, district networks, etc.) that move away from the individual systems that currently predominate<sup>17-19</sup>. For example, in Spain, more than 60% of heating comes from decentralised fossil fuel-based boilers<sup>20</sup>.

There are other factors specific to Spain that bring challenges and opportunities of their own. Design must take into account that, unlike elsewhere in Europe where there is a greater presence of single-family houses, in Spain there are many large blocks with shared car parks. Furthermore, in the terms of climate level, conditions favour the production of renewables (sun, wind), but also vary in terms of air-conditioning needs depending on the time of year or region<sup>21</sup>. Over the next three decades, the demand for household appliances, lighting and refrigeration is expected to increase globally in buildings, the latter in particular in Spain<sup>22</sup>, while demand for heating and cooking is expected to decrease<sup>1</sup>.

Also, Spain's status as an energy island, due to its low level of interconnection with the rest of Europe, limits its self-sufficiency and energy security<sup>23</sup>. This vulnerability requires a strategic response at EU level, as it also compromises European resilience to energy crises, and hampers both the use of Spain's renewable energy capacity in Europe and the achievement of decarbonisation objectives.

The measures presented in this document support connectivity and serve to strengthen energy security, especially in new urban developments and energy communities<sup>24</sup> (e.g. renewable distributed generation, collective self-consumption and demand reduction<sup>25,26</sup> or efficient systems and buildings<sup>25,27</sup>).

## Improvements in energy supply connectivity

### Strategic vision, planning and maintenance

Planning is an indispensable enabling factor for improving supply connectivity, as it allows the energy system to be integrated into the design of urban development<sup>14,28</sup>. The integration of distributed energy generation is a key aspect for the creation of new, more efficient neighbourhoods or districts, such as so-called **energy communities** or **positive energy districts**, which enhance connectivity and support climate goals<sup>29,30</sup>. Achieving the general principle of using **proximity energy** requires action at multiple levels.

### Strengthening governance

Community-based solutions require tailoring connectivity to local characteristics for which municipal and regional governments are key<sup>17</sup>. Planning based on **energy mapping** enables us, with the support of a coordination unit or public-private partnership, to develop plans to identify synergies and implement policies or incentives (related to generation and consumption) tailored to the area and the available generation, distribution and consumption options<sup>17,31,32</sup>. This type of planning unlocks a wide range of opportunities: the use of surplus and waste heat from industrial facilities (thermal power plants) and the services sector (large shopping centres, data centres), and the distribution of surplus photovoltaic production from local buildings, among others.

The Energy Efficiency Directive states that Member States shall ensure that regional and local authorities draw up heating and cooling plans, at least in municipalities with populations above 45,000<sup>7</sup>. The success of these measures is therefore dependent on local capacities and tools. So, in order to exploit the full potential and

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· **Energy communities:** In this document we refer to heterogeneous groups that may include residents, SMEs or industry and municipal authorities that self-organise to produce, share and manage energy, especially renewable energy, and thus promote efficiency, flexibility and emission reductions.

· **Proximity energy:** A model in which energy is generated, managed and consumed close to where it is needed, through distributed and local resources (rooftop solar, wind, heat pumps, storage, heating/cooling networks, etc.). It aims to reduce losses, improve resilience and benefit the community (costs, quality of supply, climate).

· **Positive energy districts:** Those that generate more energy than they consume.

· **Energy mapping:** Set of thematic maps representing, in a given territory, demand (heat/cold/electricity) and supply/potentials (local renewables, waste heat, existing networks) to identify collective project opportunities (e.g. energy communities, district networks or energy positive neighbourhoods) and prioritise investments in a cost-efficient way. Energy maps are mainly used by municipal authorities, planners and operators to connect sources and needs and to decide where and how to act first.

