



Policies for Promoting Energy Efficiency in Buildings

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Energy Industry Report



The Abdullah Bin Hamad Al-Attiyah International Foundation for
Energy & Sustainable Development





INTRODUCTION

POLICIES FOR PROMOTING ENERGY EFFICIENCY IN BUILDINGS

Energy efficiency in buildings is being promoted by governments as well as environmental and construction organisations, as a key way to reduce greenhouse gas emissions, save on energy bills, and improve quality of life. What impact will this have on future energy use, and types of consumption, in the residential and commercial buildings sectors? What policies and targets are governments adopting, and how successful are they? What does this imply for climate policy, and for suppliers of energy to buildings?



Energy Industry Report

This research paper is part of a 12-month series published by the Al-Attiyah Foundation every year. Each in-depth research paper focuses on a prevalent energy topic that is of interest to the Foundation's members and partners. The 12 technical papers are distributed in hard copy to members, partners and universities, as well as made available online to all Foundation members.



EXECUTIVE SUMMARY

- Buildings are one of the three largest energy-using sectors, consuming about 30% of final energy consumption, and 24% of greenhouse gas emissions.
- Energy use has high inertia because of a buildings' long life. Therefore, policy measures to improve efficiency are urgent.
- 73% of residential energy use and 33% of commercial energy use (in the US) relates to thermal management – space heating/cooling and water heating – making this the key area for improvements.
- Improvements in building energy typically have negative cost – they pay for the up-front cost in energy savings over time.
- However, many efficiency opportunities are not captured because of lack of priority and awareness; lack of capital; insufficient scale; and mismatches between building tenant and owner. Building codes, government audits and 'green loans', and Energy Service Companies (ESCOs) can help overcome these barriers.
- It is likely that the more aggressive targets for building efficiency will not be met globally. This will push up overall energy use, and put more stress on deeper decarbonisation of energy supply, and on reducing emissions from areas such as industry.
- This inertia means that leading gas producers probably should not be concerned about a collapse of demand. However, efficiency gains will put building gas consumption under increasing pressure in some areas, notably Europe and the former Soviet Union.
- Direct oil use in buildings is small, but it can be expected to be virtually phased out by 2050. However, liquefied petroleum gas (LPG) is expected to gain in the medium term in south Asia and Africa.
- In a climate-compatible scenario, buildings' direct gas use will expand somewhat up to about 2035, before shrinking slowly after that, due to improved efficiency and electrification.
- Major gas producers should develop strategies for building decarbonisation, which may vary by location. This could include, for instance, electrification (gas used in power generation with carbon capture and storage), converting gas to hydrogen, or introducing increasing shares of biomethane or synthetic natural gas.
- Hedging against gas demand reductions could include investment in highly-efficient heating technologies, and in gas-driven district cooling and heating systems.

IMPLICATIONS FOR LEADING OIL AND GAS PRODUCERS

- Buildings are targeted as a major opportunity for reducing energy use and greenhouse gas emissions. Reductions are, in principle, technically achievable at negative or moderate costs. However, the complexity and variety of buildings and their occupants make emissions savings from a building much more difficult than power generation or transport.



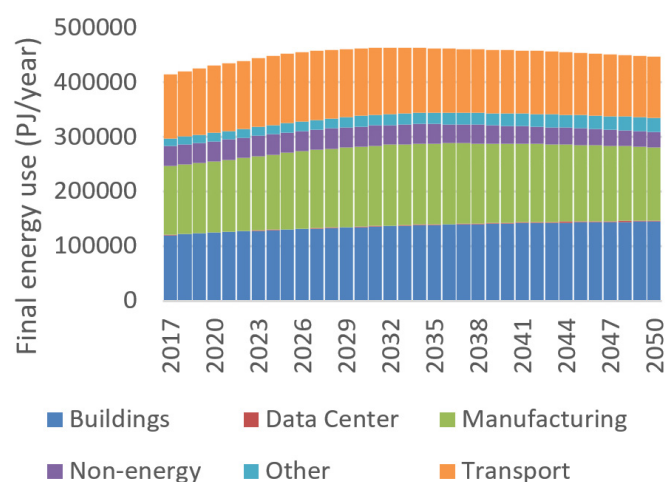
BUILDINGS ARE A LEADING CONSUMER OF ENERGY AND SOURCE OF GREENHOUSE GAS EMISSIONS

Buildings are one of the three main energy-consuming sectors, along with manufacturing and transport, each consuming about 28-30% of final energy. Continuing population growth, albeit at slower than historic rates, along with strong economic expansion in the developing world, could lead building energy use to double or even triple by 2050. But such an outcome would be incompatible with meeting goals to reduce greenhouse gas emissions sufficiently to keep warming below the 1.5-2°C limits, of the Paris Agreement.

