A radical change in the consumption of energy in cities – The case of Spain

Substantial savings can be achieved in a decade

February 2017

Arthur D Little

Content

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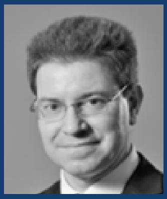

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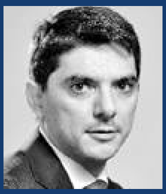

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Executive Summary

Energy efficiency has been a hot topic for several years. It is one of the most important levers when improving the productivity of developed societies, as well as their environmental impact – a unit less of energy consumed for the same productive activity reduces not only costs, but also the pollution associated with it. For many countries that depend strongly on energy imports, it also impacts the commercial trade balance.

Many administrations have been putting forward measures to pursue such efficiency – the EU's 20/20/20 targets[1] and the North American Climate, Clean Energy, and Environment Partnership Action Plan[2] are examples. Most of these objectives are, however, at national or international level. In this viewpoint, we take a different angle and look at the cities. Our rationale is threefold: (i) there is a growing trend towards urbanization across the world, with 66 percent of the population expected to live in cities by 2050, versus 54 percent today[3], (ii) many of the actions required to improve energy efficiency can be influenced by local administrations, and (iii) cities are most affected by air pollution and transport congestion, and hence the impact of these measures is particularly beneficial to them.

Arthur D. Little has been analyzing the situation and the potential for energy efficiency in the 15 largest cities in Spain – from Madrid and Barcelona (which both have more than 1 million inhabitants) down to Vigo and Gijón (at 200,000 inhabitants). Overall, the analysis concludes that circa 40 percent reduction in consumption could be achieved in the coming decade with measures that make economic, technical and social sense, and that would also offer areas of opportunity in all sub-sectors.

- In terms of economic impact, it would reduce the energy bill of the citizens, businesses and public services in these cities by 37 percent[4], or €3.4 billion annually.
- In terms of environment and quality of air, such a reduction would reduce CO2 emissions by 18.8 million tons –30 percent[5] of the target in 2030 for the non-ETS sectors in Spain – and ppm concentrations by 25 percent.
- In terms of investment, improving the energy efficiency of buildings and reducing the energy needs of urban transport would require an investment of circa €11bn over the next 10 years.

We have calculated an index on energy efficiency for each city, based on their ranks along 11 indicators associated with the key drivers for each sector. Overall, the city of Bilbao ranks the best, with Zaragoza a close second. There is no apparent relationship between the size of the city and its energy efficiency index performance – the largest cities, Madrid and Barcelona, are ranked in the

1 European Commission, "2020 climate & energy package"
2 The White House, Office of the Press Secretary
3 United Nations, "World Urbanization Prospects"
4 Arthur D. Little Analysis
5 European Commission

Arthur D Little

middle of the table. Leadership on each of the 11 indicators is spread among the 15 cities. Almost all cities are positioned among the top five in at least one indicator, and even the cities with the overall best performances are ranked among the worst in some indicators. The potential for improvement is real.

Such results highlight two broad conclusions, in our view. First, in the context of ongoing smart-cities discussions, this is a call for city and regional authorities to align their priorities through comprehensive energy efficiency policies, either stand-alone or embedded in broader programs. This is indispensable as these authorities can heavily influence many of the measures to be taken. Secondly, there are many opportunities to be captured. Investments in infrastructure and equipment, as well as services that provide opportunities for the related players, are needed – from energy companies, equipment manufacturers, engineering firms, automobile OEMs and others that are willing to engage in city strategies.

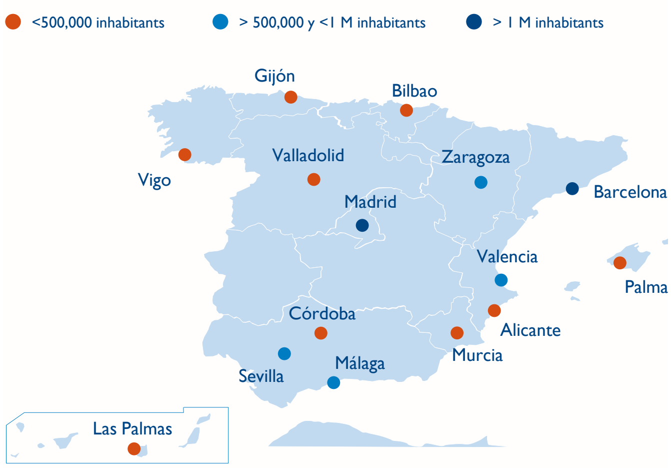
1. Energy consumption in Spain's cities

The need for a local approach to energy consumption

Until today, most of the policies implemented to tackle the world's energy and environmental challenges have been designed at national or even international levels. Examples include the EU Emission Trading Scheme, renewable subsidies in most developed countries and national incentives to buy electric vehicles. While these policies have undoubtedly changed the energy landscape in many countries, they fail to address the specific energy challenges and opportunities cities face in a comprehensive way. Unveiling the full potential for enhanced energy performance at city level requires local policies to accompany global ones: adequate urban planning, efficient public transport systems and effective traffic management have the potential to greatly reduce urban energy consumption and carbon footprint. These are all local policies, not global.

In order to understand such potential and efficiencies at city level we have analyzed, compared and estimated the reduction potential of energy consumption in Spain's 15 largest cities.