· **Conversion technologies:** Systems that transform one form of energy or matter into another, optimising industrial processes and promoting energy efficiency. These technologies cover areas such as thermoelectric, mechanical and photovoltaic conversion, as well as biomass and waste applications.

improve informed decision-making<sup>33-35</sup>, it is desirable to train municipal managers and develop cross-cutting platforms that allow local administrations to exchange experiences, lessons learned and best practices. Tools such as Community Transformation Offices<sup>36</sup> can be particularly important in strengthening local capacities in the planning-governance tandem<sup>37</sup>. Similarly, ensuring the availability of planning guidelines<sup>30,35</sup>, technological options, equity of access<sup>38</sup> and social justice<sup>39</sup>, as well as fostering the exchange of policies<sup>40</sup> and knowledge<sup>35</sup>, supports their development. In Spain, the Institute for the Diversification and Saving of Energy offers such guides<sup>41</sup>.

## Integrating the relevant sectors

Energy integration is based on joint planning to connect the electricity, HVAC and mobility sectors, along with the respective markets, which is necessary to ensure communities based on a diversified, distributed and flexible energy system<sup>20</sup>. The current energy system uses fuels (gas, liquids and solids) or electricity to produce heat, while electricity demand is met through centralised plants (including renewables such as wind) and decentralised solar generation<sup>20</sup>. A new coupled system creates synergies between sectors and new technical solutions that enhance key aspects such as flexibility, energy savings, efficiency, supply distribution and security, while strengthening the role of renewables and reducing emissions<sup>20,42,43</sup>. The transition from one to the other requires planning and roll-out of [conversion technologies](#) between energy carriers (electricity-heat and electricity-gas, among others), [cogeneration](#) and electricity and thermal storage<sup>20</sup>.

From an administrative and strategic perspective, the expert community calls for the areas of ecological transition, housing and urban planning, and energy to work on an integrated and coordinated basis with cross-cutting strategies that integrate environmental, energy and urban planning.

## Strengthening electricity infrastructures

Electrification and the roll-out of renewable technologies require the adaptation of transmission and distribution networks to connect new generation to consumption points in an increasingly complex system<sup>44</sup>. Analysis of the grid, connection queues, outage costs, congestion and development times show that electricity grids are becoming a bottleneck for the energy transition<sup>14,44</sup>. In 2024,

the development sector in Spain requested 6.7 GW of grid access, but infrastructure saturation prevented many of these requests from being processed or approved<sup>13,45</sup>. Effective reinforcement of electricity infrastructure requires long-term strategic planning, increased investment, technological innovation, flexibility solutions, resilience to extreme weather events, robust supply chains, talent development and participatory and transparent governance<sup>44</sup>.

Experts point out that investments should prioritise the modernisation and digitisation of distribution networks (see *Investing in innovation, modernisation and digitisation of the sector*), which constitute a significant part of total investment<sup>46-48</sup>. It includes aspects such as digital substations, advanced network sensors, predictive maintenance (see *Planning maintenance and lifecycle*) and comprehensive asset monitoring. This approach makes it possible to ensure adequate remuneration of operators while avoiding passing on excessive costs to consumers<sup>46-48</sup>.

## Ensuring regulatory certainty and incentives for new consumption

Self-consumption and collective consumption can favour the generation of value, the electrification of the economy and create local employment. The design of binding urban plans and agreements or ordinances that ensure commitment to user adherence (e.g., district heating supply agreements for new housing) can make investments feasible and reduce risks associated with the development of energy efficient communities<sup>31,32,49,50</sup>. These should take into account potential long-term changes in demand, such as reduced heating and increased cooling needs<sup>22,32</sup>. They could also be supported by economic incentives. These can range from providing for reduced prices that favour energy access for users to discouraging practices such as cooling systems without heat recovery for industrial or commercial uses, as is being considered in some European countries<sup>51-53</sup>.

## Streamlining administrative procedures

Redesigning district heating or cooling networks or implementing new ones can take between 3 and 10 years. Electricity grids require 5-15 years (planning, permits, construction), compared to 1-5 for renewables and less than 2 for new loads (electric vehicles, housing, industry), so it is necessary to integrate the timeframes from the design stage and align them as much as possible to avoid cost overruns or delays that prevent progress<sup>14,54</sup>.

· **Cogeneration:** Production of electricity and useful heat at the same time at the same installation, taking advantage of the heat that would normally be lost in an installation such as a conventional power plant. It is cost-saving, highly efficient and can provide energy security or, depending on fuels, serve to reduce emissions. Viability depends on a stable and close thermal demand and requires complex investment and operation.

