

Building Energy Performance Metrics

Supporting Energy Efficiency Progress in Major Economies

BUILDING ENERGY EFFICIENCY TASKGROUP

International Energy Agency
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Acknowledgements

This joint report of the International Energy Agency (IEA) and the International Partnership for Energy Efficiency Cooperation (IPEEC) was made possible by the contributions and participation of the Major Economies Forum on Energy and Climate (MEF) and G20 member and guest governments. The IEA and IPEEC gratefully acknowledge Australia, China, France and the United States for providing project support. Jeff Harris, Rod Janssen, Yamina Saheb and Nan Zhou as well as a number of other non-governmental building efficiency experts offered valuable input and feedback that improved this report.

IEA

The IEA Directorate of Sustainable Energy Policy and Technology (SPT) led the building energy data analysis for this report. The IEA project team included Marc LaFrance (lead), John Dulac (lead analyst), Brian Dean and Seungchan Chang. Didier Houssin, Director of SPT, Jean-François Gagné, Head of the Energy Technology Policy Division, and Cecilia Tam, former Head of the Energy Demand Technology Unit, provided project guidance. Roberta Quadrelli and Taejin Park provided comments. Davide D'Ambrosio, Astrid Dumond, Angela Gosmann and Therese Walsh supported graph and report production. The report was edited by Kristine Douaud.

IPEEC

The IPEEC Building Energy Efficiency Task group (BEET) facilitated the input of governmental and non-governmental experts to this report. BEET 4 project participants and designated experts from MEF and G20 member governments and guests provided and reviewed building energy data, offered project guidance and insights, and contributed to the development and review of this report. The BEET is co-chaired by Australia and the United States and supported by the IPEEC Secretariat. Adam Hinge served as an IPEEC BEET 4 project advisor and key contributor. The report benefitted from the review of the IPEEC Executive Committee.

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Executive summary

The energy savings potential in the buildings sector is massive. Globally, the wide deployment of best available technologies and energy efficiency policies could yield annual savings in buildings' final energy use of roughly 53 exajoules (EJ) by 2050 – equivalent to the combined energy use of buildings in China,[1] France, Germany, Russia, the United Kingdom and the United States in 2012 (IEA, 2015a).[2]

Capturing this energy savings potential would deliver a range of benefits: lower electricity and fuel costs for businesses and households; greater reliability in meeting energy demand without costly infrastructure and disruptions; and reductions in emissions of heat-trapping greenhouse gases (GHGs) and other pollutants that pose a threat to human health.

The countries represented in the Major Economies Forum on Energy and Climate (MEF)[3] accounted for approximately three-quarters of global building energy use over the last decade. Going forward, MEF economies could achieve an estimated 70% of the cumulative global savings potential in building final energy consumption from 2015 to 2050 with ambitious building energy policies. When the other countries within the G20[4] are included, an additional 4% of this cumulative global savings potential could be achieved.

This International Energy Agency (IEA) and International Partnership for Energy Efficiency Cooperation (IPEEC) report supports energy efficiency in major economies by providing the metrics data needed to gauge progress and identify opportunities for improvement in building energy performance. The focus is on building energy use and metrics over the period 2000 to 2012 for the sector as a whole and for residential and services buildings separately (please see annexes). Key historic drivers of building energy use are discussed, such as population, building sector size, economic activity, building energy policy, among others. However, the current analysis does not quantify the contribution of individual drivers to observed trends. Forecasts of building energy use and savings potential are also provided up to the year 2050 for three groupings of economies: the MEF, G20, and world. The data and analysis in this report may inform policy and technology-related action at the national level and in international fora such as the MEF, the G20 and IPEEC.

Key findings

For the period 2000 to 2012, the following trends in building final energy performance are observed:

- Despite significant improvements in the energy efficiency of buildings and of energy-consuming products in buildings, energy use in the buildings sector has grown or remained constant in all MEF and remaining G20 economies except the United Kingdom and Germany, in which use declined.
- Electricity use in the buildings sector has grown for all MEF and remaining G20 economies, and is being driven by the increased use of appliances, electronics and other plug loads.

[1] Refers to the People's Republic of China, including Hong Kong.

[2] Energy savings estimates are from the IEA *Energy Technology Perspectives 2015* and reflect the difference between the 6°C Scenario (6DS), leading to an average global temperature increase of 6°C, and the 2°C Scenario (2DS), which describes an energy system with an emissions trajectory allowing a 50% chance of limiting average global temperature rise to 2°C.

[3] MEF members: Australia, Brazil, Canada, China, the European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, South Africa, the United Kingdom and the United States (www.majoreconomiesforum.org).

[4] G20 members not in the MEF are Argentina, Saudi Arabia and Turkey.

- Some of this growth in energy and electricity use is due to population and economic growth, particularly in rapidly emerging economies such as China and India. However, energy use (and particularly electricity use) is growing even in economies with limited population and economic growth.
- Total building energy use per capita declined in more than half of the MEF economies, mostly in wealthier countries that started from a very high level of energy use per capita. For the MEF as a whole, building energy use per capita was virtually flat. The trend is different for electricity use per capita, which grew for all but three countries and grew rapidly in some emerging economies.
- Total building energy use per floor area declined for nearly all MEF economies (except Italy[5]), with reductions in the range of 5% to 30%. The trends vary for electricity use per floor area, with declines in only six countries even though almost all countries had fairly significant reductions in total energy per floor area.
- More energy is used in the residential buildings sub-sector than in the services buildings sub-sector for the vast majority of MEF and remaining G20 economies. For the MEF as a whole, more than twice as much energy was consumed in the residential sub-sector than in the services sub-sector as of 2012.
- In the residential and services sub-sectors, different trends in building energy use are observed. In general, the percent change in energy use in the services buildings sub-sector is larger than that of the residential buildings sub-sector, but the absolute energy use increases were larger in residential buildings in many countries due to the larger size of the residential sub-sector.

For the period 2015 to 2050, the following features and trends in forecasted building final energy performance are observed:

- Forecasts of energy savings potential show that in the IEA 2DS, the MEF as a whole could reduce annual building energy use by 37 EJ (a 30% reduction) by 2050 relative to the 6DS. The remaining G20 economies could achieve additional annual energy savings of 2 EJ by 2050.
- Forecasts of electricity savings potential show that in the IEA 2DS, MEF economies could collectively reduce annual building electricity use by 18 EJ (a 33% reduction) by 2050 relative to the 6DS. The remaining G20 economies could achieve nearly 1 EJ of additional annual electricity savings by 2050.
- The MEF could account for 76% of cumulative projected global electricity savings potential between 2015 and 2050. The remaining G20 economies could save an additional 3% of the global potential.

In addition to presenting metrics where data currently exist for building energy performance, understanding and tracking activity towards new very low-energy buildings (VLEBs, often referred to as zero-energy buildings) and deep energy renovations (DERs) of existing buildings would be useful. While work on these two topics has been done in some MEF economies, there are significant differences in approaches and in the meanings of these terms from one country to the next. Further, tracking programmes for VLEBs and DERs need to be developed to better understand aggregate energy savings. This report identifies opportunities for follow-on work and international collaboration that could improve understanding of progress in the future. Building energy codes for new construction and for major building refurbishment are an important policy lever for advancing VLEBs and DERs. The IPEEC BEET is currently undertaking a separate project focused on priorities for international collaboration on building energy code implementation.

[5] While Italy's total building energy use per floor area has grown significantly, its actual energy consumption per floor area in 2012 is still below that of the European Union and other MEF European members.

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Next steps

Through analysis and project input from government representatives and non-government experts, a number of opportunities for further work were identified. These follow-up activities could further support governments in formulating, implementing, and evaluating policies that will help realise the energy savings potential in the buildings sector. Countries could collaborate to:

1) Improve data quality

- Enable the development of more robust metrics by building capacity in the governance and management of building energy data.
- Improve the measurement of progress and opportunities in building energy performance through increased collection, analysis and sharing of data.

2) Develop and track additional metrics

- Demonstrate leadership by developing and tracking energy performance metrics for government buildings.
- Establish processes for tracking the spread of VLEBs and DERs and associated energy savings.
- Develop building sector metrics for primary energy use and associated carbon emissions.
- Quantify the multiple benefits of improved energy efficiency in buildings (e.g. financial, economic, health, and environmental benefits).

3) Model future energy use

- Identify key areas for improvement in building energy performance by modelling the energy savings associated with major policy interventions and technology adoption.
- Improve the analytical basis of building energy policy design and implementation by improving the quality of forecast modelling tools and data.
- Quantify the potential reductions in carbon emissions associated with the building sector for future policy and technology scenarios.

The MEF and remaining G20 economies could join and expand the current work being done on IEA energy efficiency indicators to ensure greater development and tracking of international metrics. IPEEC and the IEA should also continue to facilitate dialogue and data exchanges to advance metrics in collaboration with other organisations and initiatives.

Introduction

The energy savings potential in the buildings sector[6] is massive. Globally, the wide deployment of best available technologies and efficiency policies could yield annual savings in building final energy use in the range of 53 EJ by 2050 (a 29% reduction in projected building energy consumption relative to a business-as-usual scenario in 2050) – equivalent to the combined energy use of buildings in China, France, Germany, Russia, the United Kingdom, and the United States in 2012 (IEA, 2015a). Capturing this energy savings potential would deliver a range of benefits: lower electricity and fuel costs for businesses and households; greater reliability in meeting energy demand without costly infrastructure and disruptions; and reductions in emissions of heat-trapping GHGs and other pollutants that pose a threat to human health.

The countries represented in the Major Economies Forum on Energy and Climate (MEF) accounted for approximately 73% of building final energy use in 2012 (Figure 1). For context, the MEF shares of global population, global gross domestic product (GDP), and global floor area were 63%, 80% and 75% in 2012, respectively (UN DESA, 2014; IMF, 2014). By 2050, MEF economies could achieve an estimated 70% of the cumulative global savings potential in building final energy consumption between 2015 and 2050 with ambitious efficiency policies. When including the other countries within the G20, an additional 4% of this cumulative global savings potential could be achieved by 2050.

To gauge progress in achieving this potential and to identify opportunities for improvement in building energy efficiency, robust building energy metrics are needed. In January 2014, the MEF requested that IPEEC develop options for metrics to track building energy performance. Based on inputs from government and non-government energy efficiency experts, including from the International Energy Agency (IEA), the IPEEC Building Energy Efficiency Task (BEET) group identified a number of relevant metrics in the report "Building Energy Efficiency: Opportunities for International Collaboration" (BEET 2), completed in May 2014 (IPEEC, 2014).

In the BEET 2 report, the BEET identified a number of aggregate building energy metrics that are currently tracked by the IEA and other organisations. For example, the IEA has historical data or derived estimates that have been vetted for MEF economies from 2000 through 2012 for total, residential, and services building energy use, as well as drivers of this energy use, including floor area, population and GDP. The BEET 2 report also identified policy-based metrics that would be illuminating but require further development and improved data, such as the number of VLEBs and DERs.

In a second request in September 2014, the MEF asked IPEEC to work with MEF governments to develop and track aggregate building energy performance metrics. In response to this request, the IPEEC BEET and the IEA conducted a joint project on metrics, and this report is a summary of this work. This IEA-IPEEC analysis is also a component of the buildings efficiency work stream co-ordinated by IPEEC for the G20,[7] as summarised in the G20 Energy Efficiency Action Plan finalised at the G20 summit in Brisbane, Australia in November 2014 (G20, 2014).

This joint IEA-IPEEC project goes beyond the initial analysis in the BEET 2 report to further support energy efficiency in major economies by providing the metrics data needed to gauge progress and identify significant opportunities for improvement. The analysis can help inform policy and technology-related action at the national level and in international fora such as the

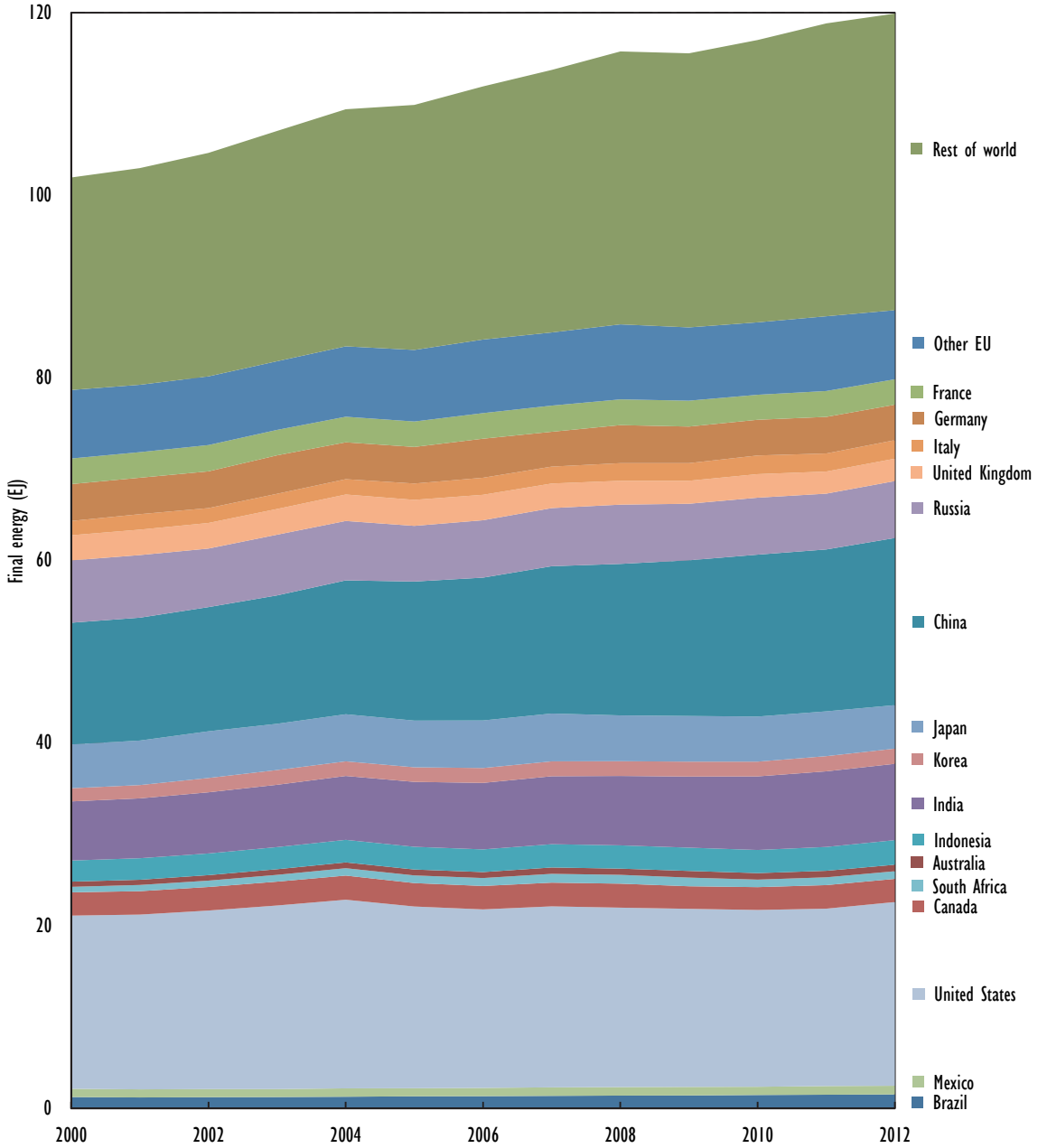
[6] The buildings sector comprises both the residential and services sub-sectors. See the Definitions section for details on energy use within these sub-sectors.