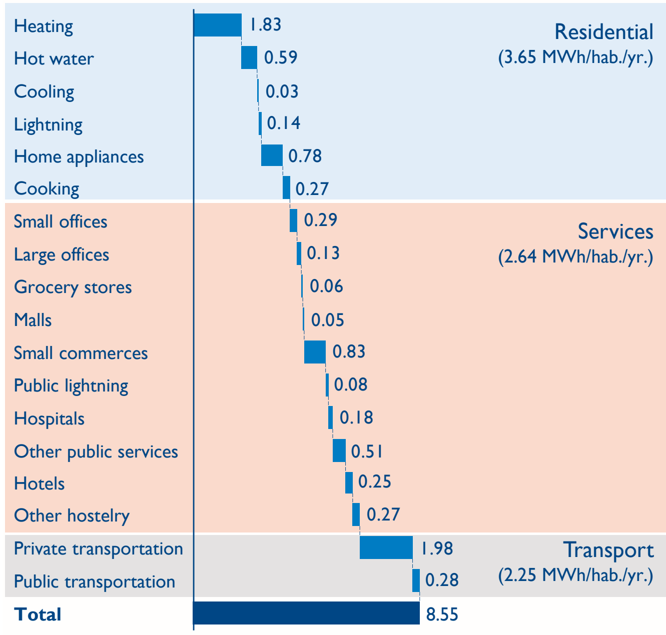
Figure 1: Spain's largest 15 cities



Breakdown of cities' energy consumption

The 15 largest cities in Spain account for 90.2 TWh[6] of energy consumption, or 18 percent[7] of the country's total. It represents 8.55 MWh per inhabitant per year on average. This energy is consumed as follows:

Figure 2: Energy consumption at the average Spanish city by sub-sector (MWh/inhabitant/year)



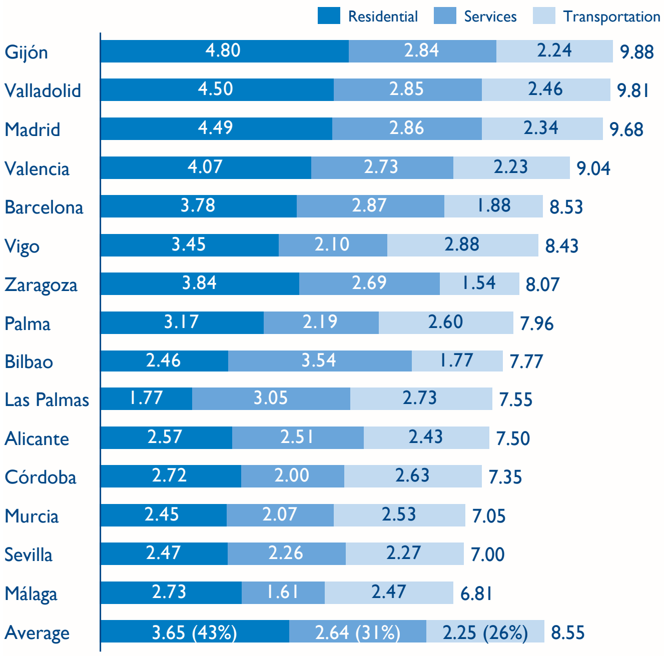
Source: Arthur D. Little

- Residences account for 43 percent of all consumption, or 38.5 TWh (8.9 MWh per household per year), of which 17.6 TWh is electricity and 15.0 TWh is gas. Of this, 50 percent is spent on heating, and the rest on lighting, home appliances, cooking, water heating and air conditioning.
- The service sector represents 31 percent of consumption, or 27.9 TWh (82 kWh per square meter of commercial surface per year). Within the service sector there are many sub-sectors, including retail services and offices, public administration buildings and services, and hospitality.
- The remaining 26 percent is transportation. Of the 23.82 TWh consumed in these activities, 22.5 TWh is diesel and gasoline, 0.5 TWh is natural gas and 0.8 TWh is electricity, with the remaining 0.02 TWh being LPG. Eighty-eight percent of the consumption is in private transportation, while

6 Minetur, *"Estadística de la Indústria de la energía eléctrica," "Estadística de la industria del Gas Natural," "Estadística de la industria del GLP"*; Cores, *"Consumo de crudo y productos petrolíferos por sectores económicos,"* Arthur D. Little analysis
7 Excluding industrial energy consumption

public transportation represents 12 percent of the total. On average, each citizen consumes 2.25 MWh per year for urban transport.

Figure 3: Energy consumption by sector (MWh/hab.)



Source: Arthur D. Little analysis

Key indicators and energy index to compare

In order to compare the situation among the different cities, we have calculated an index of their energy usage. The index takes into account not only actual energy consumption, but also how efficient that consumption is and its degree of commitment to a sustainable urban model.

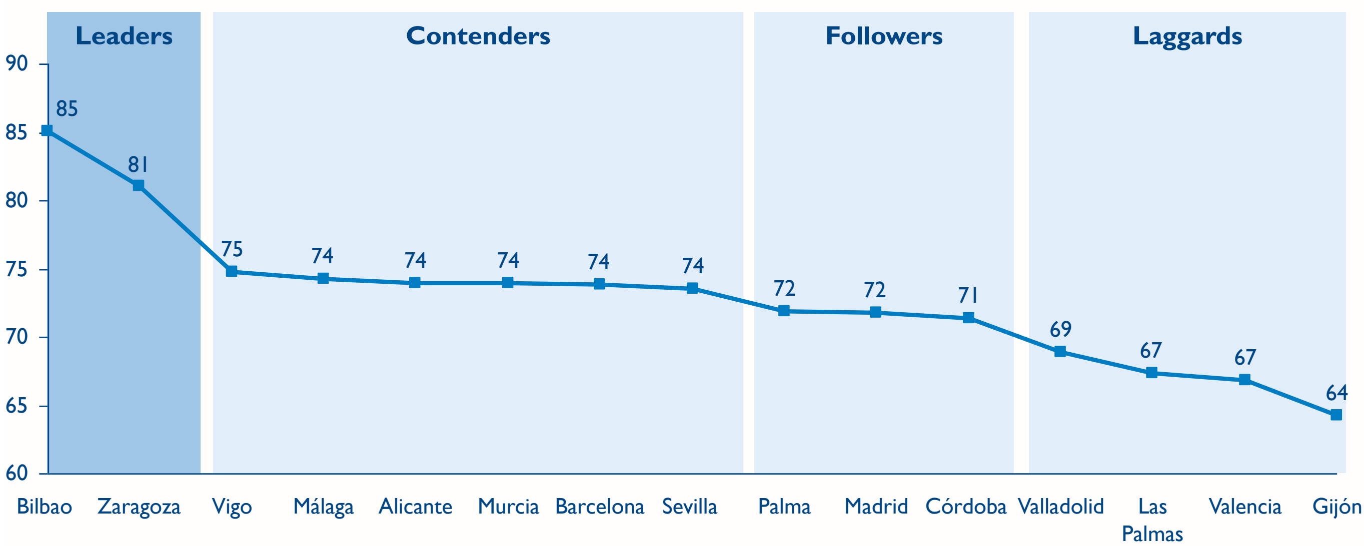
It is built upon 11 indicators that are weighted by relevance. Six of these are related to the transportation sector; they include the modal mix of transportation (public versus private, fuel consuming or not), the penetration of electric vehicles (EVs), the availability of infrastructure for EVs, the efficiency of the public transportation fleet and the share of non-diesel-fueled buses, as well as the overall consumption. All of this is publicly available information or can be estimated at city level.