· **Accessible galleries:** Underground passageways only passable by operators, housing several conduits (electricity, telecommunications, water, urban air conditioning, etc.) and accessed only through manholes/chambers located at intervals or at singular points.

The Royal Decree–Law to streamline and simplify administrative procedures in different areas of the electricity sector was repealed shortly after its entry into force<sup>55</sup>. Despite this, electricity companies are urging progress in this direction so that access and connection to the grid for new urban developments does not pose problems for access to housing<sup>13</sup>. One way to streamline management and reduce burdens for operators and users is to review concessions and simplify administrative procedures, including the assessment of licences and their validity, as well as connection rights and allocated capacity. The aim is to avoid double validations and redundant processes<sup>56–58</sup> and to optimise the management of connection queues to prioritise new housing<sup>45,59</sup>.

Work is also underway on drafting a Royal Decree–Law to harmonise and simplify the administrative procedures for district heating and cooling networks, something that these companies are also calling for and which the European Commission identifies as a barrier to their implementation<sup>60,61</sup>.

In view of these limitations, experts propose further exploring the use of the one–stop shop and creating working groups at local and regional level to implement new networks or to expand or integrate existing ones<sup>56,58</sup>.

## Reducing energy demand

Reducing energy demand and improving efficiency in all its dimensions are the most cost–effective and directly applicable measures to strengthen the connectivity and resilience of the energy system and are a priority at European level.<sup>62,63</sup> Actions can be geared towards raising awareness and changing personal habits (e.g. setting tighter temperature thresholds allows for significant energy savings without the need for investment)<sup>64</sup>. Influencing consumer demand response is key to optimising energy use (see section *Encouraging demand response*).

Demand can also be reduced through the architectural design of new urban developments<sup>65</sup>.

## Integrating low–demand and power–generating architecture

In order to build a comfortable and attractive building that requires less energy, it is necessary to consider, among other factors, the climate in which it is located, its intended use, the materials used in its construction or its geometry, which is influenced by its orientation, the position of the windows and the external surface area<sup>66</sup>. It is advisable to consider: thermal insulation measures; passive design solutions that make use of building orientation, natural ventilation and shading; and distributed generation, mainly solar<sup>66</sup>. This can be used to convert the building into an energy generator, e.g. by installing conventional photovoltaic (PV) modules on roofs or similar, or by using architectural PV integration solutions, which combine electricity generation with building functions and features appropriate to the built environment<sup>67</sup>. For example, a solar shading louvre can reduce the need for cooling and at the same time produce energy if it is made of photovoltaic material<sup>67</sup>. To facilitate these developments, experts recommend reducing the barriers of collective self–consumption regulations<sup>68</sup>. Energy–generating elements can also be included in the urban environment, in car parks or solar canopies that facilitate energy generation and storage<sup>69</sup>.

## Maintenance and life cycle planning

The finite lifespan of these systems and technological uncertainty (future needs may render them obsolete) require maintenance to be planned from the design stage. In underground infrastructures, cable and pipe saturation and faults can lead to invasive, time–consuming and costly works. [Accessible galleries](#) simplify maintenance<sup>23</sup>. Cases such as that of Pamplona<sup>70,71</sup> and others show that, despite difficulties in coordination and initial investment, they can avoid future works in the streets, reduce lifecycle costs of installations and facilitate technological adaptation and connectivity in new and historic developments<sup>71,72</sup>. Still, the expert community underlines the need to gather more evidence on the pros and cons of these solutions<sup>23</sup>. The development of digital twins is a promising advanced solution as they reduce operational costs by facilitating better planning and more efficient operation. It can apply to buildings, districts or larger scales, including processes such as predictive maintenance based on real facility data<sup>73</sup>. Before implementation, it is necessary to focus on the use of consumption data analytics, smart thermostats, and, at the building level, new developments to optimise building energy management systems (BEMS). These systems improve load forecasting, dynamically manage energy flows and reduce peak demand.

· [Flexibility of the electricity system](#): Ability to respond nimbly to variations in electricity supply and demand.<sup>14</sup>

· [Prosumer of energy](#): Energy consumer who also produces energy, often through renewable sources such as solar panels, and can feed the surplus into the grid.