[7] Including the 2014 G20 guests New Zealand, Singapore and Spain.

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MEF, the G20 and IPEEC. Specifically, the current report provides available historic building energy performance data from the IEA with additional vetting by government representatives, IEA building energy modelling results for energy savings potential, and a summary of some of the key issues for advancing VLEB and DER metrics.

Figure 1 • Total building energy use in MEF economies and the world, 2000-12



Notes: EJ = Exajoule; EU = European Union. All data and figures in this report are stated as final energy and electricity use, unless otherwise noted.

Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • Total building final energy use has grown significantly for MEF economies and the world. Total building energy use in the MEF grew from 79 EJ in 2000 to 87 EJ in 2012. Total building energy use for the world grew at a faster pace over the same period, from 102 EJ to 120 EJ, due to growth in several countries beyond the MEF. As of 2012, the MEF economies accounted for 73% of all building energy use in the world, a drop from 77% in 2000.

In response to the MEF request, the BEET 4 project was conducted as a short-term project over approximately six months. It was also resourced at a modest level. Nevertheless, it meaningfully advanced the development and tracking of metrics by leveraging the capabilities of the IEA and IPEEC. The project benefitted from the strong analytical capabilities and extensive data resources of the IEA, and significant input and collaboration by MEF and G20 governments through their representatives to IPEEC.

For BEET 4, governmental participants attended workshops hosted by the IEA and IPEEC BEET in Paris in November 2014 and in Beijing in December 2014, as well as two webinars in January 2015. The workshop in Paris focused on metrics development and data issues broadly, and followed an IEA buildings workshop focused on improving modelling capabilities and data development (IEA, 2014b). The workshop in Beijing was a regional event that went into greater detail on metrics issues for major economies in East Asia and the Pacific. Project participants were also invited to provide detailed feedback on the IEA building energy database, and a number of country representatives helped to improve the quality of metrics data. Additionally, a small number of non-governmental energy efficiency experts participated in BEET 4 and provided helpful feedback on data development and presentation at the workshops and in the review of early report drafts. The report went through the official review and approval process of IPEEC and the IEA.

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Report scope

This report focuses largely on historic (2000-12) buildings sector energy performance data for major economies. It examines the level of energy demand using various metrics (or indicators), the changes in those energy metrics over time, and relative differences among countries with different policy frameworks and different economic, social and climatic contexts. This information can help identify opportunities for improvement in building energy performance through policy measures.

A range of building energy metrics is presented that provides different perspectives on building energy performance (Table 1). This includes metrics for the buildings sector as a whole and for the major sub-sectors (residential buildings and services buildings, which includes commercial and public buildings). All of the metrics presented in this report are constructed by dividing the energy "input" (amount of energy used) by an "output" (measure of the energy services provided) within a particular section, or "scope," of the buildings sector.

Table 1 • Historical metrics presented in this report

Inputs	Total final energy consumption Final electricity consumption
	Per
Outputs	Persons served Floor area served
	For
Scope	Entire buildings sector Residential sub-sector Services sub-sector

For this report, the "input" is taken to be the total final energy consumption (including: electricity, coal, gas, oil, biomass, solar and commercial heat) and final electricity separately.[8] The analysis of final energy provides insights into the energy that is actually used within buildings. However, it is important to note that there are other components of energy consumption associated with the buildings sector that actually have their origin in the power sector. A full accounting of all primary energy – including energy losses in power generation and transmission – could be pursued as future work. Data and metrics for final (or delivered) electricity use are included in this report since final electricity is a major component of total building final energy use (approximately 30%) and, globally, more than 50% of total electricity generation is consumed in buildings.

Two "outputs" are analysed: the number of people served (using total population as a proxy) and the floor area served. Two types of metrics are derived with these outputs: final energy use per capita and final energy use per floor area. Both of these so-called intensity metrics provide insight into building energy performance. Specifically, per capita intensity metrics isolate building energy trends associated with drivers other than population, such as floor area and GDP. Similarly, floor area intensity metrics focus on building energy trends associated with drivers other than floor area, such as population and GDP. However, it is important to note that these drivers of building energy use are interdependent; for example, population is a driver of floor area and GDP, and GDP and population are drivers of floor area.

[8] Building final energy (electricity) is sometimes called end-use, site or delivered energy (electricity).

Discussion of drivers of building energy use is provided in the Background section (with related data in Annex F). The "scope" of the metrics in this study covers the buildings sector as a whole as well as residential buildings and services buildings (shown separately in Annexes D and E; see the Definitions section in "Acronyms, abbreviations and units of measure" for details on energy use within the residential and services sub-sectors). Data availability and quality considerations for "inputs" and "outputs" are provided in the Background section, with further details in Annex B. The inputs and outputs included in this report have been temperature-corrected from year to year, but have not been climate-normalised. The difference between temperature-corrected data and climate-normalised data is discussed in Annex B.

This report is a component of the G20 Energy Efficiency Action Plan, in addition to an update on metrics development for the MEF. Thus, similar energy consumption data and metrics are developed for G20 economies which are not members of the MEF (see sub-section "Additional G20 members and guests" and the annexes). These countries are Argentina, Saudi Arabia, and Turkey, as well as the 2014 G20 guests New Zealand, Singapore and Spain. Building energy use trends and per capita usage are shown for these countries. Floor area and additional residential metrics are not shown, as further data collection, sharing and vetting is needed to ensure a high level of data quality.

This report summarises some of the key issues for advancing VLEB and DER metrics. Examples of implemented programmes for VLEBs and DERs are included, as well as a discussion of current limitations and opportunities in metrics development. The report provides several recommended actions to advance these metrics.

Several scenarios of final energy use and energy savings potential are developed from the building energy model used for the IEA *Energy Technology Perspectives 2015* (*ETP 2015* [IEA, 2015a]). Projections are valuable for assessing the scale of opportunity and for policy planning. In this report, projections are shown for groups of countries: the world, MEF member economies and G20 economies. The projections show several possible building energy scenarios and their associated savings potential.

The annexes provide detailed analysis and extend the discussion of the main body of this report. Included are: details on data availability, and quality considerations and challenges (Annex A); a conceptual framework for metrics and a discussion of metric normalisations (Annex B); examples of detailed end-use metrics (Annex C); residential buildings sub-sector energy trends and metrics (Annex D); services buildings sub-sector energy trends and metrics (Annex E); building energy trends and drivers by country (Annex F); and electricity generation fuel shares (Annex G).

Project participants noted several important topics for additional analysis, which extended beyond the scope and resource availability of the BEET 4 project and could be undertaken in follow-up work. Additional topics include: primary building energy use and metrics (including the energy used in electricity generation and transmission); the multiple benefits of efficiency improvements (e.g. financial savings, increased economic activity, health benefits, etc.);[9] GHG emissions associated with building energy use; comparisons of building energy use in countries with similar contexts (e.g. similar climate, similar GDP, similar rates of new construction); and further analysis of the drivers of specific metric trends, fuel shares (including in power generation), end uses (e.g. heating, lighting and cooling), and future energy use. The Recommendations for Future Work section of the report outlines some key activities to (1) improve data availability and quality; (2) develop and track additional metrics; and (3) model future building energy use.

[9] For more information, see IEA (2014c).

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Background

Overview of drivers of energy use

Historically, several factors have been key drivers of final energy use in the buildings sector: population size; buildings sector size (e.g. as measured by floor area or number of households in the residential sub-sector); economic activity (e.g. as measured by GDP); and building energy policy, as well as other factors such as energy prices and climate. The extent to which each driver contributes to energy use differs from country to country, within countries, and over time according to variations in social, economic, geographic and demographic contexts, as well as in policy environments.

Globally, and within the MEF collectively, building energy use has increased with population (Figure 2). Still, several developed countries that have pursued assertive building policies have been able to reduce building energy use despite population growth (see Annex F for detailed country data). For example, from 2000 to 2012, the populations of France, Canada and the United Kingdom increased by 8%, 13.5%, and 6.5% respectively; over the same period, their buildings sector final energy use actually decreased by 1%, 1%, and 11% respectively. Looking ahead, efforts to limit the effect of population growth on building energy use will be an important global issue, as the world population is expected to increase by 2.5 billion by 2050 (UN DESA, 2013).

Energy use in buildings is also tied to building floor area and to economic growth. Globally, there is a trend towards increased dwelling unit size, as higher incomes enable consumers to afford larger dwellings, with improved space conditioning and more energy-consuming products in those dwellings. There are strong correlations between individual wealth level and improvements in space conditioning, as well as with increased ownership of a wide range of energy-consuming equipment and appliances. The affordability of energy relative to household income is also a contributing factor to building energy demand trends. At the country scale, the link between GDP and floor area, and also GDP and energy use, is particularly evident in emerging economies with higher rates of GDP growth (as it was previously in economies that are now highly developed).

Urbanisation is another factor that affects building energy use, and the forms of energy in use. In emerging economies, urbanisation is often associated with increased access to and use of energy services, less use of biomass for water heating and cooking, and increased use of electricity. In developed economies with large residential single-family homes, the migration to urban centres can be associated with a drop in dwelling size, which can reduce energy consumption.

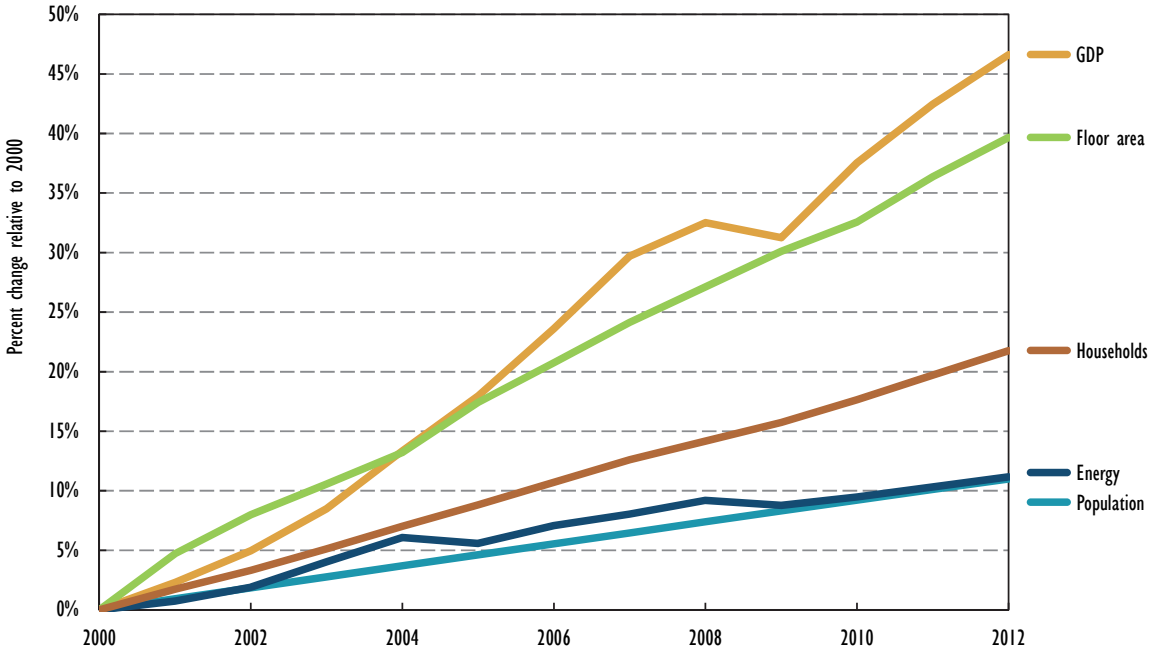
Another demographic factor that impacts building energy use is household size (i.e. number of people per household).[10] As household size declines, the number of households increases for a given population. This can drive up building energy use, as the number of households is a key driver of energy use from appliances, heating, lighting and space cooling, in addition to other energy services. This is an important factor for the MEF, as the shift in almost every MEF country has been towards smaller households (fewer people per dwelling). This phenomenon generally results from increased wealth, although it is also impacted by social and cultural factors (e.g. number of children per family and prevalence of single-person households).

Several energy policy measures can act together to decouple aggregate building energy use from historical drivers. These policy measures include improved building energy codes for both new

[10] In this report the terms household and dwelling are used interchangeably. In certain statistical data collection systems, specific definitions may be preferred.

buildings and existing ones when they undergo retrofits; appliance standards and labels; whole-building rating, labelling and disclosure programmes; educational programmes and capacity building; and improved data availability and quality to inform policy design and implementation (IPEEC, 2014; IEA, 2013).

