BUILDINGS AND HEAT PUMPS IN THE INTERNATIONAL ENERGY AGENCY'S TECHNOLOGY ANALYSIS

Michael Taylor[1], Energy Analyst, Energy Technology Policy Division, International Energy Agency, Paris, France

Abstract; The International Energy Agency's (IEAs) *Energy Efficient Buildings: Heating and Cooling Equipment* roadmap lays out the "big picture" vision for stakeholders in the buildings sector of the goals for heating and cooling equipment if the world is to achieve a 50% reduction in energy related CO_2 emissions by 2050 outlined in the IEAs *Energy Technology Perspectives 2010* BLUE Map scenario. It provides concrete advice on how to achieve the savings in the BLUE Map scenario, highlights the key technology options, the barriers they face and the policy options to address these barriers. The end-uses of space heating and cooling dominate energy consumption in OECD buildings, while cooling will be a major source of energy demand growth in developing countries. Heat pumps are a particularly important abatement option and are a key part of the solution for buildings in the BLUE Map scenario.

Key words: heat pumps, energy scenarios, technology roadmaps

1 ENERGY AND CO2 EMISSIONS FROM BUILDINGS IN THE BASELINE SCENARIO

In the Baseline scenario, global final energy demand in buildings increases by 60% between 2007 and 2050. Carbon dioxide (CO_2) emissions from the sector, including those associated with electricity use, nearly double from 8.1 gigatonnes (Gt) of CO_2 to 15.2 Gt CO_2. This is driven by a 67% increase in the number of households, a near tripling of the service building area, higher ownership rates for existing energy-consuming devices, and increasing demand for new types of energy services.

Total energy demand in the buildings sector increases from 2 759 Mtoe in 2007 to 4 407 Mtoe in 2050 in the Baseline scenario (Figure 1).[2] The residential sector accounts for 59% of this growth and the service sector for around 41%. The service sector grows the most rapidly at 1.5% a year between 2007 and 2050, with the residential sector growing by 1.0% per year. As a result, the service sector's share of energy consumption increases from 30% in 2007 to 34% in 2050, and that of the residential sector declines from 70% to 66%.

[1] Contact: michael.taylor@iea.org

[2] In line with the treatment in the *World Energy Outlook,* the service sector total includes the projections for "non-specified (other)".

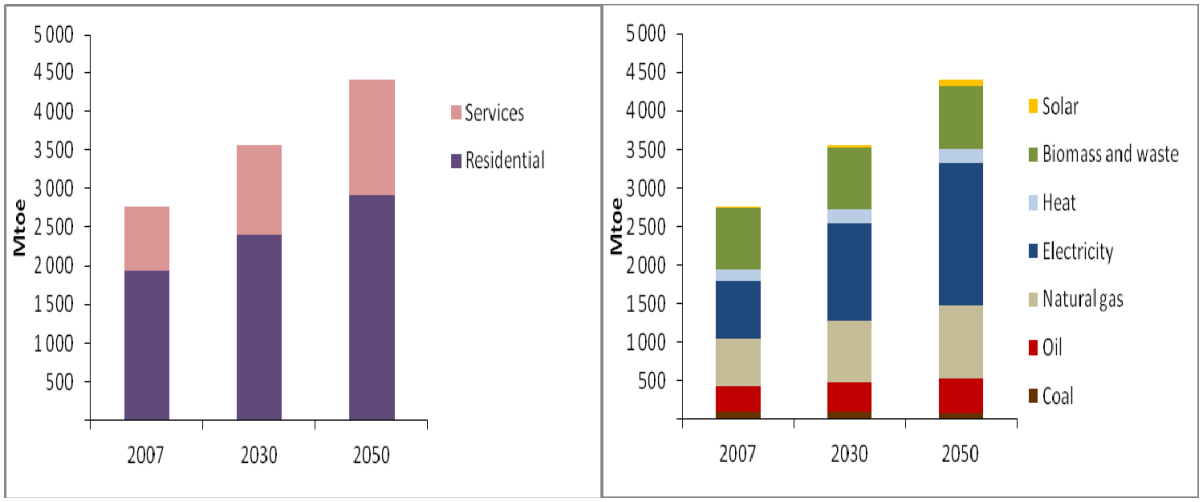

Figure 1: Buildings sector energy consumption in the Baseline scenario by sector and by energy commodity

Key point: The share of buildings sector energy consumption accounted for by electricity increases by 2050.