Three indicators relate to the residential sector. These include the share of homes that do not comply with the existing technical norms of the residential buildings (see more detail in the next section), the percentage of homes holding energy certificates and the actual consumption per home. Information on these is also available in each city or can be estimated.

Two more indicators refer to the service sector performance. This is the sector with least availability of relevant public data. Some cities have started to publish similar certifications of buildings in the residential segment, but there is clearly room for better transparency in this important sector. The indicators used are more aggregate: consumption per 100 square meters of surface in the sector, and consumption per 1,000€ of value added.

The index grants a score to cities ranging from 1 to 100. A theoretical city with a score of 100 would be the leading city in all 11 indicators. Some of the indicators have been normalized to compare cities in equal terms. For instance, considering that in Spain there are sixteen climate areas according to the severity of winter and summer, heating consumption has been adjusted to normalize conditions among cities belonging to different areas. (See separate box for methodology in the annex.)

Figure 4: Efficiency Index Ranking of Spain's 15 largest cities



Results

Figure 4 shows how cities rank in terms of our index of energy efficiency.

The index ranking shows two clear leaders, Bilbao and Zaragoza, a large group of contenders and followers with intermediate rankings, and a final group of laggards. The difference between the first and the last group is substantial and already indicates the potential for doing things differently.

We find that there is no apparent relationship between size of the city and energy efficiency index performance – the two largest cities, Madrid and Barcelona, are ranked in the middle of the table.

Nevertheless, as Figure 5 shows, leadership on each of the 11 indicators is spread among the 15 cities. Almost all cities are in the top five in at least one indicator. On the other hand, even the cities with overall best performances are ranked among the worst in some indicators:

- Zaragoza is the city with the lowest consumption per capita in the transport sector, due to the limited use of the private vehicle as a means of transport – only 34 percent[8] of urban trips – whereas Vigo is the city with the higher consumption per capita, with 69 percent of trips made by private vehicles.
- Bilbao is the clear leader in terms of EV penetration, although even in this city EVs are still testimonial, with a penetration of 0.23 percent[9].
- In terms of charging infrastructure for EVs, Barcelona emerges as the city with the higher investment in electric charging points (10 charging stations per 100,000 inhabitants).
- Regarding the fuel efficiency of public buses, Valladolid has the most energy-efficient fleet, due to its large share of buses fueled by LPG. The presence of electric buses is still testimonial in most cities.
- As shown in Figure 7, climatic conditions, particularly winter severity, have a direct impact on heating consumption. Cities located in the most severe climatic zones consume around 3.5 times more energy in heating in comparison to cities in the mildest regions.
- As shown in Figure 6, once heating consumption is normalized, we find that the residential sector in Bilbao shows the lowest energy consumption, with 5.0 MWh per household per year, while Valencia shows the highest consumption and almost doubles that of Bilbao, with 9.7 MWh per year.

Figure 5: Comparative of city performance by indicator

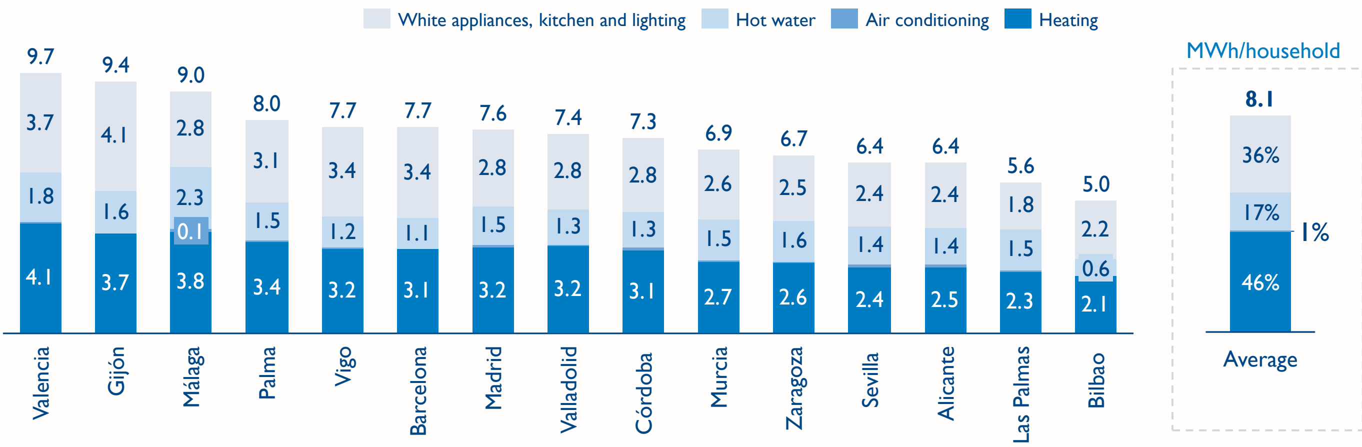
	Energy efficiency index	Transport consumption (MWh/hab.)	Share of car trips (%)	Penetration Electric vehicle (%)	E.V. chargers (#/100.000 hab.)	Bus fleet fuel efficiency (MWh/100km)	Share of buses other than diesel (%)	Consumption per residence (MWh/home)	Share of homes EFG (%)	Share of certificated homes (%)	Consumption services (kWh/100m²)	Intensity services (kWh/1,000€)
Bilbao	85.1	1.8	42	2.3	2.0	499	72	5.0	90	3.3	55	289
Zaragoza	81.0	1.5	35	0.7	3.2	461	100	6.7	82	1.7	68	256
Vigo	74.7	2.9	70	0.2	3.4	582	100	7.7	79	3.6	62	223
Málaga	74.3	2.5	60	0.2	1.2	477	60	9.0	88	4.8	51	214
Alicante	73.9	2.4	60	0.2	2.7	499	70	6.4	90	11.0	62	290
Murcia	73.9	2.5	64	0.1	4.3	582	100	6.9	93	5.1	58	255
Barcelona	73.8	1.9	31	0.3	10.0	493	50	7.7	90	11.6	99	248
Sevilla	73.6	2.3	55	0.8	6.2	522	100	6.4	88	4.8	94	251
Palma	71.9	2.6	61	0.1	6.2	475	10	8.0	89	6.7	57	248
Madrid	71.7	2.3	41	0.5	2.6	522	100	7.6	79	7.8	111	237
Córdoba	71.3	2.6	64	0.5	2.1	455	10	7.3	88	4.8	64	233
Valladolid	68.8	2.5	60	0.1	5.6	387	100	7.4	81	4.3	119	271
Las Palmas	67.3	2.7	65	0.1	2.9	499	70	5.6	90	6.7	96	360
Valencia	66.8	2.2	54	0.2	2.3	483	20	9.7	90	11.0	68	280
Gijón	64.2	2.2	55	0.1	3.6	467	0	9.4	83	1.9	86	284