Figure 2 • Change in major drivers and building energy use in MEF economies, 2000-12



Note: The graph does not provide information on the relative contributions of various drivers to building energy use, but rather shows that the trend for building energy use is similar to the trends of major historical drivers of building energy use.

Sources: GDP: IMF (2014), *World Economic Outlook Database*, April, www.imf.org/external/pubs/ft/weo/2014/01/weodata; Population: UN DESA (2013), *World Population Prospects: The 2012 Revision, Medium-Fertility Variant*; calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • Historically, the size of the buildings sector, population and economic activity have been key drivers of energy use in the buildings sector. From 2000 to 2012, building energy use in MEF economies steadily increased – corresponding to the increases observed in the major historical drivers of building energy use: GDP, floor area, number of households and population. Effective energy efficiency policies for buildings can work over time to decouple energy use from these historical drivers of building energy use.

IEA energy efficiency indicators work

The metrics developed in this report are based on extensive analysis of energy efficiency indicator (EEI) data development that the IEA has conducted with its member countries for many years. In 2014, the IEA published two guidebooks, *Energy Efficiency Indicators: Fundamentals on Statistics* and *Energy Efficiency Indicators: Essentials for Policy Making,* to provide energy analysts with information on the priority areas for developing EEIs and how to select and develop the data and indicators that best support energy efficiency policy (IEA, 2014d; IEA 2014e). The IEA policy-making guidebook suggested a hierarchy of indicators, represented as a pyramid with aggregate indicators at the top and detailed indicators at the bottom. For example, in the residential buildings sub-sector, the Level-1 indicators (top of the pyramid) are aggregate sectorial indicators such as residential energy use per floor area, per capita, and per occupied dwelling. Level-2 indicators (middle of the pyramid) may be based on end-use consumption, such as lighting

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energy consumption per floor area or water heating per dwelling. Level-3 indicators (bottom of the pyramid) include energy use by equipment type, such as water-heating electricity consumption per household with an electric or heat-pump water heater. This IEA EEI work has informed the joint IEA-IPEEC BEET 4 project, which focuses mostly on the Level-1 sectorial indicators, but which also includes some detailed indicators (Annex C).

Data availability and quality

Developing building energy performance metrics that can be compared across countries and regions is complex, with a variety of data availability and quality challenges. Metrics can help in identifying important trends in performance and opportunities for savings, but the reliability of some data sources needs to be considered. Some of these challenges include:

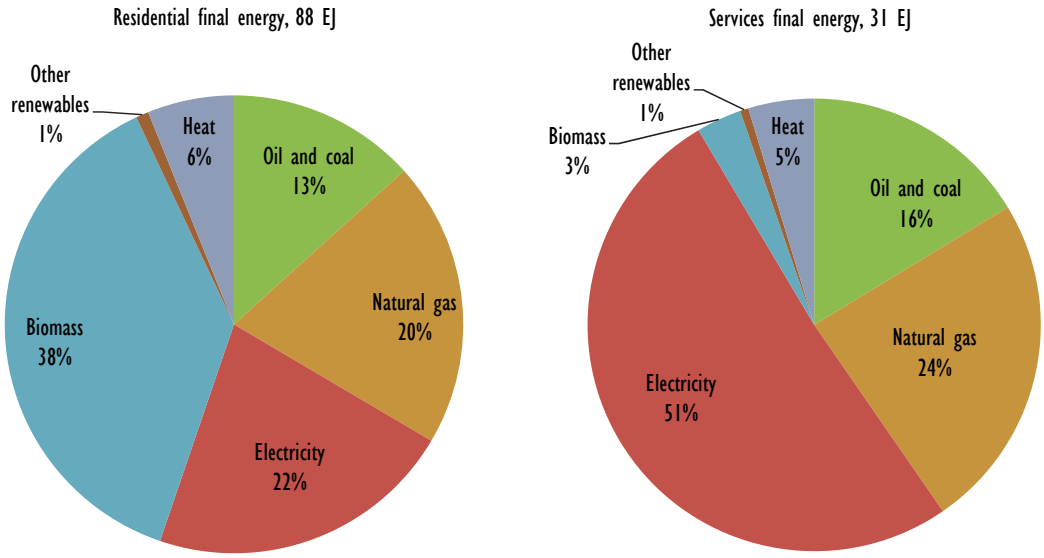
- Energy use: The IEA collects data from national sources. In some cases, data is incomplete or inconsistent in particular energy categories (e.g. biomass and commercial heat). In such cases, the IEA has to make estimates to resolve energy balance issues, which may not always agree with data collected and reported by individual countries.
- Floor area: The data for floor area collected and reported by countries to the IEA include some inconsistencies due to differences in definitions of floor area and in collection procedures, particularly in the services sub-sector.
- Number of households: The data for number of households collected and reported by countries to the IEA include some inconsistencies due to varying definitions for “household,” and whether reported households are partially or fully space-conditioned (heated or cooled) and have access to electricity.
- Normalisation factors for services buildings: Beyond energy use per floor area (used in this report), other normalisation factors for service building energy use could include economic activity (services GDP or value-added or number of service sub-sector employees). However, data availability and consistency are significant challenges.

More information about data availability and quality is presented in Annex A.

Historic building energy trends

The buildings sector consumes almost 120 EJ globally, or over 30% of total final energy consumption for all sectors of the economy (Figure 3). Buildings also account for half of global electricity demand. Despite significant policy efforts to improve energy efficiency in buildings, building energy use has risen by nearly 20% since 2000. Fossil fuels – including coal, oil, and natural gas used directly within buildings and in electricity generation – account for a significant portion of the energy used in buildings globally. When upstream power generation is taken into account, the buildings sector represents nearly 30% of global CO_2 emissions.

Figure 3 • Global building final energy use fuel shares for residential and services, 2012



Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • Globally, fuel shares for residential and services buildings differ considerably, with a higher share of biomass used in the residential sub-sector (mainly in emerging economies) and higher shares of electricity and direct fossil fuel use in the services sub-sector.

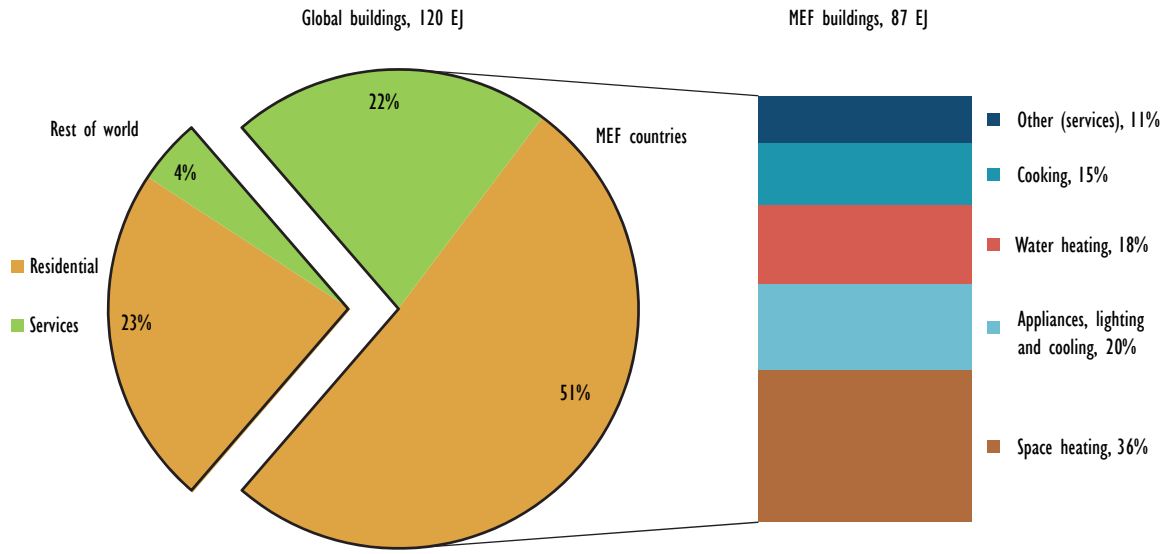
Energy use

MEF economies represented 73% of 2012 global building final energy consumption and thus have the potential to significantly affect global building energy use through energy efficiency policies and practices, as well as through the deployment of energy-saving technologies (Figure 4). Total building final energy and electricity use are fundamental measures of the buildings sector's energy performance that reflect the cumulative effect of all drivers of energy and electricity use in buildings (Figures 5 to 8). Electricity is reported separately because it is a major component – one of the fastest growing ones – of total building energy consumption. Differences in total building energy and electricity use can also be segmented according to buildings sub-sectors to reveal different trends in residential and services buildings (detailed graphs provided in Annexes D and E).

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The metrics in this report focus on final (site or delivered) energy (expressed either in petajoules [PJ] or kilowatt hours [kWh]), which provides insights into the energy consumed in buildings. But it is important to consider the primary (source) energy used to produce and deliver electricity and certain other fuels to gain a full understanding of the energy use associated with the buildings sector. A full accounting of primary energy includes the energy lost in electricity generation, transmission and distribution, and losses associated with other forms of building energy. Primary energy consumption trends can differ significantly from final energy consumption trends. To provide some context for these considerations, fuel shares for the electric power sector of MEF economies are provided in Annex G.

Figure 4 • MEF final residential and services energy use as a portion of world usage, 2012



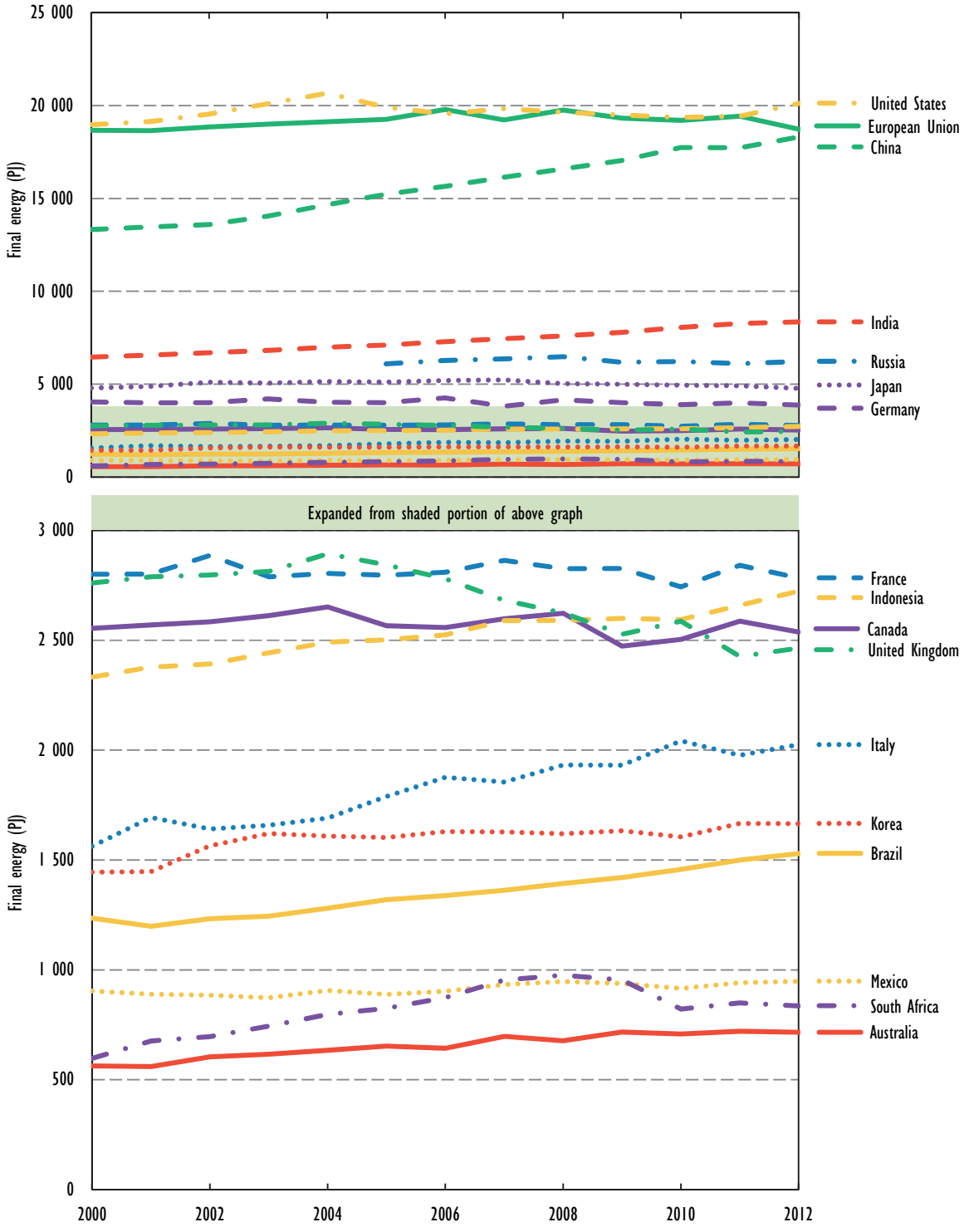
Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • As of 2012, the MEF final residential and services building energy use accounted for 51% and 22% respectively of all global building energy use. MEF economies accounted for 69% of global residential sub-sector energy use and 84% of global services sub-sector energy use in 2012. For context, the MEF shares of global population, global GDP and global floor area were 63%, 80% and 75% in 2012, respectively (UN DESA, 2014; IMF, 2014).

For the period 2000 to 2012, the following features and trends in building energy and electricity use are observed:

- Despite significant improvements in the energy efficiency of buildings and of energy-consuming products in buildings, energy use in the buildings sector has grown or remained constant in all MEF and remaining G20 economies except the United Kingdom and Germany, in which use declined.
- Electricity use in the buildings sector has grown for all MEF and remaining G20 economies, and is being driven by the increased use of appliances, electronics and other plug loads.
- Some of this growth in energy and electricity use is due to population and economic growth, particularly in rapidly emerging economies such as China and India. However, energy use (and particularly electricity use) is growing even in economies with limited population and economic growth.