## Promoting inclusive solutions

The development of positive energy districts offers, among other advantages, important co-benefits and social opportunities<sup>74,75</sup>. By generating more energy than they consume, this surplus can benefit other neighbourhoods and benefit vulnerable and electricity-dependent consumers, contributing to energy equity and reducing system costs<sup>74,76</sup>. Property managers and social workers with energy expertise can also play an important supporting role in this regard.

Although vulnerable groups and rural communities are not typically the main residents of new developments, connectivity improvements must be designed with them in mind to ensure they are not left behind. Energy poverty must be considered transversally in Spain, in line with the Institute for the Diversification and Saving of Energy<sup>77</sup>. To ensure energy equity, it is necessary to protect the consumer and guarantee an affordable price for energy that includes mechanisms (financial or other) to avoid additional costs for households<sup>76,78</sup>. For solutions to reach everyone, it is essential to have: public support, promotion of social innovation (not just technological innovation) in energy, and corporate engagement through mechanisms such as dedicated social energy departments<sup>79,80</sup>. It is also important to empower all consumers to exercise their energy rights<sup>78</sup>.

Incorporating social and environmental impact measurement systems into these policies is key to assessing their effectiveness and ensuring a necessary condition for reliable data to guide informed decisions<sup>81-83</sup>. It is also important for demand planning to include energy-vulnerable households, not only based on historical data, but also accounting for projections and future energy needs of these people<sup>84</sup>. This integrates the needs and realities of all social groups and ensures that the energy transition delivers real, equitable and sustainable benefits.

## Promoting the flexibility of the energy system

Renewable generation in Spain depends mainly on solar PV and wind<sup>85-87</sup> technologies with variable production depending on the availability of sun and wind. Their increasing penetration poses challenges to the stability and **flexibility** of electricity grids, which must manage frequent imbalances between energy supply and demand<sup>88</sup>. Promoting flexibility balances the load on the network and is a measure that avoids costly investments in new infrastructure. Active monitoring and real-time

control of consumption and generation processes are the basis for unlocking flexibility and optimising grid operation, e.g. in the event of peak demand. This requires a digitised system that is transparent and visible to all stakeholders, including informed consumers.

## Encouraging demand response through informed and proactive consumers

In a context of high penetration of renewables, where dispatchable fossil fuels are not an alternative for absorbing demand peaks, energy and the time at which it is consumed are no longer independent factors, but are interconnected with each other and with social patterns<sup>89</sup>. In order to plan the energy model, it is therefore important to understand how human energy-consuming activities change throughout the day and across the seasons<sup>89</sup>.

Demand response is a strategy that seeks to balance energy supply and demand in electricity grids through incentives that help shift individual electricity consumption to times when renewable energy is more abundant or demand is lower.<sup>14</sup> This reduces the impact of variability in renewable generation and provides grid stability<sup>90</sup>. To optimise consumption, reduce parasitic loads and facilitate a change in energy demand, it is necessary to make the required information available to the consumer (and their homes<sup>91</sup>): encourage the digitalisation of homes, the improvement of sensors and meters, as well as the analysis of data and energy consumption patterns that allow for the integration of habits, home automation and smart building solutions.

In order to incentivise consumers to change their consumption habits, economic mechanisms (low prices and tariffs during peak renewable production hours or times of lower energy demand, receiving credits for reducing consumption at times of high demand, etc.) and information campaigns, used to raise awareness of how consumption habits can contribute to improving the efficiency and decarbonisation of the energy system<sup>90,91</sup>. The consumer also has the potential to take on new roles in distribution networks, including the ability to store energy (e.g. with electric vehicle charging) or to produce energy (as a **prosumer**, e.g. with solar panels on their home)<sup>92</sup>.

This scenario allows the entry of new stakeholders to facilitate a shift in consumer habits, such as utilities and all stakeholders (administrations, energy social workers, social innovation organisations, etc.) implementing

· **Smart grid:** Electricity distribution system that uses digital technology to improve the efficiency, sustainability and security of the grid

demand response and energy advice programmes<sup>91,93</sup>. These programmes use technologies to provide real-time information (e.g. on energy prices) to facilitate decision-making. They may also include the automation of household appliances so that they operate autonomously according to market conditions<sup>91</sup>.