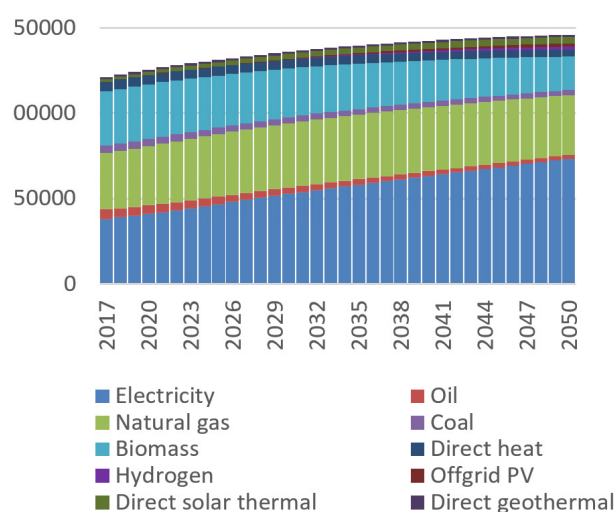
Building energy use is driven by the number of new buildings (a function of growth in population and economy), building size (the area of floor space, determined by factors including land availability, commercial trends such as teleworking and home shopping, demographic and social preferences such as family sizes, and income levels), service demands (the amount of heating, lighting, electronics and so on), and efficiency – which is partly a function of the buildings' construction, and partly of the way it is used.

Building efficiency changes only slowly with new construction and refurbishment. Some 80% of current building energy use will be 'locked in' by 2050, because of this slow turnover.

In contrast, the method of use can change quickly with energy price changes, regulations and increased awareness of energy consumption.



In the lead up to 2050, strong action on climate change requires buildings' total energy use to grow slowly (0.6% annually), while manufacturing hardly grows and transport shrinks. This would leave buildings as the top consuming sector by 2050, but would limit the rise in consumption and emissions.



Currently, energy use in buildings is usually split equally between electricity, natural gas and biomass, with oil, coal and direct heating making smaller contributions. By 2050, in a climate-compatible scenario, it is anticipated that electrification will have expanded enormously, gas remains at about the same level, and biomass fallen. Off-grid solar photovoltaics (PV), direct solar thermal and hydrogen will have expanded from very low levels. They remain quite minor but, in the 2040s, essentially all growth in buildings' energy use would be met by self-generation of various types.

Buildings' greenhouse gas emissions – including the upstream emissions from their electricity use – are about 24% of the energy-related total (excluding land-use changes and agriculture).

Improving energy efficiency has two main effects on emissions:

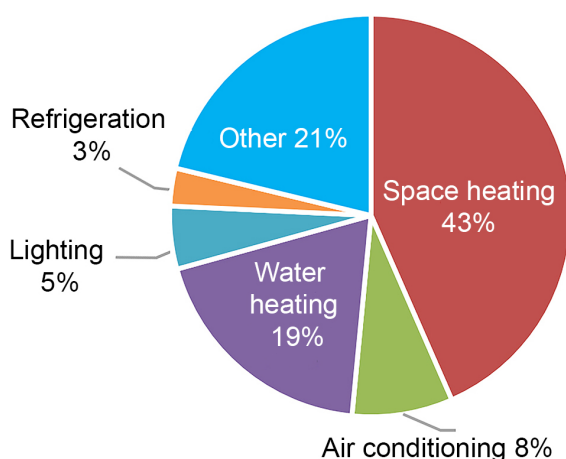
- Reduces electricity and direct heat use, hence cutting upstream emissions from coal, gas and oil combustion.
- Reduces in-situ heating demand, hence cutting emissions primarily from natural gas, and to an extent oil and coal.

Improving buildings' energy efficiency is one of the most cost-effective options for greenhouse gas mitigation, with many measures having negative life-cycle costs as well as bringing co-benefits.