2 ENERGY AND CO2 EMISSIONS IN THE BLUE MAP SCENARIO

The BLUE Map scenario presents different policy challenges depending on the country. The policy challenge facing OECD countries and the Economies In Transition (EITs) is very different from that facing developing countries. OECD countries, and EITs to a lesser extent, are characterised by a large stock of residential buildings that is not growing quickly and that will be retired only slowly. So most of the CO_2 reduction potential is in the current stock of buildings. OECD countries and EITs also have significant heating loads, as does China. In developing countries, buildings have much shorter life spans, commonly of 25 to 35 years. The rate of growth of the overall building stock is also very rapid. The priority for developing countries is, therefore, to address the energy consumption of new buildings, especially in respect of cooling loads, through building standards and codes.

In the BLUE Map scenario, energy consumption in the buildings sector is reduced by around one-third of the Baseline scenario level in 2050 (Figure 2). Energy consumption in 2050 is only 5% higher than in 2007, despite an increase in households of 67% and in service sector floor area of 195% over that time. The energy consumption of fossil fuels declines significantly, as well as that of traditional biomass. The residential sector accounts for 65% of the buildings sector's energy savings from the Baseline scenario in 2050.

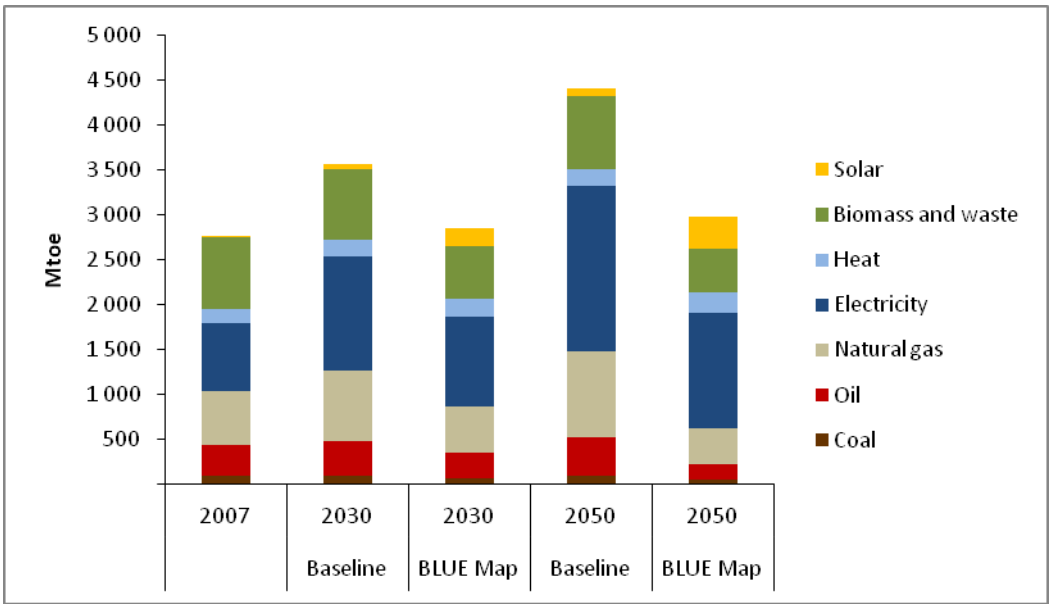

Figure 2: Buildings sector energy consumption by fuel and by scenario

Key point: Energy consumption in the buildings sector is 5% higher in 2050 than in 2007 in the BLUE Map scenario.