## Investing in innovation, modernisation and digitisation of the sector

The traditional energy system is undergoing modernisation towards a digitally managed system through **smart grids**, in which the benefits of distributed resources, such as rooftop solar or electric heat pumps, and all sources of flexibility, are leveraged<sup>44</sup>. Digitisation and data management are essential for planning, monitoring and optimising the urban energy system<sup>94</sup>. Their implementation can unlock the potential of demand response and energy storage, and facilitates the integration of new active players (such as **aggregators** and prosumers), as well as emerging models of energy organisation (such as self-consumption and energy communities)<sup>44</sup>. The range of technologies includes everything from smart meters and sensors, as basic building blocks for monitoring energy flows, to advanced systems such as digital twins, which can be used to monitor, model and optimise processes<sup>95</sup>. Finally, digitisation requires investment in the training of professionals<sup>44</sup> as well as in cybersecurity, in order to avoid disruptions and cyber-attacks on these critical infrastructures<sup>94</sup>.

The digitisation of networks faces several challenges, including high upfront costs, privacy and data security concerns, and the digital divide, especially among the most vulnerable groups<sup>44</sup>. Furthermore, system integration, particularly in legacy infrastructures, is limited by reduced interoperability and the lack of standardised communication protocols<sup>96</sup>. To overcome these challenges, it is essential to foster the scalability of digital solutions and improve incentives for digitisation in the energy sector and in buildings, thus ensuring efficiency, interoperability and accessibility<sup>96</sup>.

## Facilitating access to and transparency of energy consumption data

Access to information on electricity consumption data is key for consumers to play an active role in managing their demand (identifying patterns, adjusting their habits and reducing their energy bills)<sup>93,97</sup>. Although most smart meters record real-time consumption data, this information is not immediately or easily accessible and is not easily interpreted by the end-user, limiting their ability to make informed decisions and actively participate in the energy market. Therefore, strategies are required for the exchange and coordination of data between the stakeholders of the energy system, including consumers, energy suppliers, distribution and transmission operators and new figures such as aggregators<sup>90</sup>.

## Promoting the creation of electricity flexibility markets

Market platforms serve as an alternative to grid extension investments and enable efficient grid management in a context of high penetration of renewable energies. Electricity **flexibility markets** must be adapted to facilitate the incorporation and free participation of new social actors (energy communities, aggregators, distribution grid operators, etc.) to promote their ability to manage energy properly and benefit from the best prices<sup>98</sup>. The creation of **sandboxes** or regulatory environments for flexible markets at local level and in distribution networks can facilitate the expansion and scaling up of innovative solutions. In Spain, EU Directive 2019/944<sup>99</sup> on the internal electricity market addresses incentives for the use of flexibility in distribution networks, but further efforts are needed to promote local flexibility markets<sup>100</sup>. At European<sup>98,101</sup> and national<sup>100,102</sup> level, initiatives and evaluations that can drive change in the Spanish context have been identified.

## The future of heating, ventilation, and air conditioning

In 2023, in the residential sector in Spain, about 40% of heating and 70% of domestic hot water was obtained from fossil fuels, mostly from gas and then from oil products<sup>103</sup>. The demand for cooling, which has increased and will continue to grow, was covered by electricity,<sup>22,103,104</sup> although not all of the population has access due to situations of energy poverty<sup>105,106</sup>. There is an absence of official indicators on the situation<sup>107</sup>.

## Prioritising alternatives to decarbonise air

· **Aggregator:** A natural person or legal entity combining multiple forms of customer consumption or electricity generated for sale, purchase or auction on any electricity market.

## conditioning

EU Directive 2024/1275 requires all new buildings to be zero-emission from 2030<sup>65</sup>. In addition, public incentives for the installation of fossil fuel boilers will be prohibited from 2025<sup>65</sup>. To meet zero emission targets by 2050, the International Energy Agency recommends banning all fossil fuel boilers in new buildings and reserving gas (natural or biogas) for industrial uses. These require higher temperatures and add value, such as the processing of raw materials.<sup>104,108</sup> This would also reduce external energy dependence, with important economic and security benefits<sup>5</sup>. Germany has already taken steps in this direction<sup>109,110</sup>.