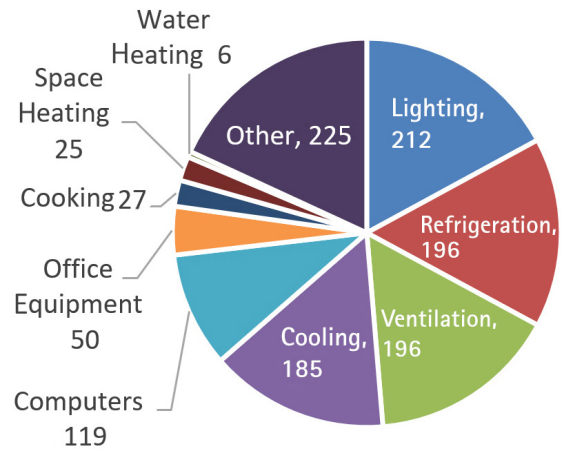
COMMERCIAL AND RESIDENTIAL BUILDINGS ARE DIFFERENT – BUT THERMAL MANAGEMENT IS KEY

Energy uses vary considerably between residential and commercial buildings. The figures below are for the USA, and would be significantly different for other countries. It can be seen that 73% of residential energy use, though only 33% of commercial energy use, relates to thermal management – heating and cooling. 21% of residential energy and 32% of commercial energy is required for appliances, mostly electrical – computers, televisions, machinery and so on.

Building Energy Use, USA (%)



Building Energy Use, USA (Million KWH/Year)



Energy used for lighting is relatively small for residences, but significant for commercial. Improving efficiency of appliances is important given their growing share of consumption, but does not relate to the efficiency of building structures themselves. Appliances are becoming more efficient, but the introduction of new devices (WiFi, smartphones, gaming consoles, home cinemas, household robot cleaners, 'smart' connected homes), and no doubt other inventions to be introduced in future, is likely to lead to a rising share of consumption.

Cooling is generally produced by electrically-driven air-conditioning. In some countries, such as those in the middle east, district cooling via chilled water from central plants is being increasingly used as a more efficient and cost-effective solution for high-density neighbourhoods.

Space and water heating in buildings today is delivered by a mix of electric heating, and the in-situ combustion of natural gas, biomass and to some extent oil and coal. Some countries, particularly in the former Soviet Union and China, make use of district heat supplied through pipes from central plants. Electricity is generally expensive, making direct electric heating less attractive. Oil is also expensive, and coal and oil are polluting, as is biomass (wood) if not burnt in modern systems.

This, along with relatively cheap natural gas in many countries, and an expansion of the gas grid, has led to a preference for gas heating. Modern condensing gas boilers have high efficiencies, around 92-95%. However, since gas still emits carbon dioxide when burnt, a variety of alternatives are available for heating. These include:

- Electric heating (assuming the grid is also being decarbonised). This raises issues of expense, low efficiency, and of the very high peak electric loads that could occur during cold spells;
- High efficiency insulation, heat exchangers and other systems, which reduce space heating load. This allows buildings to be adequately heated by natural solar gain, occupants' body heat and appliances' waste heat;
- Solar thermal, geothermal or electrically-driven heat pumps;
- Alternative low-carbon fuels, including biomethane, synthetic natural gas, and hydrogen.

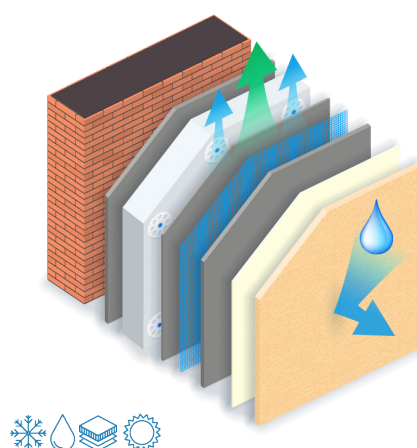
ENERGY-EFFICIENT BUILDINGS HAVE MULTIPLE BENEFITS

Building energy efficiency policies have been adopted for two main reasons: to cut energy use, and to reduce greenhouse gas emissions. 'Upstream' pollution from power plants can be minimised by saving electricity consumption. Cutting energy use not only reduces occupants' bills but also limits the whole economy's exposure to energy price shocks. For instance, the US Department of Energy calculates that current building codes reduce consumption by more than 30% versus those of just a decade ago, saving consumers \$ 60 billion. Future codes are anticipated to save \$126 billion of energy costs and 841 million tonnes of carbon dioxide emissions between 2012 and 2040.