In the Baseline scenario, the buildings sector emits 15.2 Gt CO_2 in 2050, an 87% increase over 2007 levels. The BLUE Map scenario reduces CO_2 emissions from the buildings sector by 12.6 Gt CO_2 from the Baseline scenario level in 2050, with 6.8 Gt CO_2 of this reduction being attributable to the decarbonisation of the electricity and heat sectors. As a result, buildings sector CO_2 emissions are 83% lower than the Baseline level in 2050. This reduces the direct and indirect CO_2 emissions attributable to the buildings sector to 2.6 Gt CO_2 in 2050, one-third of the 2007 level.

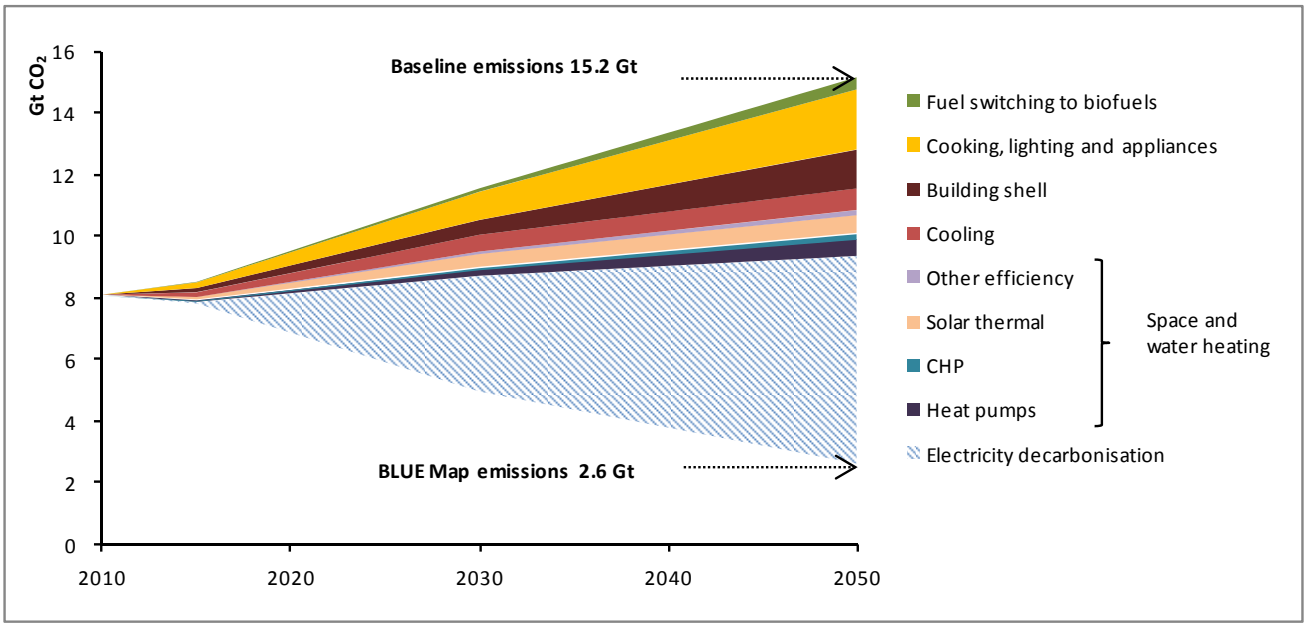

Figure 3: Contribution of CO_2 emissions reduction options

Key point: All end-uses contribute significantly to reducing CO2 emissions in the buildings sector in the BLUE Map scenario.

3 ENERGY TECHNOLOGY ROADMAPS AT THE IEA

We are facing challenging economic times, with a range of events yet again highlighting the vulnerability of the global economy to high energy prices. At the same time, all nations share a responsibility to ensure their energy sectors become more sustainable and more secure to manage the risks and impacts of climate change.
The need for action is urgent, but drastically changing energy infrastructure and end-use equipment on a national scale is a complex and expensive undertaking. Careful planning is required to ensure that limited resources are devoted to the highest-priority, highest-impact actions in the near term while laying the groundwork for longer-term improvements.