Alternatives to decarbonise and optimise air conditioning in new urban developments, which could be reflected in the building code<sup>22</sup>, would include:

- electrification of heating, with solutions such as heat pumps that allow the use of ambient heat (from the air, water or ground) and operate efficiently.
- efficient electric cooling systems.
- the establishment of district heating and cooling networks<sup>20,104</sup>.

## Choosing the best option

The most appropriate strategy depends on the context, in terms of both the climate and the resources available, and on coordination between different stakeholders<sup>104</sup>. The installation of heat pumps is one of the simplest and quickest alternatives to implement as it can be done on an individual basis<sup>104</sup>. They are also highly efficient, reducing costs, and can provide both heating and cooling<sup>104</sup>. Heating and cooling networks could be an alternative to reduce peak demand in densely populated areas<sup>5</sup>. They are based on economies of scale, where centralisation and the high number of users contribute to their efficiency<sup>111</sup>.

Despite the high initial investment and the need for time and regulations to facilitate their implementation in Spain, if the project is large enough, heating and cooling networks can bring benefits in new neighbourhoods, such as<sup>5,60</sup>:

- Avoiding the purchase of individual air-conditioning units.
- Outsourcing the maintenance of environmental conditioning systems.
- Gaining space in buildings.
- Increasing the safety of the installations by reducing, among other factors, health risks (fewer cooling towers are needed).

Although these networks are rare in Spain compared to other European countries, there are currently more than 500 registered, principally in Catalonia and Castilla y León<sup>112</sup>. Most are biomass-fired heat distribution networks, with temperatures close to 90°C<sup>112</sup>. There is great growth potential for cooling or cooling and heating networks and for networks transporting water at intermediate temperatures, which are even more efficient and can be combined with heat pump technologies (aerothermal, geothermal, hydrothermal)<sup>111,112</sup>.

In order to gain flexibility and resilience, electrification can benefit from digitalisation and thermal storage, both of which allow for cost reductions and better integration of renewables<sup>104</sup>. There may also be opportunities for recovery of heat or cold from industrial activities, such as data centres<sup>104</sup>. Spain may be attractive for these activities due to the more competitive price of electricity.

One of the main barriers, common to both electrification and district networks, is the reluctance of users to abandon traditional HVAC systems, due to initial costs, lack of knowledge of long-term benefits or the obligation to share assets with other residents<sup>5,104</sup>.

· **Flexibility market:** A mechanism within the energy system that allows different stakeholders (such as consumers, producers, aggregators, etc.) to offer services that help balance electricity supply and demand in real or near-real time.

· **Sandbox:** A test environment or isolated, controlled space for experimenting with software or new technologies without affecting the main system.

## Integrating the electric vehicle

Connectivity in new neighbourhoods must be planned taking into the account the projected increase in the number of electric cars<sup>104</sup>. This includes:

- Ensuring that the network is able to respond to increased demand. To do so, charging must be coupled with the availability of renewable energy, for example, during the day, which would shift the load to workplaces<sup>104</sup>. The installation of digital systems is recommended to optimise vehicle charging according to energy prices, system congestion or battery age<sup>104</sup>. They can also be useful for coordinating charging in shared carparks without having to increase power.
- Guaranteeing the right to charge, with access to charging stations at home, at work or in public spaces<sup>104</sup>. This is complicated in buildings such as apartment blocks or offices where many users would need access to charging facilities at the same time<sup>104</sup>. Furthermore, some estimates indicate that 70% of cars in Spain are parked overnight on the street and would not have access to affordable charging facilities on a daily basis if a network of charging stations is not established<sup>113,114</sup>.
- Establishing safety and fire prevention measures for the electric car from the planning stage, especially in carparks with many vehicles.

To reduce car dependency in new neighbourhoods, experts recommend planning public transport and other active transport alternatives such as cycling infrastructure or pedestrian-friendly planning from the outset<sup>115</sup>.

## Perspectives

Improved connectivity is not exclusive to new developments. Although not addressed in the scope of this question, urban and building renovation represents one of the main challenges for Spain, especially in view of the forthcoming transposition of EU Directive 2024/1275 on the energy performance of buildings.

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