Additional benefits of good insulation include a more comfortable interior temperature, interior dust and pollen reduction, and a reduction in outdoor noise.

However, maintaining interior air quality does depend on effective air circulation.

Efficiency of buildings is a component of larger-scale urban design. Buildings can support other efficiency goals, for instance, by facilitating electric vehicle charging. Urban design also influences the size of buildings (suburban sprawl versus high-density apartments), and their thermal load via shading from other structures, or by reducing the effect.



Demand side management (DSM) has been adopted by numerous electricity utilities. It encompasses overall load reduction, and a reduction and shifting of peak loads. This in turn minimises the utility's costs to meet peak demand, and cuts its emissions. DSM can include overall efficiency measures, as well as behavioural changes and time-of-day load management. This, can be incentivised by time-varying tariffs, encouraged by education campaigns, and implemented through smart meters and control systems.

DSM can also allow buildings to meet a larger share of their demand from on-site renewable energy, by reducing the overall energy requirement, and by timing loads - for instance to meet midday solar photovoltaic generation. This can also reduce the size of batteries required for a building to go 'off-grid'.

IMPROVING BUILDINGS' ENERGY CONSUMPTION IS COMPLICATED

Buildings have a great variety of use (residential houses and apartments; leisure, such as hotels and museums; commercial including shops, malls and offices; government, and specialised functions such as hospitals, sports centres, scientific laboratories and universities). They typically have long useful lives, which may extend to 100 years or more. They are usually custom-designed, and vary greatly. Reconstruction or refurbishment is complicated by building and zoning codes, preservation of historic features, comfort, aesthetics, ongoing occupation, difficulty of urban access, and the needs of neighbours.

Different climates and countries have varied building styles and methods. Developing countries contain many informal buildings, without professional design and construction, and using locally-available materials. Vernacular designs, with local knowledge, can be more appropriate than standard international construction. For instance, they can be naturally cooled, and avoid the need for air-conditioning.

Buildings should be evaluated on a life-cycle basis. Building materials such as concrete, steel, aluminium, brick, glass, plastic and copper are energy-intensive to produce, with high carbon footprints. Conversely, wood, if sustainably grown, helps sequester carbon. Recycled and reused materials, and low-carbon alternatives (such as low-CO₂ cements), can help reduce the carbon and energy footprint, but the question is, who will absorb the increased cost?

Water use is another important component of assessment, particularly in arid countries. Desalination, pumping and treating waste-water are additional consumers of energy, and have other environmental impacts.

There are significant barriers to building energy efficient buildings. Among these are lack of priority, up-front costs, diseconomies of scale, and tenant-owner misalignment.

A common thread to tackling these issues is the use of Energy Service Companies (ESCOs), which fund and execute efficiency improvements, and are paid back over time from the realised savings.