The International Energy Agency's (IEAs) energy efficient and low-carbon technology roadmaps are strategic plans that help to outline activities, policies and organisation to transform the market for a given technology or grouping of technologies. The roadmaps are designed to identify, and provide solutions to overcome, all of the technical, market, R&D, regulatory, consumer acceptance, legal, etc. barriers to the uptake of these technologies as well as lay out specific goals and outcomes for technology R&D, development, costs and performance and deployment.

3.1 The Buildings Sector Heating and Cooling System CO_2 Savings

The heating and cooling technology solutions that will allow the buildings sector to shift to a more sustainable energy and environmental future contribute 2 Gt CO_2 of the total savings. The increased deployment of heat pumps for space and water heating, as well as the deployment of more efficient heat pumps for cooling account for 63% of the heating and cooling technology savings.

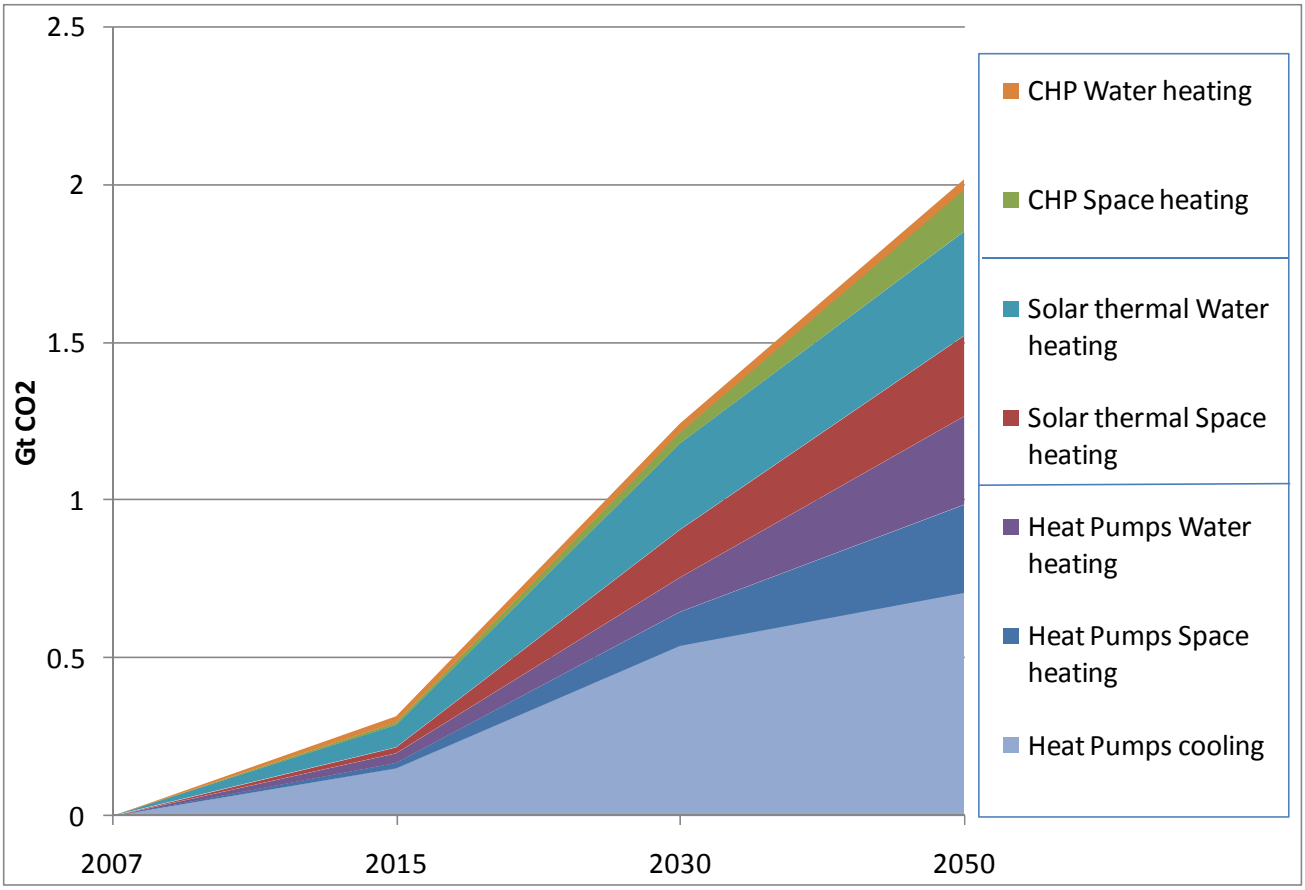

Figure 4: CO_2 emissions reductions in buildings from heating and cooling systems in the BLUE Map scenario (reduction below the Baseline)