Ranking position 1-5 | Position 6-10 | Position 11-15

Source: Arthur D. Little analysis

8 Eurostat
9 Dirección General de Tráfico, Arthur D. Little analysis

Figure 6: Breakdown of normalized energy consumption in the residential sector for each city analyzed

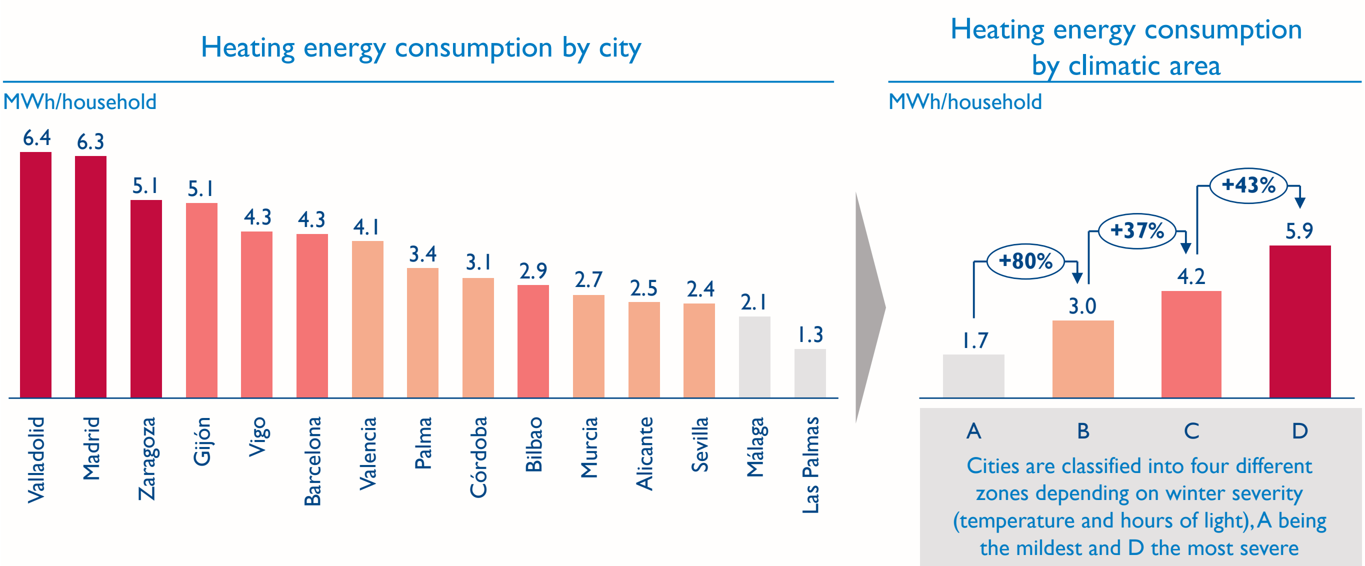


Source: Arthur D. Little analysis

- In terms of share of non-compliant homes (E, F or G certificate level), Vigo, Madrid and Valladolid are the best.
- In the service sector, Malaga scores best on both indicators (energy consumption and energy intensity), while Valladolid and Las Palmas show the worst performances.

Overall, the situation indicates that a great deal of improvement is possible and that all the cities sampled have areas of opportunity.

Figure 7: Relationship between heating energy consumption and climatic conditions



Source: Arthur D. Little analysis

2. The potential for energy efficiency

There are several ways to assess the potential for energy savings, depending on how different factors are taken into account: (i) absolute activity and mix, since potential savings depend on the evolution of absolute magnitudes, such as economic activity and population; (ii) technological impact and cost, since savings can be calculated on the basis of the currently available technologies or considering the expected technological evolution; (iii) time frame, since the longer it is, the higher the potential for efficiency gains and the more uncertain the results; and (iv) economics, as there are many different ways to achieve energy savings, but not all of them are profitable today.

In our analysis we have taken the following approach: (1) all improvements are based on volumes of activity per city and sub-sector, *ceteris paribus*, in 2015; (2) only currently available technologies are considered according to their existing improvement potential; (3) a decade is considered the time frame – long enough to allow for public policy to be defined and implemented, and short enough for forecasts to be meaningful; (4) we have considered profitable investments only, as defined by current energy prices and technological costs.