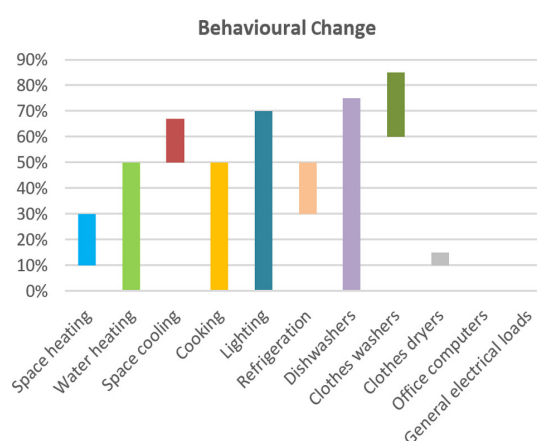
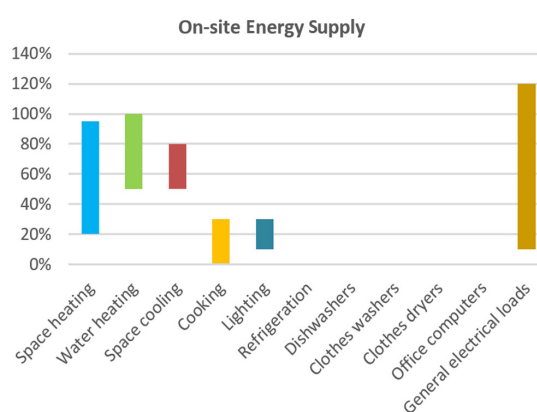
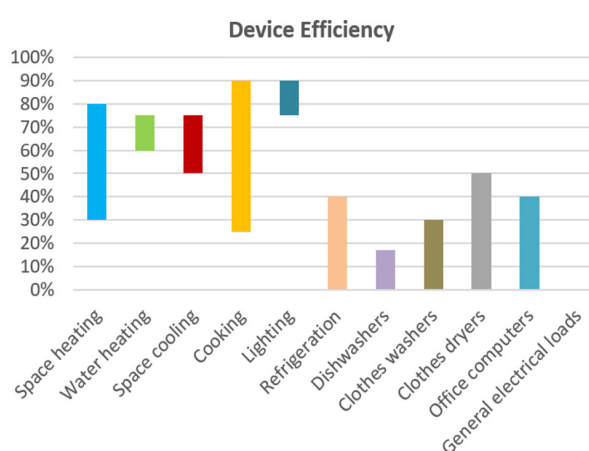
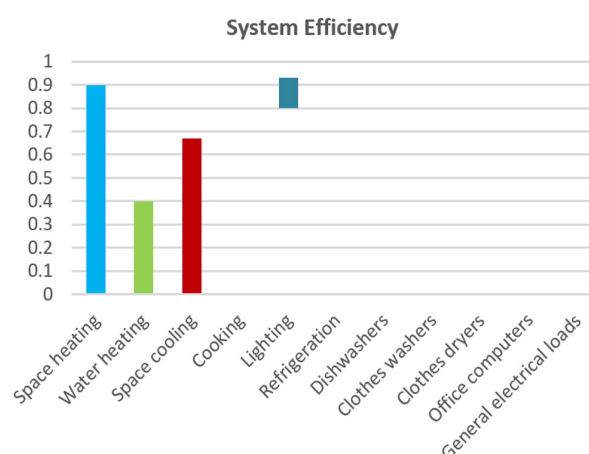
Issue	Description	Solutions
Lack of priority	Where energy costs are a relatively low share of overall expenditure, attention may not be given to reducing them	Regulation; building codes; information provision Training schemes for builders
Up-front costs	Occupant may have a high implicit discount rate for capital, or an outright lack of capital to fund up-front improvements	Energy Service Companies (ESCOs); 'green' loans and subsidies; subsidised efficient products
Diseconomies of scale	High cost in money and time for non-expert occupant to evaluate and carry out efficiency works	ESCOs with larger packages of work; government-subsidised energy audits
Tenant-owner and owner-builder misalignment	Tenant, not owner, benefits from building improvements in lower energy bills, but does not want to fund them given limited tenancy period Builder may underinvest in efficiency because owner lacks information or awareness to pay a premium	ESCOs with transferrable contracts; building codes and leasing regulations Consumer pressure on builders

MAIN APPROACHES TO IMPROVE BUILDING EFFICIENCY

Energy efficiency can be improved through four methods:

1. On-site energy supply to include solar photovoltaic and active solar heating.
2. Device efficiency includes measures such as more efficient boilers, air-conditioners, motors, appliances and lights (LEDs replacing incandescent bulbs or kerosene lamps).
3. System efficiency to reduce thermal losses by methods such as better insulation, shading, heat exchangers, design to use or avoid passive solar heat, and reducing hot water distribution losses. It also makes use of natural light. 'Green roofs' improve insulation, make use of rainwater, provide habitats, and have pleasant aesthetics.
4. Behaviour change such as less extreme thermostat settings, washing on full-load, turning off unused lights, and showering instead of bathing.

These changes are not necessarily all additive, but some can be. This raises the possibility of entirely eliminating outside energy demand for some classes of use. In hot desert climates, it is possible to cover all water-heating requirements with solar thermal. In cold climates, the Passivhaus standard developed in Germany can cut heating energy demand by 77–95%. There is growing interest in near-zero energy buildings (NZEB), or even in net energy-producing buildings (with solar photovoltaics).



A RANGE OF GLOBAL POLICIES AND TARGETS AIM TO REDUCE BUILDINGS' ENERGY USE

Countries may address building energy efficiency as part of over-arching policies on climate change. Within that are numerous specific policies. Probably the most important is building codes for new construction and retrofits.