Key point: Heat pumps play a critical role in reducing CO_2 emissions from heating and cooling equipment in the buildings sector

3.2 The Heating and Cooling Equipment for Buildings Roadmap

The roadmap establishes a "big picture" vision for stakeholders in the buildings sector[3] of the goals for heating and cooling equipment, and provides concrete advice on how to achieve the savings in the BLUE Map scenario. It highlights the key technology options, the barriers they face and the policy options to address these barriers.

The roadmap lays out a well structured and comprehensive vision of the appropriate and feasible long-term goals for the sector, as well as identifying specific milestones and packages of policies to achieve these goals. An integral part of the roadmap is the identification of the role and contribution of different stakeholders in this process and how

[3] The "Buildings sector" is defined as the buildings of the residential and service sectors. The service sector includes activities related to trade, finance, real estate, public administration, health, food and lodging, education and commercial services (ISIC codes 50-55 and 65-93). This is sometimes also referred to as the commercial and public services sector. The energy savings potential in industrial buildings is not covered in this roadmap, although the technologies described in this roadmap are those also found in these buildings.

they will need work together to reach the common objectives outlined in the BLUE Map scenario. The key areas addressed in this roadmap are:

- The status, costs and future developments in selected heating and cooling technologies;
- The areas where specific R&D needs have been identified, as well as future technology development goals and milestones
- Specific deployment goals for heating and cooling technologies in the buildings sector
- Policy recommendations, to overcome existing and future barriers to heating and cooling technologies, and their timing to ensure achievement of the BLUE Map scenario results.

The key technology options for heating and cooling in buildings have been narrowed down to those with the greatest long-term potential for CO2 emissions reductions, or facilitating them. This roadmap covers the following technologies for space and water heating, heat storage, cooling and dehumidification:

- Heat pumps for cooling and space and water heating
- Active solar thermal
- Combined heat and power (CHP)
- Thermal storage

The increased deployment of heat pumps for space and water heating, as well as the deployment of more efficient heat pumps for cooling account for 23% of the total savings in the buildings sector including all end-uses. Solar thermal systems for space and water heating account for around 12% of the savings. CHP plays a small but important role in reducing CO_2 emissions, as well as assisting in the balancing of the renewables-dominated electricity system in the BLUE Map scenario.

3.3 Heat Pumps in Buildings in the BLUE Map Scenario

The potential energy and CO_2 savings from the wider use of heat pumps are substantial, given their high efficiency and relatively low market penetration for space and water heating. The efficiency of today's BAT for air-conditioners is considerably higher than average installed efficiencies, offering further scope for CO_2 emission savings. When combined with thermal storage, to enable load to be shifted out of peak periods, heat pumps could also help reduce the costs in the BLUE Map scenario of integrating a high share of intermittent renewables into the grid.
The BLUE Map scenario will require nothing short of a complete transformation of the way space and water heating is provided, while the global average efficiency of cooling systems will have to more than double by 2050. Highlights for space and water heating include:

- The share of useful space and water heating demand met by fossil fuels will drop to between 5-15% (depending on region) from today's position of dominance.
- Heat pumps will dramatically increase their share of space and water heating, with total installed units for heating and cooling reaching almost 3.5 billion by 2050.
- Installed solar thermal capacity will increase by more than 25 times today's level to reach 3 743 GWth by 2050.
- The installed capacity of distributed CHP in buildings will be 50 times greater than today's level, reaching 489 GWe in 2050.