This implies that our estimates are conservative, opting for a more realistic – although still substantial – ambition so it can be achieved in a manageable time frame.

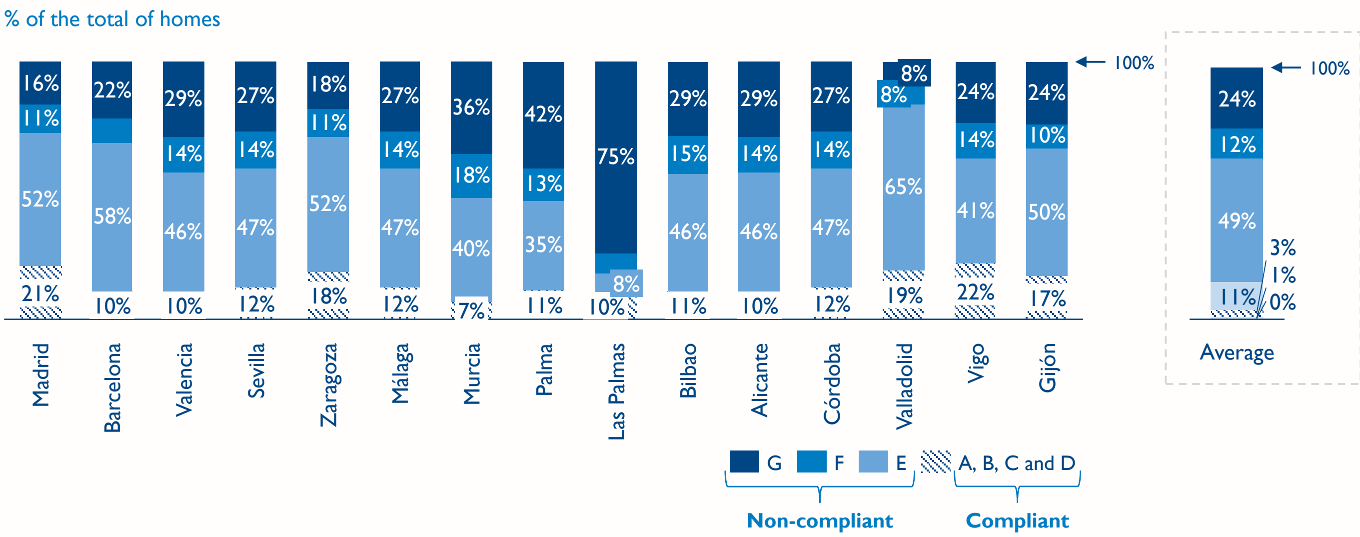
Residential sector

Since 2006 there has been a technical construction norm and an appraisal required for all residential buildings, which indicates, among other things, its energy efficiency. Compliant buildings are ranked from A (best) to D (worst) according to the quality of insulation and their use of adequate heating, cooling and lighting technologies. Beyond D, grades E, F, and G indicate progressively worse degrees of non-compliance with the existing norm. In Spain's 15 largest cities, 87 percent[10] of residential buildings are estimated to be non-compliant. (See Figure 8 for the percentage in each of the analyzed cities.)

Optimization of consumption to levels that are compliant, without resorting to full reforms, are well known. They include condensation gas and low-temperature boilers, better insulating materials and elements, self-supply applications, LED and low-consumption lightning, and solar and condensation water heating. Most of these measures are self-financing and only require substitution of existing, less-efficient equipment.

The potential for improvement is substantial. Only applying readily available, self-financing measures (within three to five years) to homes in the worst conditions (non-compliant with existing building standards – 86 percent of the total) can yield a reduction of 40 percent of the total energy consumption in the

Figure 8: Distribution of homes according to their energy efficiency certificate (% of total)



10 Regional registers for energy certificates

residential sector, from 3.65 MWh to 2.19 MWh per home per year.

Note that there are many more measures that can play roles in this segment, but these have not been included in our estimates: there are measures that imply refurbishment or better design of the buildings, but these typically take longer that our time frame. There are other measures that are harder to quantify but nevertheless significant, such as substitution of appliances for more efficient ones and improvement of efficiency on already-compliant buildings (those in the A to D range).

The service sector

The service sector encompasses a wide variety of sub-segments. It includes large hospitals and shopping centers, as well as public buildings, street lighting, smaller offices, retailers and hospitality. The bulk of consumption is centered on smaller offices, restaurants, bars and other businesses.

The measures needed to optimize energy consumption in these segments are well known and available too. For larger buildings, whether these are hospitals, public services or commercial buildings, these measures encompass heating/cooling and power co-generation, managed efficient lighting and climate, renewable-based self-supply and others. For smaller premises, measures are similar to those of the residential segment: use of more efficient heating and cooling systems, insulation improvements, etc. These measures are self-financing in most cases, and numerous engineering firms, installers and utilities facilitate the set-up of energy service companies (ESCOs) to optimize the consumption.

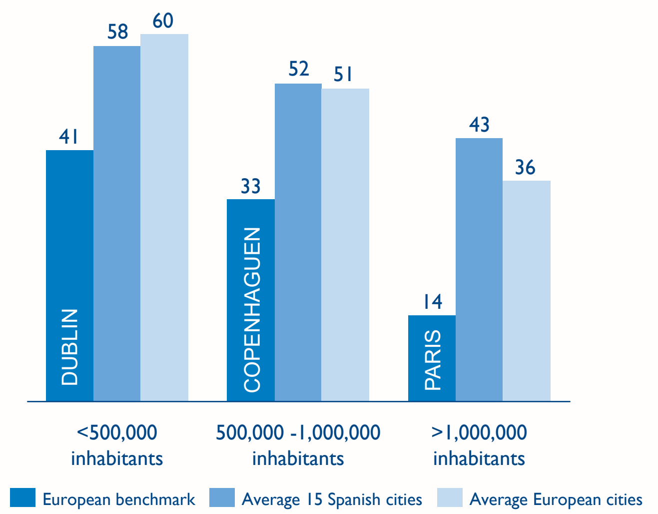
Some of the cities have also started to measure the efficiency of the services segment in a certifying system analogous to the one used in the residential segment. Only Barcelona and Valladolid publish their situations, which show that 45 percent of the services buildings in both cities are non-compliant.