Figure 5 • Building energy use in MEF economies, 2000-12



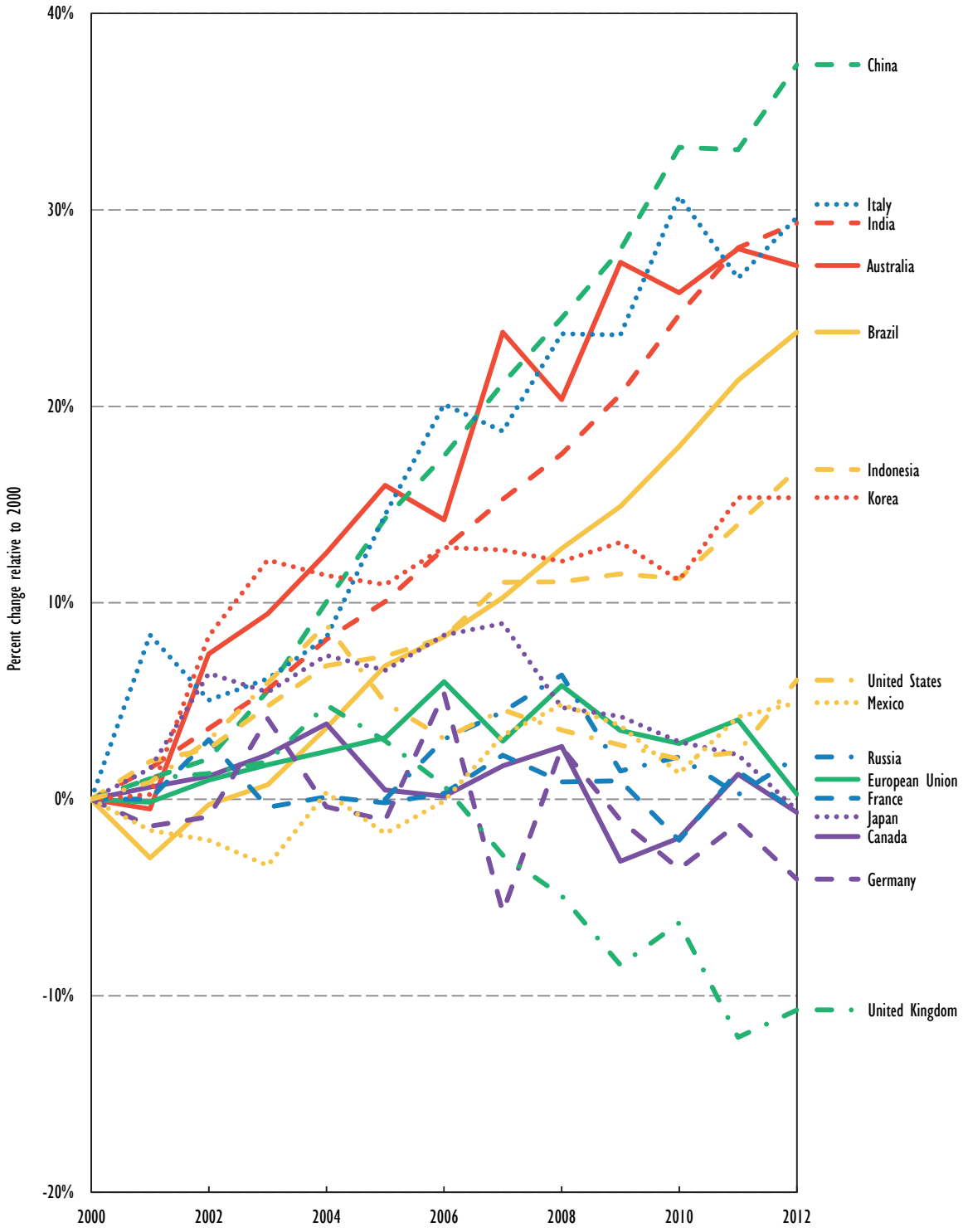
Notes: Russia data throughout the entire report is shown for 2005 to 2012 due to reporting differences that started in 2005. South Africa energy balance data show large variations that may be attributable to significant year-to-year differences in coal reporting for the buildings sector. The IEA has a long-term co-operation initiative with South Africa to improve collection and reporting of energy balances data. Because of this, corrections to present and future data sets can be expected.

Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • As of 2012, total building energy use varied by more than a factor of 20 across MEF economies. Countries with the largest populations and economies were generally the largest energy users, and energy use increased at a faster pace in growing economies.

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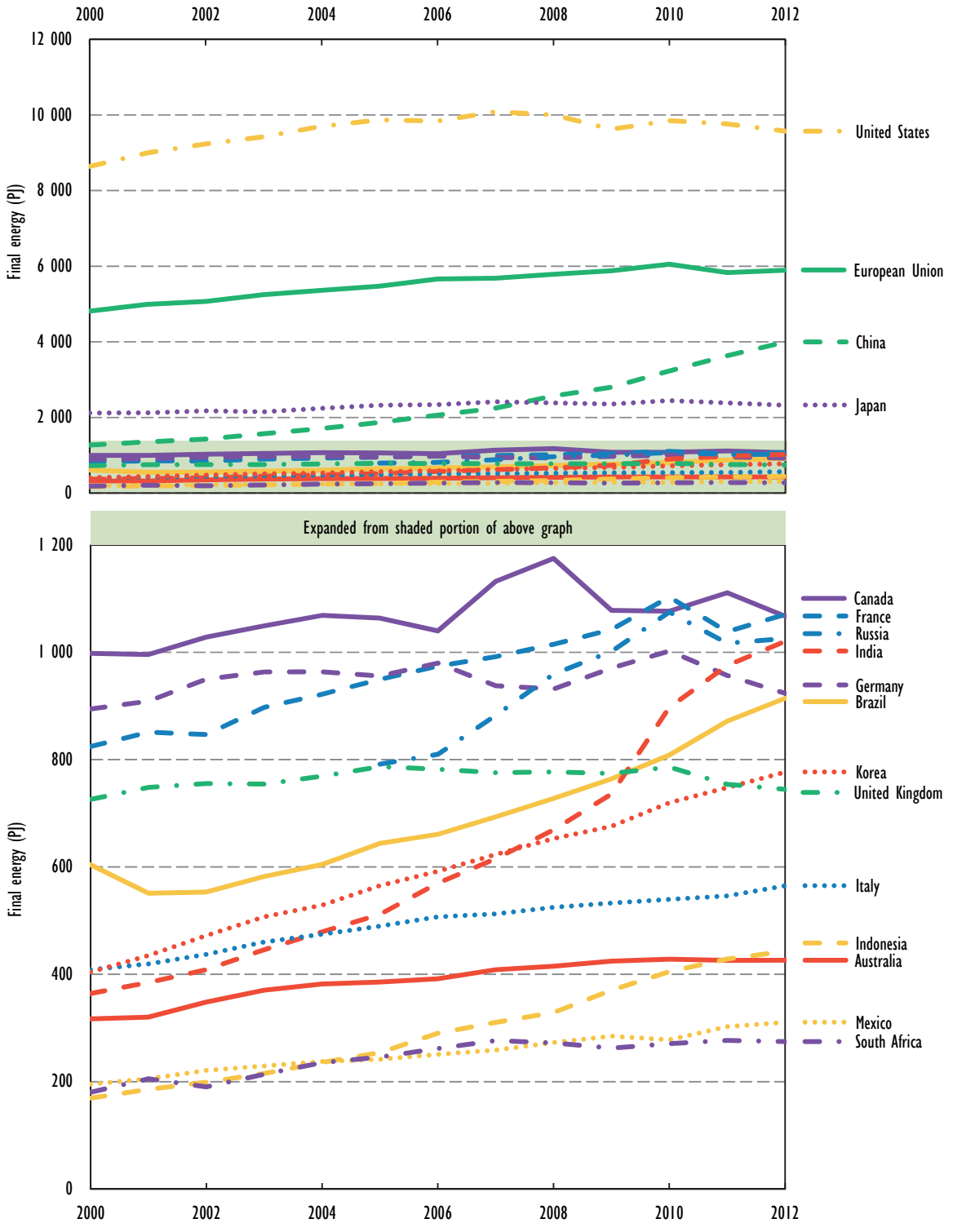
Figure 6 • Change in building energy use in MEF economies, 2000-12



Note: South Africa data are not shown due to data quality concerns; see Figure 5 note for more information.
Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, total building energy use increased for the majority of MEF economies. The rate of growth during this period is highest in China, Italy, India and Australia. A significant reduction in total building energy use occurred in the United Kingdom, and smaller reductions occurred in Germany, Canada, Japan and France.

Figure 7 • Building electricity use in MEF economies, 2000-12

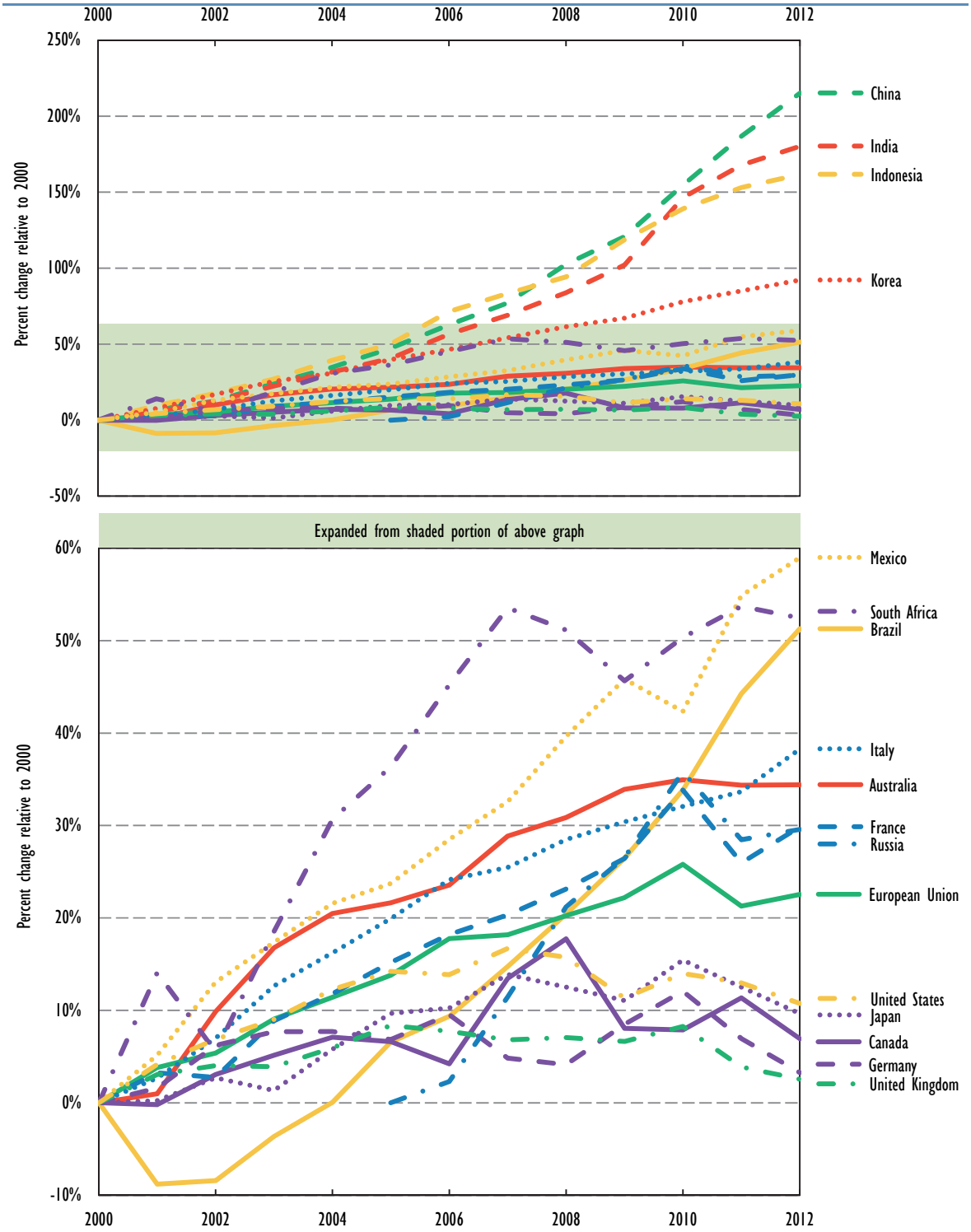


Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • As of 2012, total building electricity use varied by more than a factor of 30 across MEF economies, reflecting significant differences in population and GDP, among other factors.

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Figure 8 • Change in building electricity use in MEF economies, 2000-12



Note: South Africa data has data quality concerns; see Figure 5 note for more information.

Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, total building electricity use increased for all MEF economies. The growing importance of electricity as an energy source for buildings is a common trend associated with large increases in the use of electrical equipment and devices, as well as more extensive electric network connectivity. Growth rates in total building electricity use are highest in major emerging economies such as China, India and Indonesia. Growth rates are lowest in developed economies such as the United Kingdom, Germany and Canada.

Energy metrics

Building energy use per capita

While many factors impact how much energy is consumed in the buildings sector, population is a key element. Both population size and changes in population growth have varied considerably in recent years among MEF economies, although growth has occurred in the vast majority of countries, with implications for building energy use (Table 2).

To better understand building energy trends associated with factors other than population, it can be helpful to examine energy use per capita. For many developed economies, building energy use per capita declined or remained relatively constant over the past decade (Figures 9 and 10), as the growth in energy use for many building services had already been widely achieved. For major emerging economies, energy use per capita has been growing over the past decade, having not yet achieved comparable levels of energy consumption for building services. Globally, total building energy use per capita has been growing slowly over the past decade, while the growth rate in electricity per capita has been larger as the global buildings sector has become more electrified and the use of electrical devices has grown (Figures 9 to 12).