- Thermal energy storage will be associated with half of all space and water heating systems by 2050.

The deployment of today's heat pumps systems will give way in the BLUE Map scenarios over time to integrated systems providing space heating, water heating and cooling, and hybrid heat pumps systems (i.e. combined with solar thermal systems) for improved efficiency. Although heat pumps are often competitive today, the large-scale global deployment of heat pumps for heating and higher efficiency air-conditioning devices will require additional R&D, demonstration programmes and support policies to help transform the market for heating and cooling.

Worldwide, around 800 million heat pumps are estimated to be installed in the residential sector in 2010 and this will grow to 3 500 million in the BLUE Map scenario.[4] Three-quarters of today's heat pumps are small air conditioning or reversible units with an average capacity of 2.5 kW. Their contribution to space and water heating at a global level is modest. The estimated total installed capacity of heat pumps for space and water heating needs to grow to 6.6 times today's level or to 4 876 GWth, critically, with installed capacity for water heating going from virtually nothing today to 1 300 GWth by 2050.

The roadmap sets goals for a 20% improvement in COPs by 2020 and 50% by 2030, at the same time as reducing costs by 15% in 2020 and by 25% in 2030. Further R&D, as well as wider deployment will help to achieve these goals, while at the same time heat pumps systems capable of providing simultaneous space and water heating, and cooling for all market segments need to be developed, as well as hybrid systems (*e.g.* heat pump/active solar thermal systems) to achieve very high efficiencies and CO_2 emissions reductions.

To achieve the level of deployment envisaged in the roadmap, and hence the energy and CO_2 emissions reductions, will require strong, consistent, stable and balanced policy support. The roadmap recommends the policy focus should be in the following four main areas:

- Increased technology R&D, significant demonstration programmes and the development of beyond BAT technologies.
- Improved information for consumers and agreed, robust metrics for analysing the energy and CO2 savings of heating and cooling technologies, as well as their life-cycle financial benefits.
- Market transformation (deployment) policies, which are ideally technology neutral, to overcome the current low-uptake of the many energy efficient and low/zero carbon heating and cooling technologies.
- International collaboration to foster greater collaboration in R&D, best-practice policy packages and deployment programmes to maximise the benefits of policy intervention, as well as the transfer of technical knowledge between countries and regions.

The market transformation policies need to focus on addressing current and future market barriers (lack of prioritisation of energy efficiency, capital market barriers, absence of external costs) and address market failures (lack of adequate number of market participants, lack of perfect information, principal-agent problems, transactions costs and delays, inadequate financial mechanisms etc). The roadmap recommends specific policies to:

- Improve information availability and relevance for decision makers.

[4] This is based on a mixture of actual installed capacity data (predominantly in the OECD); and sales data married with assumptions about product lifetimes. Although some confidence can be had in the order of magnitude of the total, better publically available data is still required. This figure is thought to be accurate to within 50 million units.

- Improve heating and cooling system actors (architects, engineers, installers, etc) knowledge and competence with energy efficient and low-carbon heating and cooling technologies
- Implement deployment policies to accelerate uptake and reduce costs through economies of scale.
- Expand quality assurance schemes to encompass the entire sector and provide consumers with the confidence to invest.
- Remove regulatory, policy, fiscal and other barriers.

Achieving complete market transformation in the building sector is an extremely challenging policy goal, due to the large number of individual decision-makers and the fact that the buildings sector is large, diverse and fragmented. A clear message from the roadmap is that policies need to be “broad”, to tackle the range of barriers, and “deep” to ensure the barriers faced by all those in the decision-making chain are addressed. Another clear message is the important role heat pumps play in achieving CO_2 emissions reductions in the buildings sector, in the OECD for space and water heating and in non-OECD countries for water heating and cooling.

REFERENCES

International Energy Agency (IEA) 2010, “Energy Technology Perspectives: Scenarios and Strategies to 2050”, OECD/IEA, Paris
International Energy Agency (IEA) 2011, “Energy Efficient Buildings: Heating and Cooling Equipment”, OECD/IEA, Paris