The potential for improvement is important in most sub-sectors. By applying self-financing, readily available solutions exclusively, energy use can be reduced by 30–35 percent in shopping centers and hotels and 45-55 percent in hospitals[11]. A weighted average of these would yield an overall 41 percent reduction of energy use in the service sector, from 82 kWh to 48 kWh per square meter per year.

The transportation sector

The transportation sector in cities has several levers that are relevant to its energy efficiency. The first and foremost is the modal mix. Our sample includes cities with comparatively low rates of private vehicle usage (Barcelona, with 31 percent, is the best performer in the group), and cities where private vehicles account for an overwhelming majority of trips (Vigo, 69.9 percent). Several reasons might explain wide differences, such as city density, size, topography or infrastructure, and local customs and attitudes towards walking or using bicycles, for example. However, a comparison with other similar-sized European cities reveals a substantial potential for improvement, as shown in Figure 9.

Figure 9: Modal mix comparison against European cities and potential for improvement (% of private transportation)



Source: Arthur D. Little analysis

Public transportation represents 12 percent of the total sector consumption. The consumption of energy is mainly driven by the type of engines of public buses and the fuel they consume. Our analyses indicate that although Spanish cities have been experimenting with alternative fuels for some time, there is substantial room for improvement. Electric buses, for instance, have only been modestly introduced. (Madrid, the leading city in this aspect, has only 20 electric buses out of a total of 1,903.)

Private transportation represents most of the energy consumption in this sector at city level, and nearly 100 percent of consumption is either diesel or gasoline; EV penetration is still at an incipient level. Only 2,342 electric vehicles were sold in Spain in 2015, 0.23 percent of the 1,034,232 vehicles sold in 2015. This is a large difference from the 9.6 percent of EV sales versus the total in the Netherlands or the 22 percent in Norway.

Overall, in the transportation sector, 27 percent of energy use can be avoided if the modal mix can be optimized to close half of the gap with European peers, public bus systems are electrified and about 1 million private EVs are on the Spanish roads (a 4 percent penetration over a current fleet of 27.95 million). This would represent a reduction in the energy consumed for urban transportation from 2.25 MWh to 1.65 MWh per inhabitant per year.

11 GTR: *"Estrategia para la rehabilitación – claves para transformar elsector de la edificación en España 2014"*

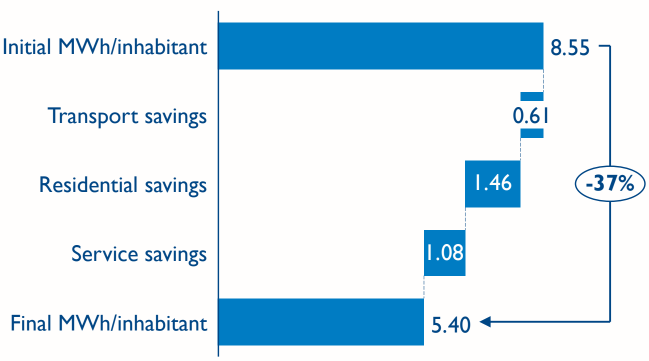
3. The implications of more efficient use of energy in Spain's largest cities

As indicated at the beginning of this viewpoint, the absolute potential for energy efficiency can go far beyond what we are considering if longer time frames or better and more efficient technologies are considered.

Within our self-imposed boundaries of a decade, existing technologies and self-financing solutions, our analysis concludes that achieving energy savings of around 40 percent on a per-capita basis is realistic in Spain's 15 largest cities.

This reduction amounts to 33.2 TWh, or the equivalent of the annual aggregated consumption of the cities of Córdoba, Vigo, Alicante, Las Palmas, Gijón, Bilbao, Valladolid, Palma, Murcia and Málaga.

Figure 10: Potential energy savings by sector



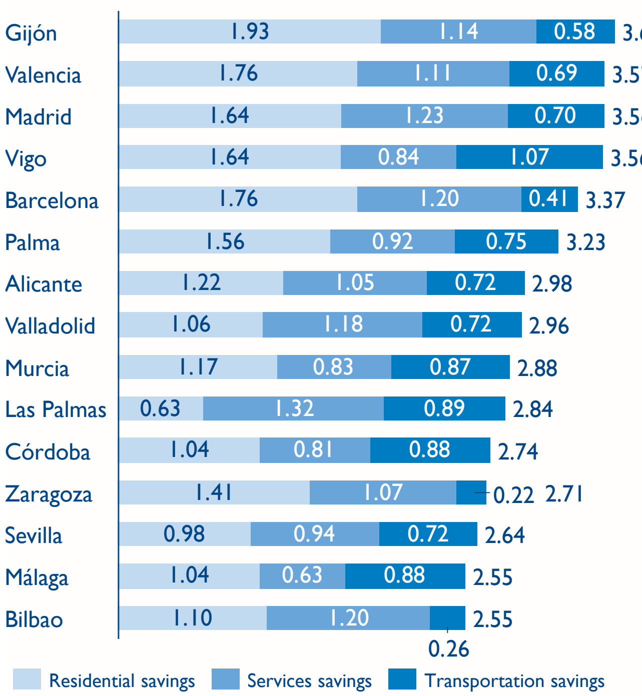
Source: Arthur D. Little

As Figure 10 shows, the main contributor to these savings would be the residential sector, due to the obsolete state of the Spanish stock of residential buildings. Within this sector, around 80 percent of the savings would be on heating, achieved by replacing inefficient heating systems with more advanced systems – such as low-temperature boilers – or by improving the insulation of households. Within the service sector, around 60 percent of these savings would also be obtained by improving the efficiency of heating and air conditioning systems and improving the insulation of buildings. The remaining 40 percent of savings within the service sector would mostly be obtained from lighting improvements – particularly relevant in offices and commercial centers – and efficiency gains in hot-water systems, which would be especially relevant for hotels and hospitals. In the transport sector, the modal shift towards a lower use of the private vehicle would represent 63 percent of the savings, whereas the penetration of the electric vehicle would account for 27 percent of the reduction in energy consumption. The electrification of public buses would represent 10 percent of the savings potential within the sector.