Table 2 • Historical population and percent change in MEF and G20 economies, 2000-12

Economy	Population (million) in 2000	Population (million) in 2012	Change in population (%)
World	6 085	7 030	15.5%
MEF 17	4 000	4 439	11.0%
Australia	19	23	19.7%
Brazil	175	199	13.8%
Canada	31	35	13.5%
China	1 287	1 384	7.5%
European Union	488	508	4.2%
France	59	64	8.0%
Germany	84	83	-0.9%
India	1 042	1 237	18.7%
Indonesia	209	247	18.2%
Italy	57	61	6.8%
Japan	126	127	1.2%
Korea	46	49	6.6%
Mexico	101	117	16.0%
Russia	147	143	-2.4%
South Africa	45	52	16.8%
United Kingdom	59	63	6.5%
United States	285	318	11.6%
Remaining G20	120	143	19.2%

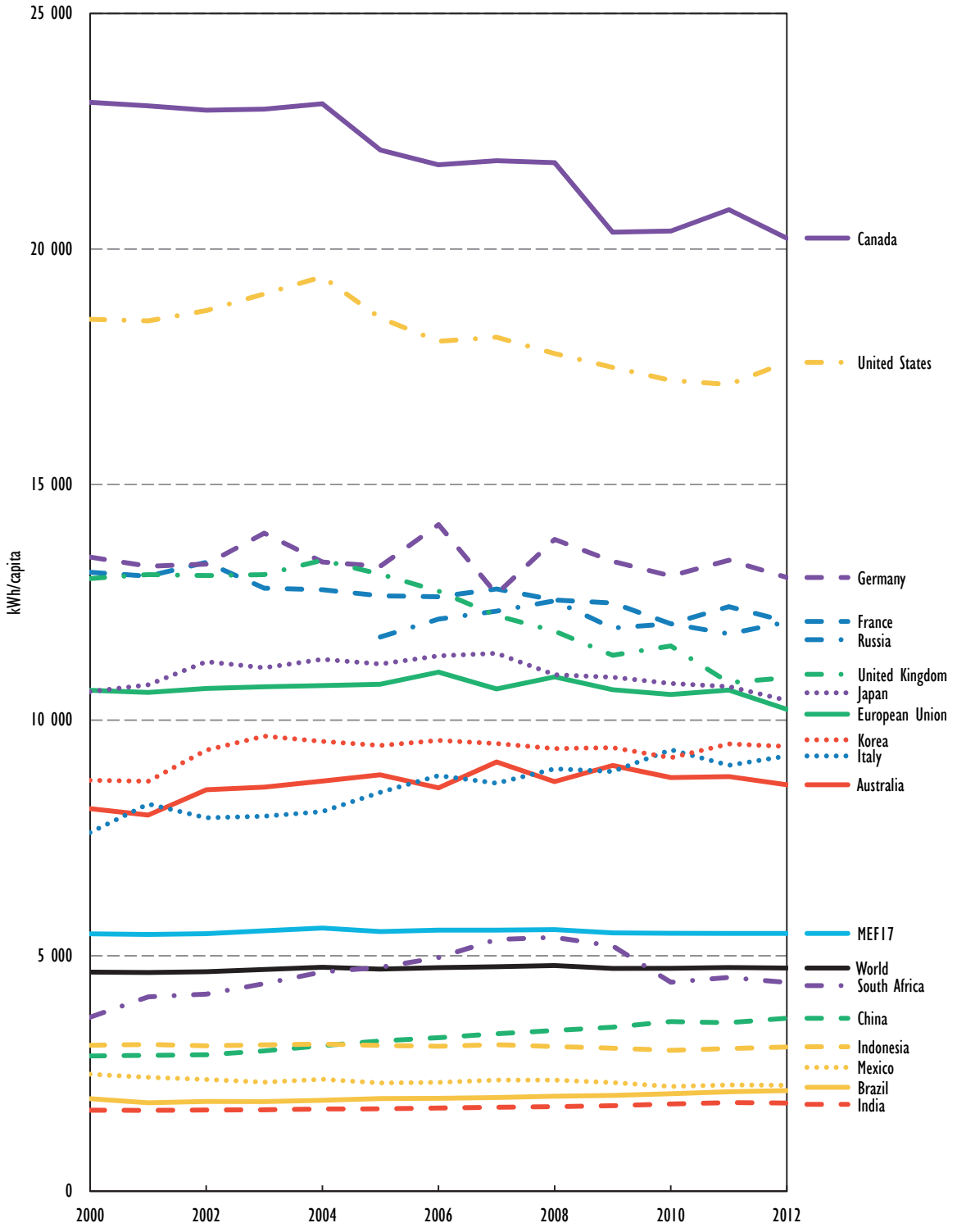
Source: IEA (2015b), *Statistics Database*, www.iea.org/statistics/statisticssearch.

For the period 2000 to 2012, the following features and trends in per capita metrics are observed:

- Total building energy use per capita declined in more than half of the MEF economies, mostly in wealthier countries that started from a very high level of energy use per capita. For the MEF as a whole, building energy use per capita was virtually flat.
- The trend is different for electricity use per capita, which grew for all but three countries and grew rapidly in some emerging economies.

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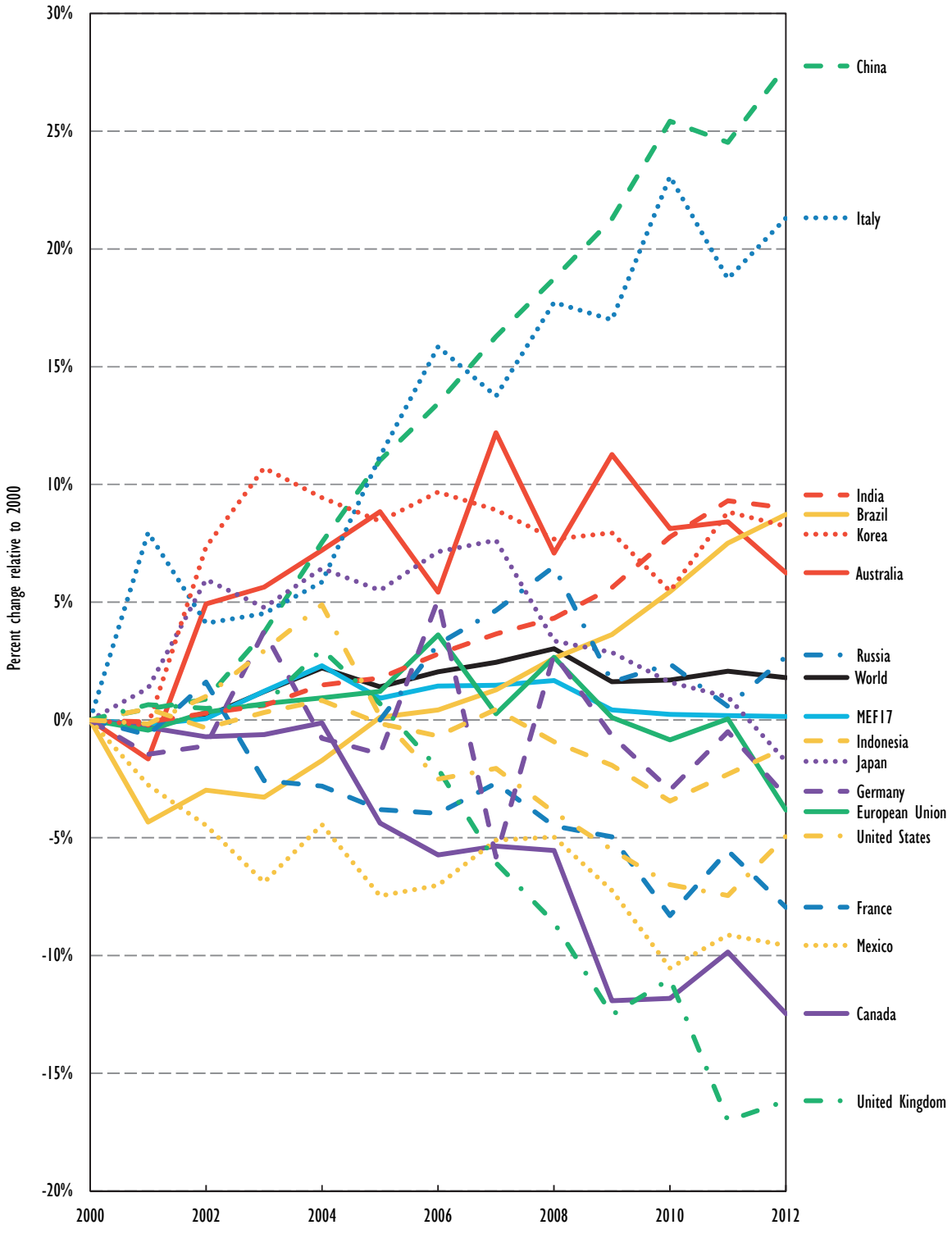
Figure 9 • Building energy use per capita in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • Globally, building energy use per capita has remained fairly stable (slight growth) since 2000, with growth trends in some economies and declines in others that have largely offset one another. Building energy use per capita has declined significantly in several economies with high heating energy use, such as Canada, France, the United States and the United Kingdom. However, energy use per capita in these economies is still significantly higher than the global average.

Figure 10 • Change in building energy use per capita in MEF economies, 2000-12



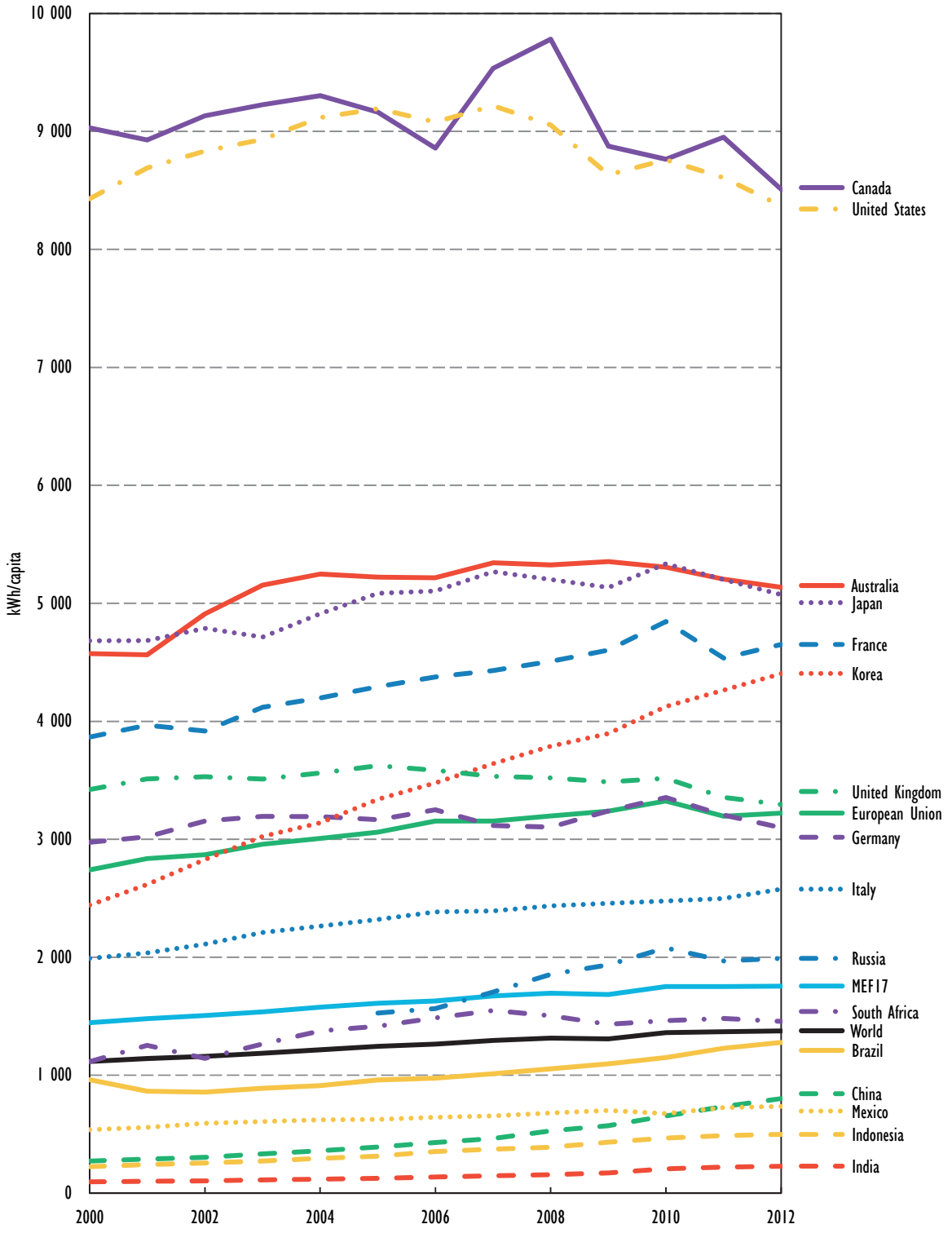
Note: South Africa data are not shown due to data quality concerns; see Figure 5 note for more information.

Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, building energy use per capita for the world and for MEF economies changed only slightly. In many fast-growing economies, building energy use per capita increased with GDP and the associated demand for energy services. In most developed economies, building energy use per capita decreased.