The focus of policy varies by country. For instance, Germany has an old building stock and little population growth, and therefore concentrates on retrofits. China continues to build rapidly and demolish old buildings, and so new construction is the target, with heating the most important issue. The US comes in-between, with both new and retrofitted buildings, a larger area per person, and a higher share of appliance use. Its efficiency targets and standards are typically set at the state or municipal, rather than the national level. Japan has focussed more on commercial buildings, behavioural change, and appliance standards, with its Top Runner programme.

The Energy Performance of Buildings Directive (EPBD) in the EU, introduced in 2010 and revised in 2018, includes a range of policies. Modern buildings under the EPBD consume only half the energy of

1980s vintage; the building stock is aimed to be decarbonised by 2050, while all new construction should be NZEB.

Building codes are typically tailored for the local environment. The US Green Building Council's Leadership in Energy and Environmental Design (LEED) is probably the most widely adopted worldwide, with a number of tiers on a points system, up to Platinum. LEED incorporates energy efficiency as well as water efficiency, materials use, indoor environmental quality, sustainable siting and other criteria.

The Passivhaus standard developed in Germany has now also been widely used in cool climates in the UK, Scandinavia and US. There is a lack of highly-efficient standards tailored to hot climates. Singapore's Green Mark Scheme is designed for tropical locations; 31% of buildings in Singapore are now covered by the Green Mark, with a target of 80% by 2030.



Improving building energy efficiency is key to meeting greenhouse gas emission reduction goals, and is a major part of most climate change plans. Major technical scope for reductions at low or negative costs exists. If realised, building energy use would only grow slightly to 2050, and related CO₂ emissions would drop from 8 billion tonnes in 2017 to 4.6 billion tonnes in 2050. Building use of electricity would almost double, natural gas would rise slightly, and coal and oil mostly be phased out.

However, problems of information, incentives, priorities and financing make it hard to achieve this potential. NZEB and Passivhaus standards are gaining applicability, but their impact on the housing stock is small, with less than 1% of it turning over annually in Europe. The effect of moderate tightening of standards in developing Asia would be more significant, given continuing population growth, urbanisation and highly active construction.

Major gas suppliers need to consider building energy demand patterns when planning new investments. Each market has to be assessed separately, since the efficiency drivers and solutions are very different. Efficiency gains will have a major role in determining electricity demand (and hence partly the demand for gas), and the direct demand for gas in buildings for heating and cooking. Building codes and government policies also strongly influence what low-carbon options will be taken for home heating – whether electricity, synthetic gas and biomethane, or hydrogen.

Overall, it is likely that building efficiency targets will be met and exceeded in some jurisdictions, such as Japan, and in large commercial sectors, but will fall well short overall. That will lead to higher energy demand than in projections such as DNV's. The burden of meeting countries' Paris Agreement commitments will then have to fall more heavily on decarbonising energy supply, and on other areas such as industry.



APPENDIX

- 1 - Intergovernmental Panel on Climate Change (2018), https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter9.pdf
- 2 - https://www1.eere.energy.gov/buildings/publications/pdfs/corporate/bt_stateindustry.pdf
- 3 - From data in DNV Energy Transition Outlook 2019, <https://eto.dnvgl.com/2019>
- 4 - From data in DNV Energy Transition Outlook 2019, <https://eto.dnvgl.com/2019>
- 5 - Energy Information Administration, <https://www.eia.gov/energyexplained/use-of-energy/homes.php>
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- 7 - <https://www.energy.gov.au/sites/default/files/hvac-factsheet-boiler-efficiency.pdf>
- 8 - From data in Intergovernmental Panel on Climate Change (2018), https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter9.pdf, p17
- 9 - <http://www.ecobuildingpulse.com/award-winners/volkshouse-santa-fe-nm.aspx>, http://erg.ucd.ie/pep/pdf/Energy_Saving_Potential_2.pdf, http://erg.ucd.ie/pep/pdf/Irena_Kondratenko.pdf
- 10 - <https://climatepolicyinitiative.org/publication/buildings-energy-efficiency-in-china-germany-and-the-united-states/>
- 11 - https://aperc.ieej.or.jp/file/2017/11/17/08_JPN.pdf
- 12 - <https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/energy-performance-buildings-directive>
- 13 - https://sustainabledevelopment.un.org/content/documents/1545Climate_Action_Plan_Publication_Part_1.pdf



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