Going down to the city level, as Figure 11 shows, the amount of potential savings, as well as how these are distributed across sectors, vary by city. We find that Gijón, the least efficient city according to our index, is also the city with the highest potential for energy savings, as it has a large share of buildings that are not compliant with existing energy standards and the modal mix is dominated by the private vehicle.

Nevertheless, in any city there are large efficiencies to be captured, which would have profound economic, environmental and social implications.

Figure 11: Energy savings by sector and city (MWh/hab.)



Source: Arthur D. Little

Economically, the implied measures would reduce the energy bill for consumers by €3.4bn every year. As Figure 12 shows, the investment required to capture these efficiencies would be of the order of €11bn, without taking into account the acquisition of private electric vehicles.

Environmentally speaking, it would reduce CO2 emissions by 18.8 million tons, which, excluding the heavy industry, represents 30 percent of the reduction target for Spain in 2030.

Socially, these energy savings, on top of the cost reduction, would reduce atmospheric particulate-matter concentration levels in Spanish cities, especially those related to the transport sector. According to the World Health Organization, air pollution is responsible for the deaths of 6,800 citizens every year in Spain. We estimate that a more efficient transport sector would reduce ppm concentration levels in Spanish cities by 25 percent.

Capturing those efficiencies requires two sets of actions from different types of actors: administrations, both local and regional, and the private sector.

Figure 12: Investment needs by sector

		Description / estimate	Approximate investment
Transport	Modal shift	Calculated considering the cost of the buses needed incrementally to accommodate the shifting demand from private transport to public transport	1,100 M€
Transport	Electric buses	Calculated taking into account the cost of electrifying the fleet of public buses	3,200 M€
Transport	Electric vehicle	Calculated considering the public charging infrastructure needed, assuming a ratio of electric vehicles per charging point equal to the European average	400 M€
Residential		Mix of different investments required – boilers, lightning, insulation – with 4-year payback	4,000 M€
Services		Mix of investments in small offices, restaurants, bars, small retail and large buildings (public and private)	2,300 M€
Total investment			**11,000 M€**

Source: Arthur D. Little analysis

Barriers to change and how to circumvent them

For most cities and companies there is a great challenge ahead, and it will require a leap forward from all stakeholders. The gains to be made by all of them – from local administrations to private companies and citizens – are vast, and it is worth the effort.

There are several aspects that constitute a barrier to change, and these need to be addressed in order for the leap forward to take place.

In the residential sector, for instance, most of the potential for change lies in the hands of a large number of private homeowners. For many individuals and families, energy savings are often not high priority since energy does not take a big share of their budgets. Also, residential measures often imply reforms and construction, which can have a high cost and a negative impact in daily activities. Therefore, if the change is to happen, bold political action is needed.

Similarly, in the services sector, barriers lie in the low priority many landowners give to energy efficiency. Policies can be applied to accelerate the rate of change. These can range from communication to increased requirements for commercial licenses or changes in local tax policies.

Lastly, in transport, the biggest barriers lie in the lifestyle of a big share of the population which relies heavily on the private vehicle for their daily activities. The reason for this is manifold. For instance, the layout of modern cities, with extended suburban areas, makes it unfeasible for many to abandon the private vehicle. Also, public transport is far from universal in many places or its design is suboptimal, making some trips unreasonably long. From this starting point, cities can encourage the change in many ways: investing directly in greener and more accessible public transport, pursuing educational measures for the promotion of EVs, enacting positive reinforcement measures such as free parking for greener vehicles, or establishing punitive policies such as traffic restrictions.

For local and regional administrations there are many lines of action that will influence the pursuit of the discussed outcomes:

- First of all, local administrations must include ambitions and objectives which are aligned to the aforementioned. Many of the cities sampled have plans and emerging initiatives to tackle some of these aspects, and emerging initiatives are in place to act. Others are pursuing efficiency as part of broader clean-air or smart-city initiatives. Few, however, have structured programs with appropriate prioritization according to the impact to be achieved.
- There is a clear need to have more transparency and better data on the actual performance. Some of these cities have their own indicators and others are available regionally or nationally, but as with anything that needs to be transformed, it should be measured with certain granularity, and in many key segments this is not the case today.
- There is also a need for combined and coordinated policies to overcome market failures. There are many market failures which act as barriers to achieving these efficiencies that need to be addressed.
- Coordination with the private sector is to be envisaged by local and regional administrations. Energy companies, equipment manufacturers and many other service providers already have technologies to make these changes happen, and there is capital available to be invested if the adequate framework can be put in place.

Local administrations can take leadership on their own or facilitate the formation of consortia with the private sector to pursue such a transition to a more efficient, lower carbon footprint and better quality of life for their citizens. Many different ways of getting organized are possible, and examples of such initiatives exist worldwide.

From the private sector, this transition will require investments in equipment and infrastructure – from installation of electric vehicle chargers in public spaces to replacement of obsolete heating systems with more efficient technologies – and many types of services, thus creating opportunities for energy companies, equipment manufacturers, engineering firms, automobile OEMs and other players. However, this requires active engagement with city authorities and specific strategies:

- Adequate levels of communication with city authorities. Many energy companies and equipment manufacturers have their own regulation departments, but these are typically focused on the relevant ministries and in nation-wide legislation. Building the appropriate level of communication with key cities requires a different approach.
- Organize for city strategies. In the end, cities are a different customer segment and, as such, it requires organizing marketing, sales and delivery teams in a way that recognizes it.
- Develop solutions and integrated packages to tackle city needs. These can take different forms – ESCOs, partnerships with other key players – to provide integrated solutions or other options.
- And finally, an overall effort to position the company vis-à-vis cities.