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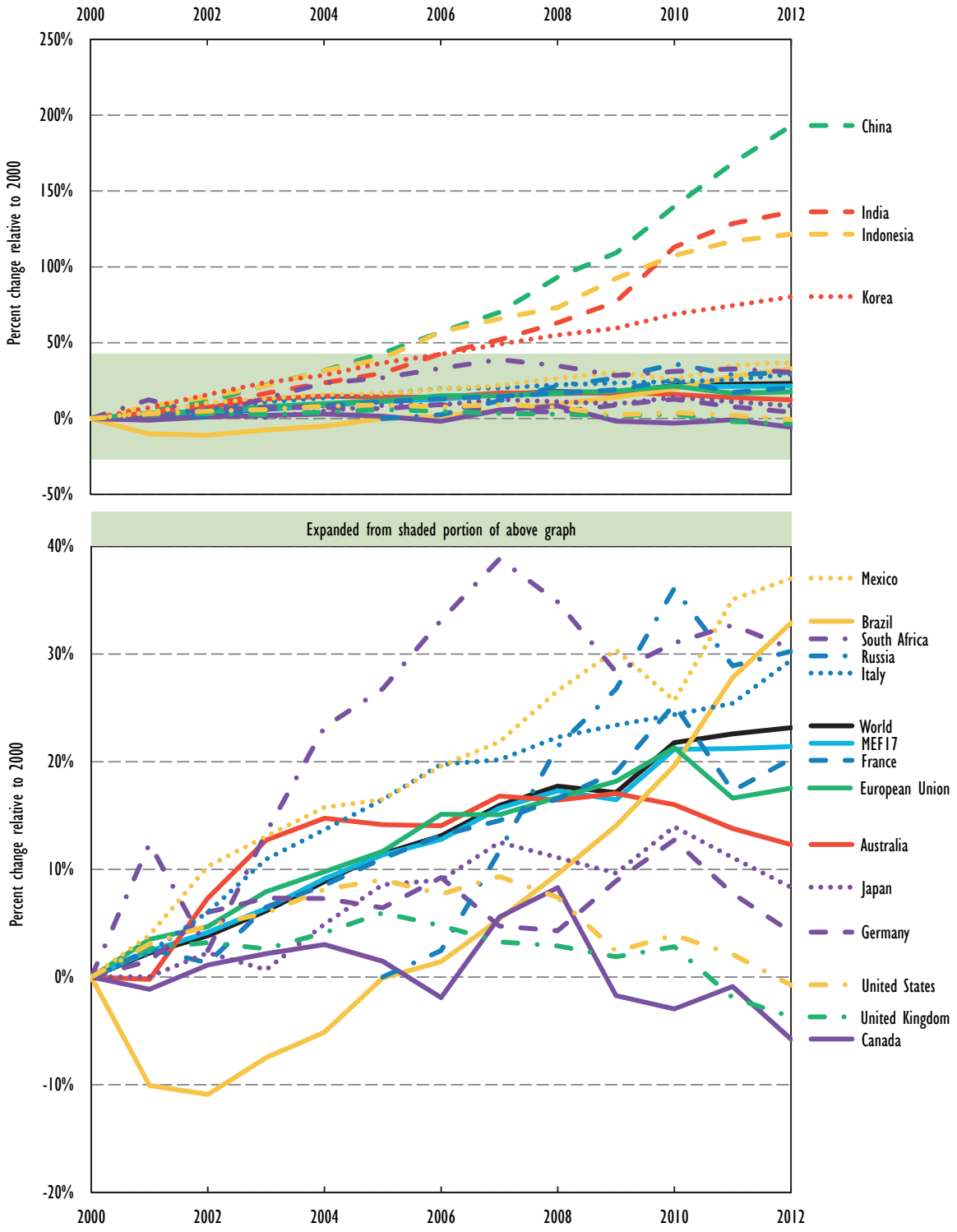
Figure 11 • Building electricity use per capita in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, building electricity use per capita varied significantly across MEF economies, with the highest values in Canada and the United States, and the lowest values in India and Indonesia.

Figure 12 • Change in building electricity use per capita in MEF economies, 2000-12



Note: South Africa data has data quality concerns; see Figure 5 note for more information.

Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, building electricity use per capita increased for most economies, most significantly in China, India, Indonesia and Korea. Slight declines are observed for a few developed economies. For the world and MEF member economies collectively, building energy use per capita increased by more than 20% over this period.

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Energy use per floor area

For the world, MEF economies overall, and MEF economies individually, the size of the buildings sector as measured by floor area is growing (Table 3).[11] Total floor area is derived through the collection of floor area per capita data streams that are then combined with population data. As discussed previously, floor area is a major driver of building energy use. Notable differences in the rates of new construction are evident among MEF economies (see percent change in floor area in Table 3), with significant implications for growth in building energy use. However, the metrics in this section – involving building energy use per floor area – actually provide information on trends in building energy performance that are due to factors beyond floor area (Figures 13 to 16).

Table 3 • Historical building floor area and percent change in MEF economies, 2000-12

Economy	Floor area (million m^2) in 2000	Floor area (million m^2) in 2012	Change in floor area (%)
World	142 106	203 889	43.5%
MEF 17	109 176	152 477	39.7%
Australia	1 156	1 668	44.3%
Brazil	2 746	3 937	43.4%
Canada	2 106	2 644	25.6%
China	28 154	49 583	76.1%
European Union	23 127	27 917	20.7%
France	2 942	3 461	17.6%
Germany	5 057	5 133	1.5%
India	9 149	13 994	53.0%
Indonesia	2 451	4 081	66.5%
Italy	2 802	3 182	13.6%
Japan	5 868	6 674	13.7%
Korea	1 878	2 760	46.9%
Mexico	4 339	5 560	28.1%
Russia	2 785	4 189	50.4%
South Africa	737	1 209	64.0%
United Kingdom	2 938	3 609	22.8%
United States	24 680	28 263	14.5%
Remaining G20*	--	--	--

Note: m^2 = square metres.

* Floor area estimates for G20 economies are currently only available at more aggregate regional levels.

Building energy use per floor area provides a measure of building energy performance relative to building space. For example, improvements in building envelopes (e.g. insulation, air sealing and better windows) can reduce overall building energy use and building energy use per floor area. It is important to note, though, that non-efficiency factors can also affect building energy use per floor area. For example, in the residential sub-sector, the addition of larger living spaces (greater floor area per person) can also reduce the building energy use per floor area, since some components of energy use in homes do not grow in proportion to floor area (e.g. water heating, cooking and refrigeration). Thus, it is instructive to consider changes in building energy use per floor area in tandem with estimates of total energy use.

[11] The IEA and Tsinghua University have done extensive research on floor area projections (IEA, 2014c).

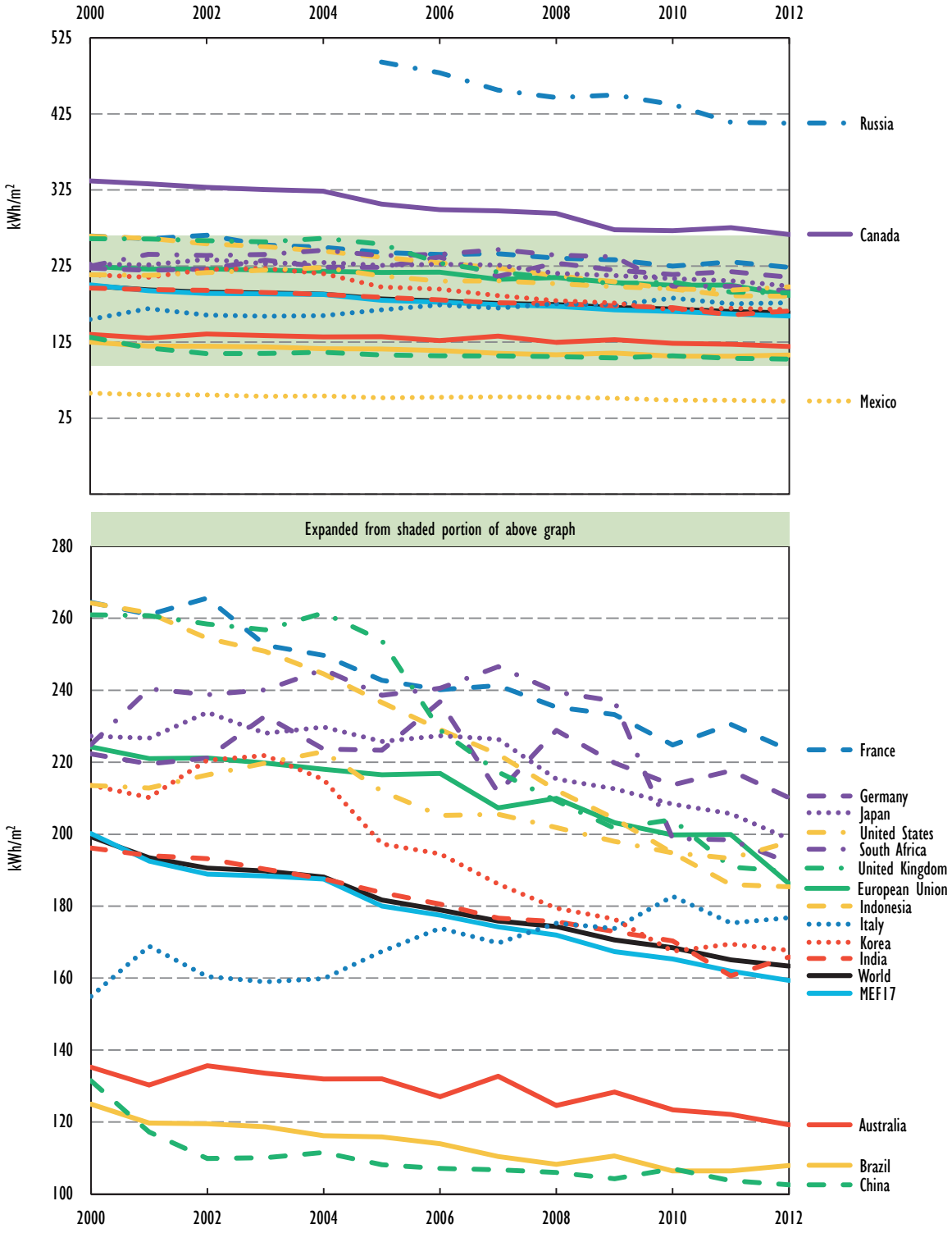
It is also important to note that with variations in the definition of "floor area" and differences in data collection processes among MEF economies, direct comparisons of countries may not be possible with high levels of accuracy. The quality of floor area data, particularly as it changes year to year, is less reliable than population data, particularly for service buildings. Additional work is needed to improve floor area data in the future.

For the period 2000 to 2012, the following features and trends in per floor area metrics are observed:

- Total building energy use per floor area declined for nearly all MEF economies (except Italy), with reductions in the range of 5% to 30%.
- The trends vary for electricity use per floor area, with declines in only six countries even though almost all countries had fairly significant reductions in total energy per floor area.

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Figure 13 • Building energy use per floor area in MEF economies, 2000-12

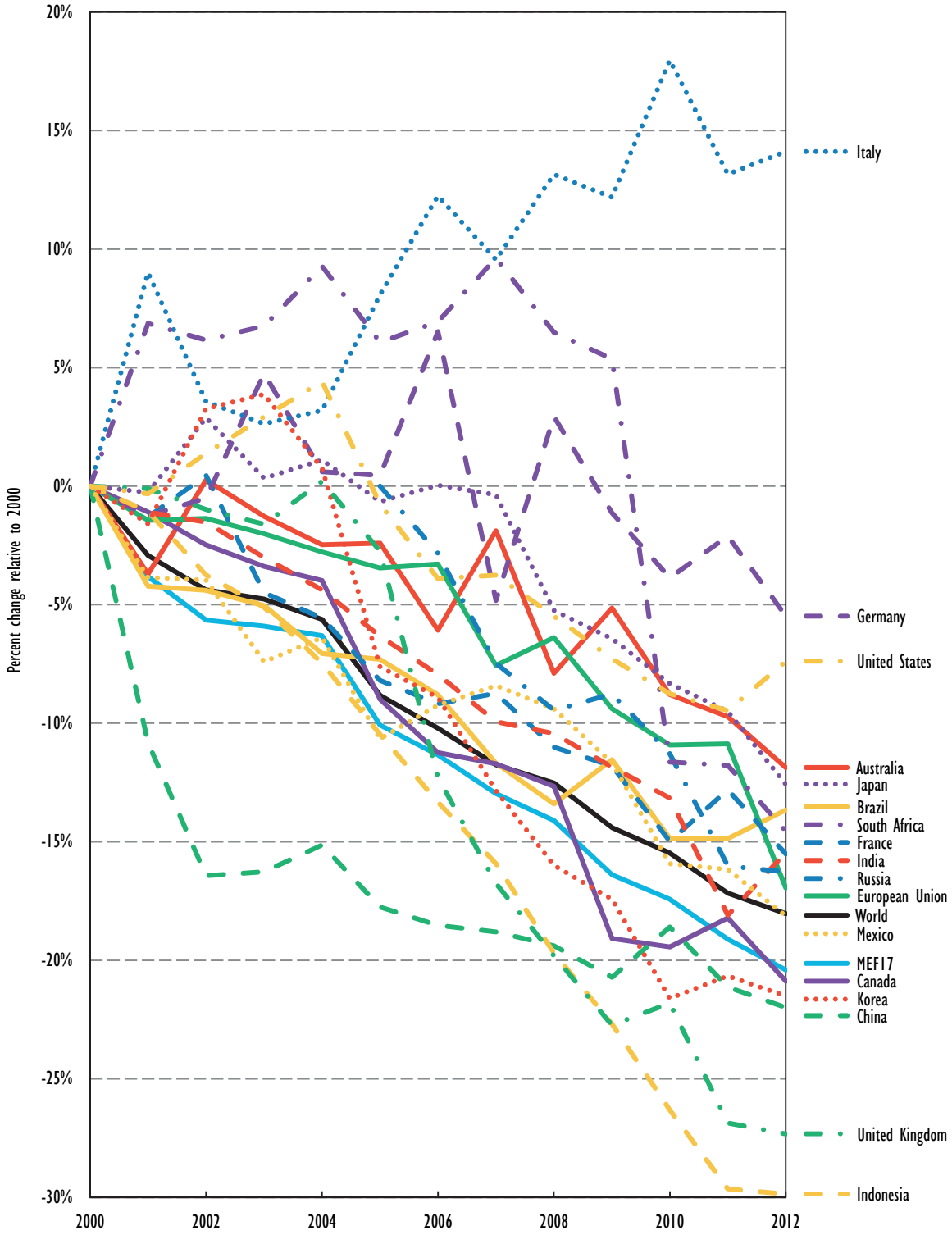


Note: South Africa data has data quality concerns; see Figure 5 note for more information.

Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • As of 2012, building energy use per floor area varied significantly across MEF economies. In general, for nearly all countries and for the world, energy use per floor area declined from 2000 to 2012.

Figure 14 • Change in building energy use per floor area in MEF economies, 2000-12



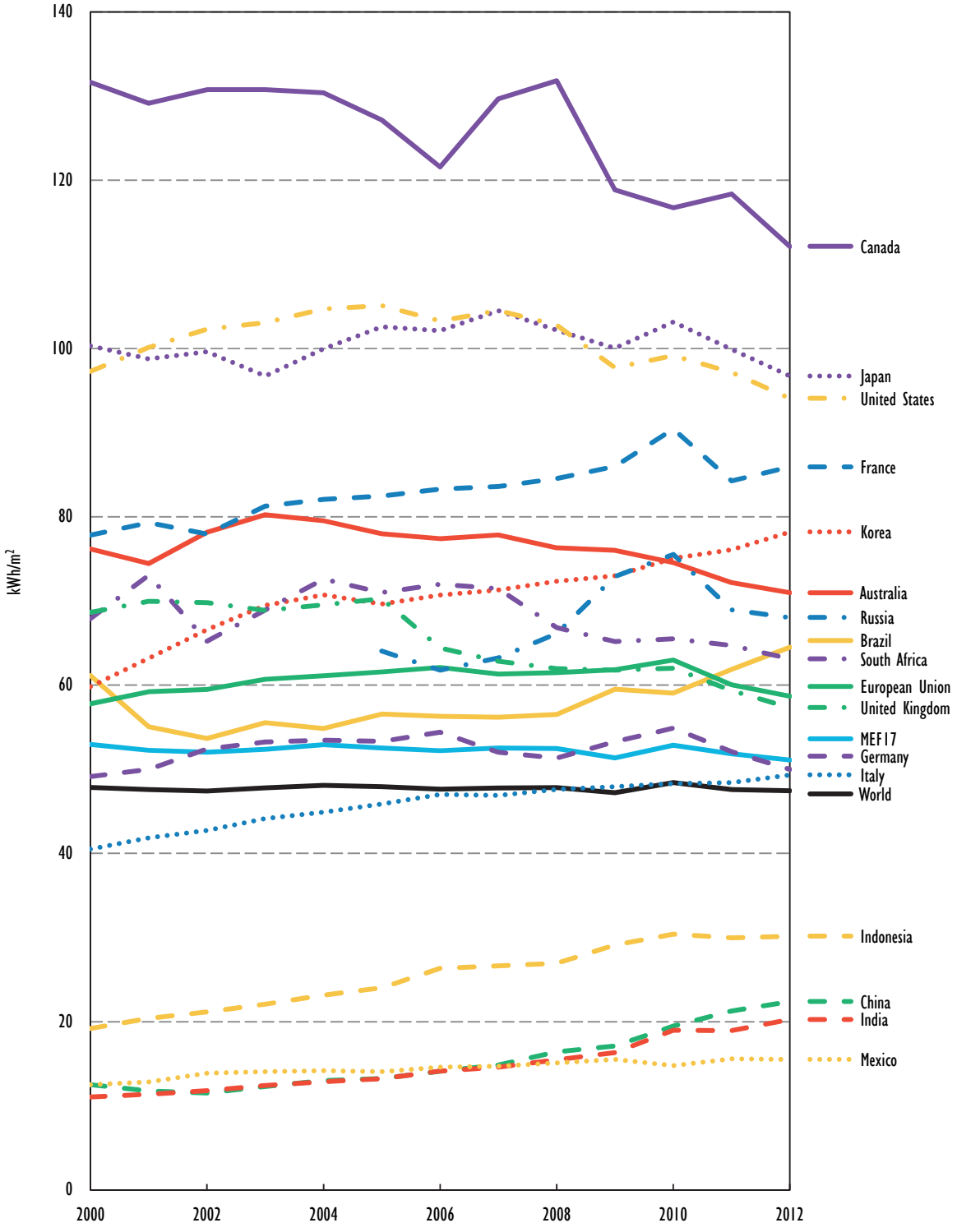
Note: South Africa data has data quality concerns; see Figure 5 note for more information.

Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, building energy use per floor area declined for nearly all MEF economies, indicating improved building energy performance with respect to the size of the buildings sector. Growth trends in the floor area unrelated to direct improvements in energy performance also affect building energy use per floor area. Unlike other countries, Italy has experienced significant increases from a relatively low level in 2000 (Figure 13).

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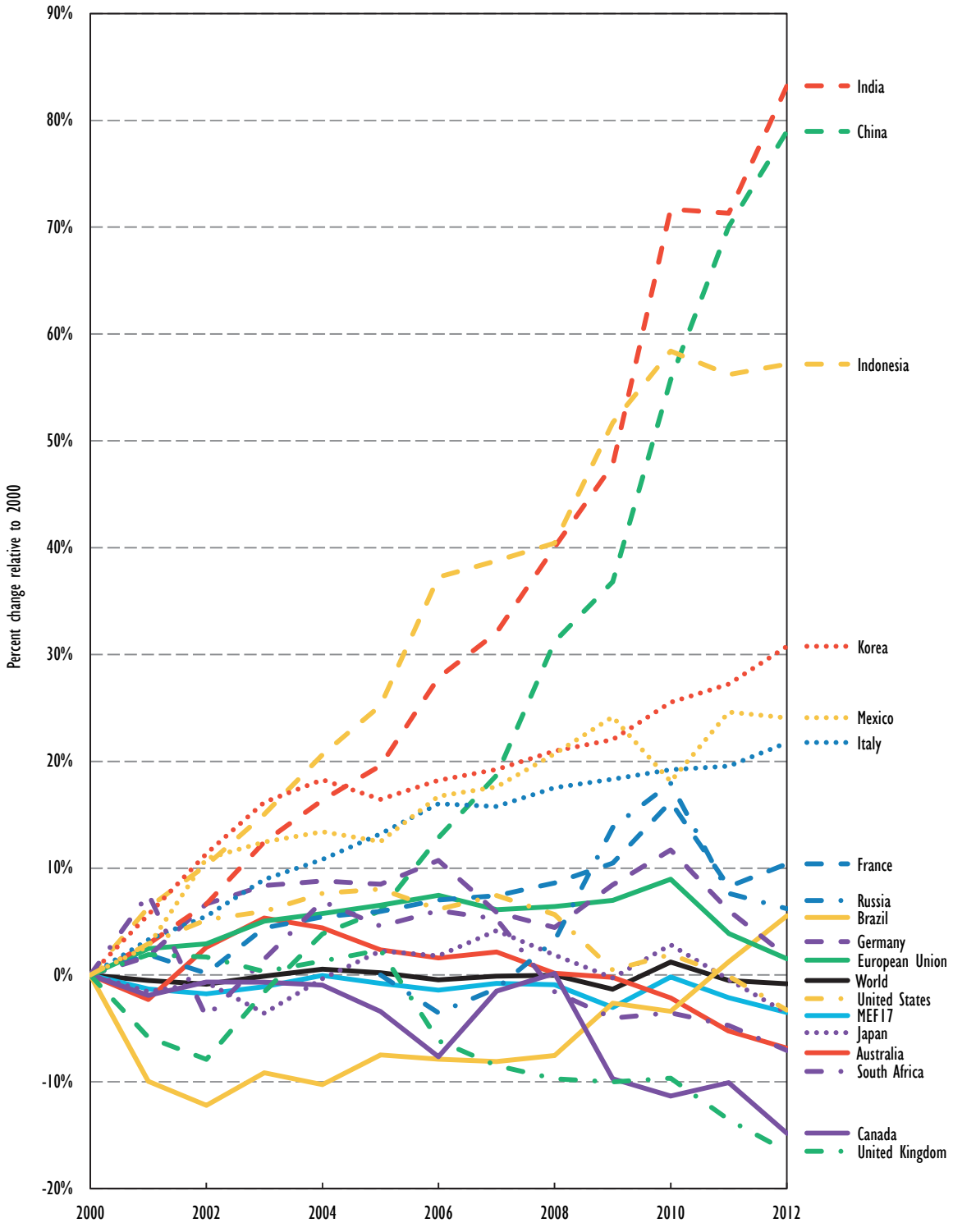
Figure 15 • Building electricity use per floor area in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • As of 2012, electricity use per floor area varied by more than a factor of six across MEF economies, with the values highest for Canada, Japan and the United States, and lowest for Mexico, India and China.

Figure 16 • Change in building electricity use per floor area in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

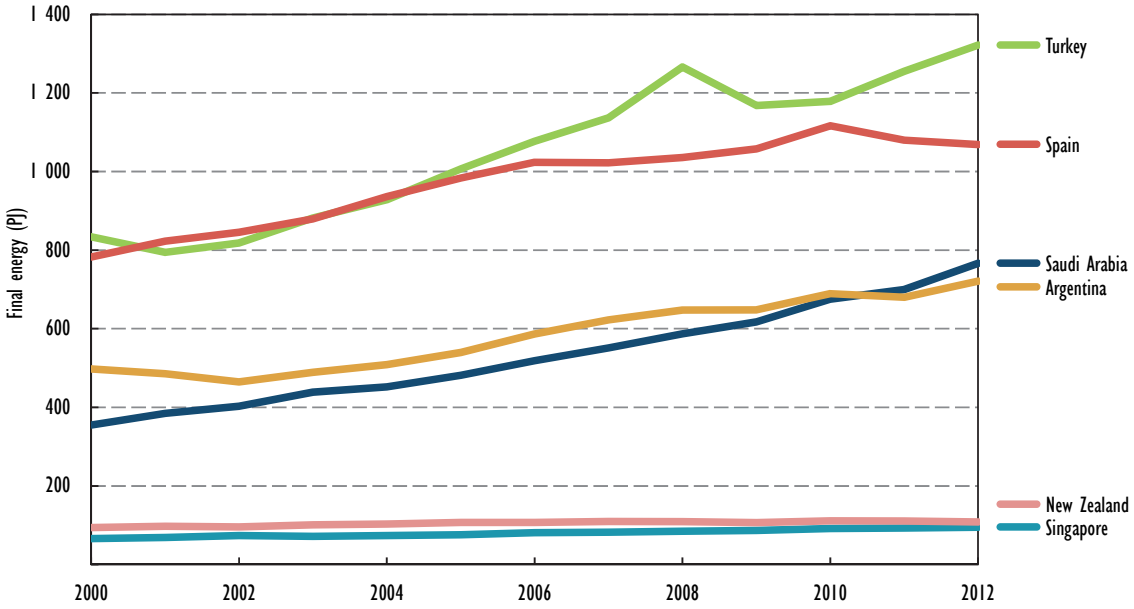
Key message • From 2000 to 2012, electricity use per floor area for the world and for MEF economies held nearly constant, while total energy use per floor area declined (Figure 14). Electricity use per floor area increased for most MEF economies, and grew the fastest in India, China and Indonesia. This is due in part to the increased penetration of appliances, electrical devices and air conditioning. The most pronounced declines in electricity use per floor area occurred in Canada and the United Kingdom.

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Additional G20 members and guests

Energy use

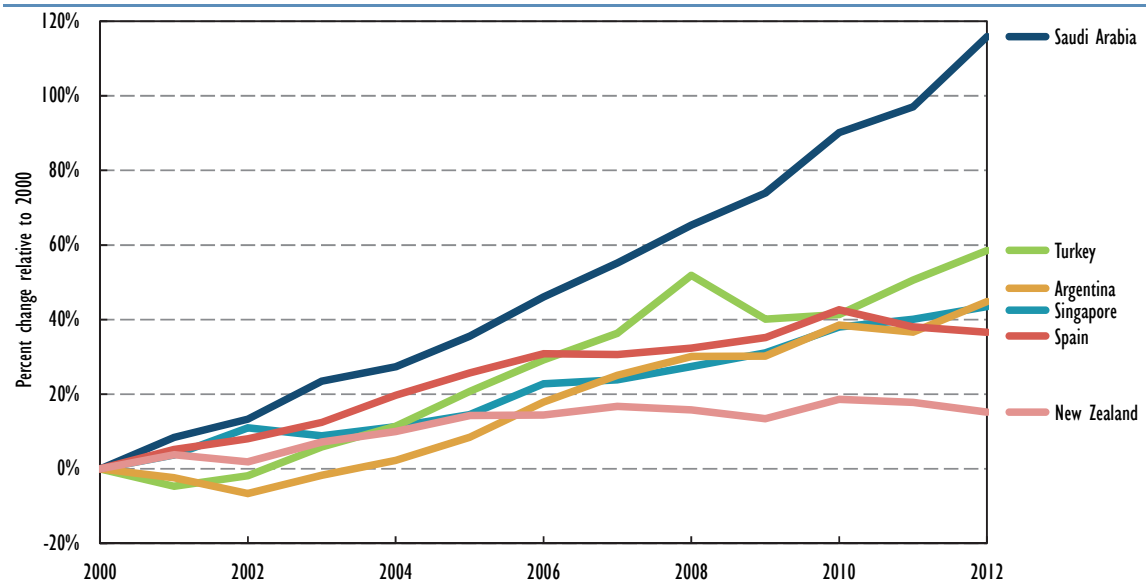
Figure 17 • Building energy use in G20 and guest economies, 2000-12



Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, building energy use varied among G20 members and guests beyond the MEF, owing in part to large differences in population and GDP – two of the major historical drivers of building energy use.