At Arthur D. Little, we have accompanied and helped local administrations and private players making bold decisions to tackle such challenges. While not easy or straightforward, these strategies are feasible and worth the effort.

4. Annex: Index calculation methodology

The energy efficiency index is composed of 11 indicators, as described in Figure 13.

Figure 13: Indicators used for the index

Sector	Indicator	Description	Weight
Transportation	01	Energy consumption in urban transport (MWh/hab./yr.)	13.5%
Transportation	02	Share or urban displacements in private vehicles (%)	2.7%
Transportation	03	Penetration of electric vehicles (%)	2.7%
Transportation	04	Number of electric cars per 100.000 inhabitants	2.7%
Transportation	05	Average consumption of bus fleet (MWh/100km)	2.7%
Transportation	06	Share of buses running on fuels other than diesel	2.7%
Residential	07	Normalized energy consumption (MWh/household/yr.)	21.0%
Residential	08	Share of households non-compliant with building standards	18.9%
Residential	09	Share of households holding an energy certificate	2.1%
Services	10	Energy consumption service sector (kWh/100m2/yr.)	15.5%
Services	11	Energy intensity service sector (kWh/1000€ GDP)	15.5%

Source: Arthur D. Little analysis

The index takes into account not only actual energy consumption, as shown by indicators 1, 7 and 10 but also how efficient that consumption is, as shown, for instance, by indicators 2, 5, 8 and 11. Indicators 3, 4 and 6 represent the degree of compromise with a sustainable urban model.

Every city has been awarded a score for each indicator. This score ranks from 0 to 100, with 100 being the score for the best-performing city in the sample and 0 for the worst. For instance, as shown in figure 14, Bilbao has the highest E.V. penetration and the lowest normalized household consumption, with a 100 score in both indicators. On the other hand, its number of certified households is one of the lowest at 3.3%, so its score on that indicator is very low.

In order to calculate a unique energy index for every city, different weights have been attributed to each indicator, according to the following criteria:

- The sum of the weights of all indicators belonging to one sector (transport, residential, services) matches the weight that the particular sector has over total consumption. That is, the sum of the six indicators of transport amount to 27 percent of the total index weight. The same happens in residential and services, with 42 percent and 31 percent, respectively.
- Within transport and residential, most of the weight has been given to actual consumption, as it is the most objective measure for comparison. That is, indicators 1 and 7.
- In services, the actual consumption and the energy intensity are equally weighted (15.5 percent each).

The contribution of each indicator to the index of a particular city comes from multiplying the weight of each indicator (common to all cities) and its respective score (specific for each city). The sum of the contributions from each indicator results in the final efficiency index for each city.

Figure 14. Example of index calculation for some cities

Sector	Indicator	Bilbao Value	Bilbao Score	Bilbao Index	Zaragoza Value	Zaragoza Score	Zaragoza Index
Transportation	01 Transport consumption	1.8	87	11.8	1.5	100	13.5
Transportation	02 Modal mix	32.0	73	2.0	34.7	88	2.4
Transportation	03 E. V. Penetration	0.23	100	2.7	0.07	29	0.8
Transportation	04 E. V. chargers	2.0	20	0.5	3.2	32	0.9
Transportation	05 Bus fleet efficiency	499.3	77	2.1	461.2	84	2.3
Transportation	06 Share of non-diesel buses	72	72	1.9	100	100	2.7
Residential	07 Household consumption	5.0	100	21.0	6.7	74	15.6
Residential	08 Non-compliant households	89.5	88	16.6	81.6	96	18.2
Residential	09 Certified households	3.3	29	0.6	1.7	14	0.3
Services	10 Services consumption	55	93	14.4	68	74	11.5
Services	11 Energy intensity	289.2	74	11.5	256.4	83	12.9
		Efficiency Index		85.1	Efficiency Index		81.0

Sector	Indicator	Barcelona Value	Barcelona Score	Barcelona Index	Madrid Value	Madrid Score	Madrid Index
Transportation	01 Transport consumption	1.9	82	11.0	2.3	66	8.9
Transportation	02 Modal mix	30.6	100	2.7	41.0	75	2.0
Transportation	03 E. V. Penetration	0.03	12	0.3	0.05	12	0.5
Transportation	04 E. V. chargers	10.0	100	2.7	2.6	26	0.7
Transportation	05 Bus fleet efficiency	492.7	78	2.1	521.7	74	2.0
Transportation	06 Share of non-diesel buses	50	49	1.3	100	100	2.7
Residential	07 Household consumption	7.7	64	13.5	7.6	65	13.7
Residential	08 Non-compliant households	89.7	88	16.5	79.4	99	18.7
Residential	09 Certified households	11.6	100	2.1	7.8	68	1.4
Services	10 Services consumption	99	52	8.0	111	46	7.1
Services	11 Energy intensity	247.6	86	13.4	237.3	90	14.0
		Efficiency Index		73.8	Efficiency Index		71.7

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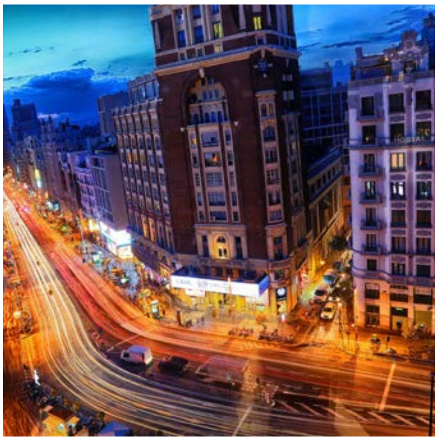

Arthur D. Little

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Our consultants have strong practical industry experience combined with excellent knowledge of key trends and dynamics. Arthur D. Little is present in the most important business centers around the world. We are proud to serve most of the Fortune 1000 companies, in addition to other leading firms and public sector organizations.

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