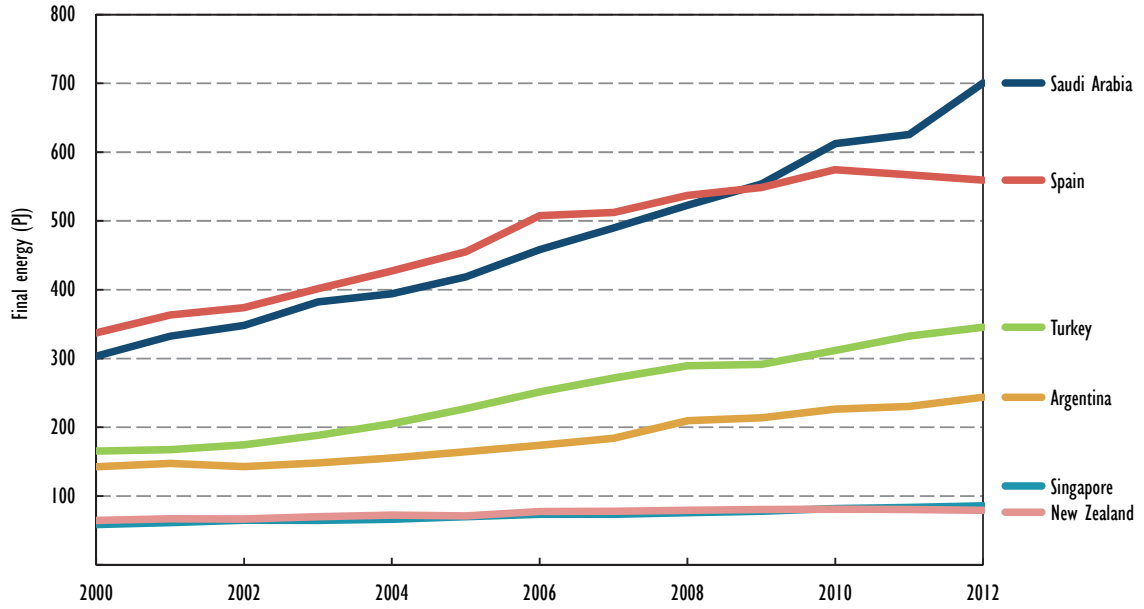
Figure 18 • Change in building energy use in G20 and guest economies, 2000-12



Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, building energy use increased for all G20 members and guests beyond the MEF. The growth rate was largest for Saudi Arabia and lowest for New Zealand.

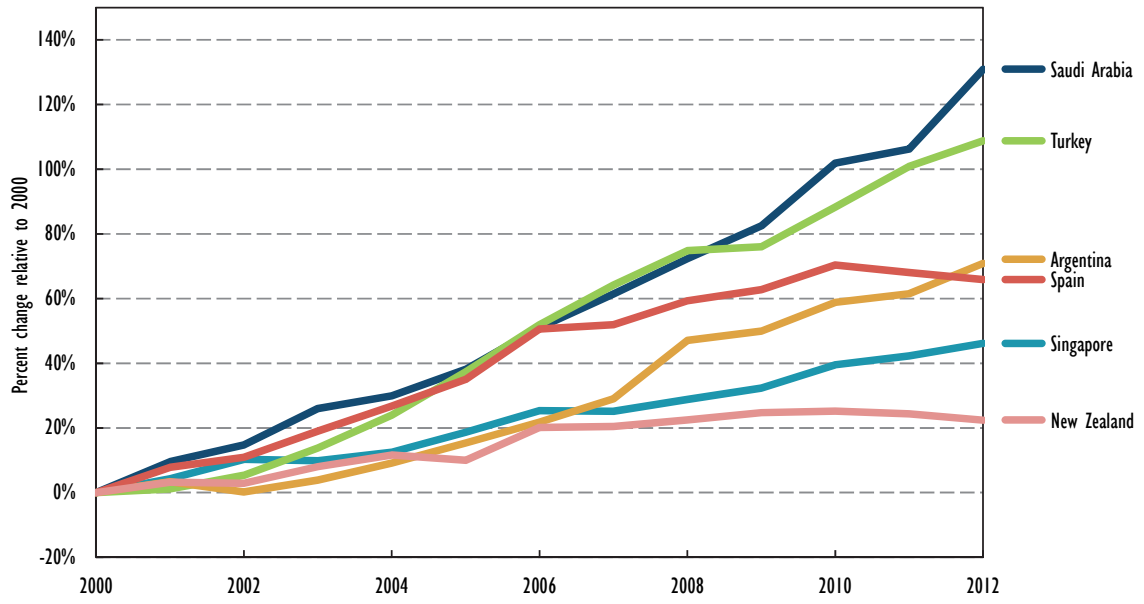
Figure 19 • Building electricity use in G20 and guest economies, 2000-12



Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2010, total building electricity use grew more rapidly than total building energy use in Saudi Arabia, Spain, Turkey and Argentina.

Figure 20 • Change in building electricity use in G20 and guest economies, 2000-12



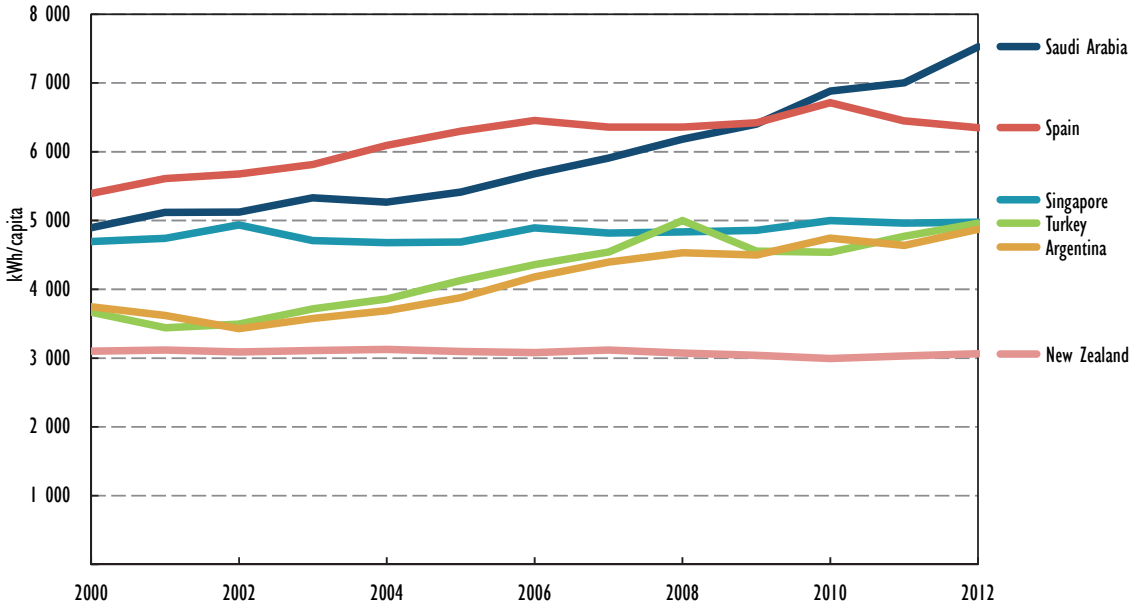
Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, electricity use increased for all G20 members and guests beyond the MEF, though with some stabilisation in Spain and New Zealand in recent years.

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Energy use per capita

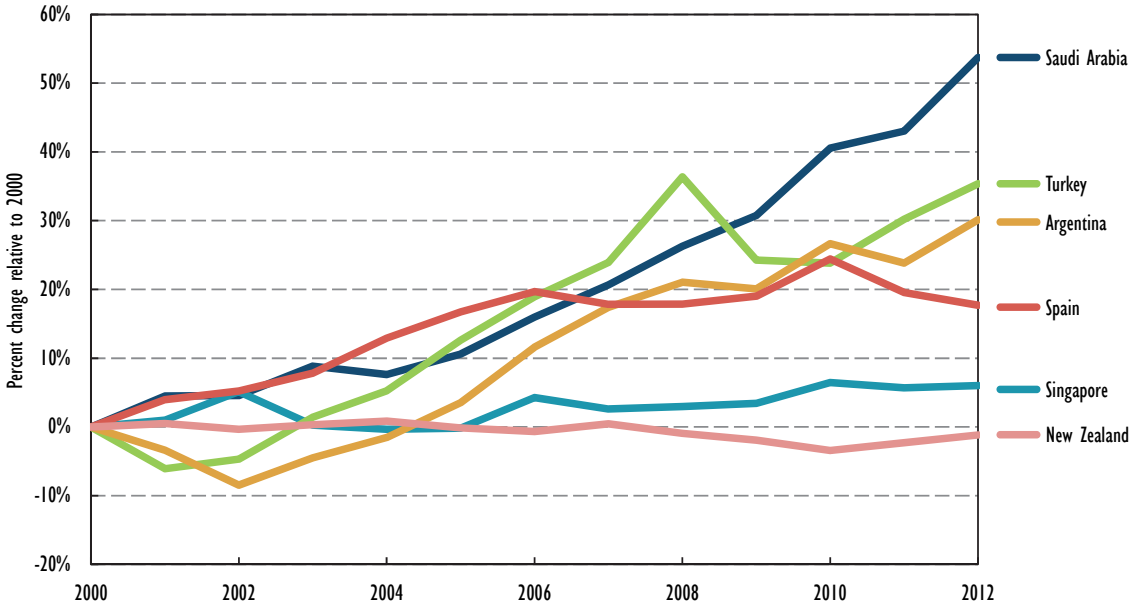
Figure 21 • Building energy use per capita in G20 and guest economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, energy use per capita varied considerably among the G20 members and guests beyond the MEF.

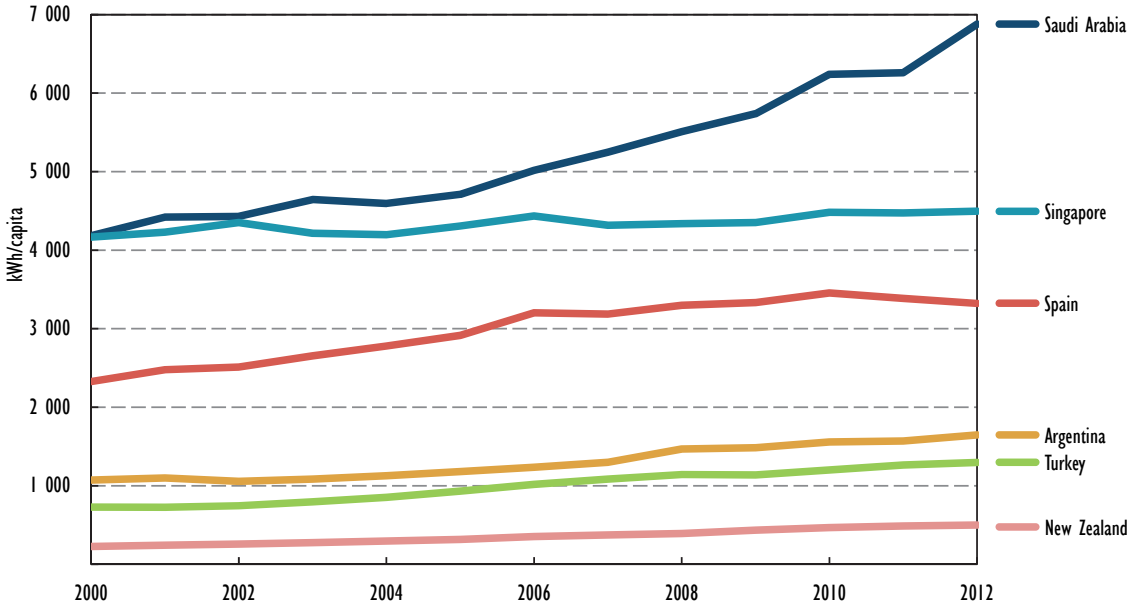
Figure 22 • Change in building energy use per capita in G20 and guest economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, energy use per capita increased considerably for Saudi Arabia, Turkey, Argentina and Spain. Energy use per capita was more stable in New Zealand and Singapore.

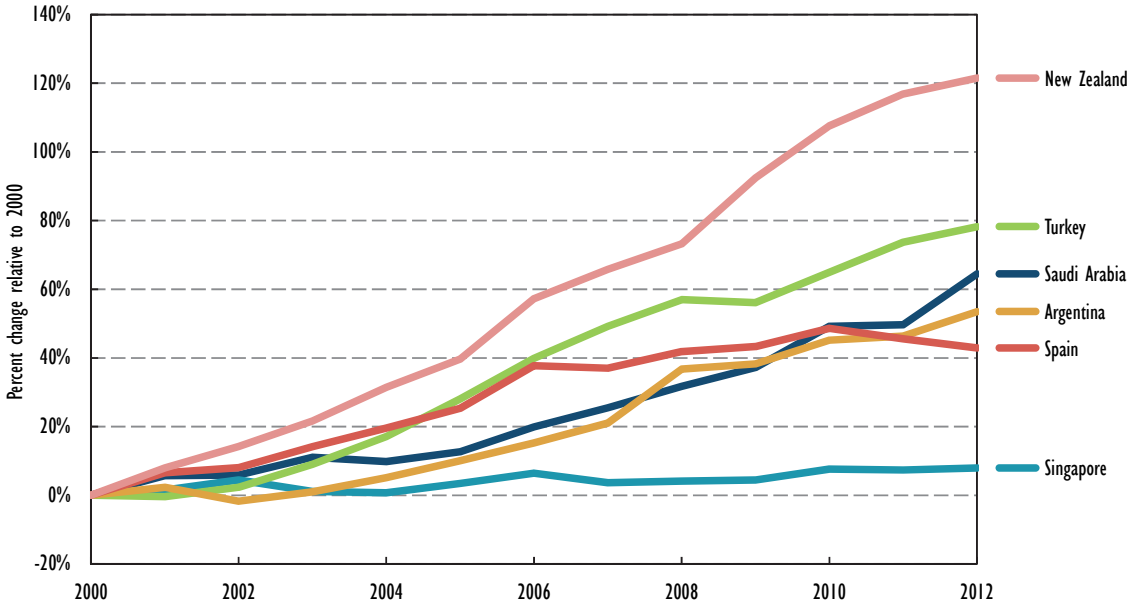
Figure 23 • Building electricity use per capita in G20 and guest economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, electricity use per capita varied considerably among the G20 members and guests beyond the MEF. Higher values in Saudi Arabia and Singapore are due in part to greater air-conditioning demand.

Figure 24 • Change in building electricity use per capita in G20 and guest economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • From 2000 to 2012, electricity use per capita increased for all G20 members and guests beyond the MEF. The growth rate was greatest for New Zealand, which started from a low base level in 2000 (Figure 23) and lowest for Singapore, which started from a higher base level in 2000 (Figure 23).

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Projected building energy trends

The following sections provide energy use and savings forecasts derived from IEA analysis for its *ETP 2015* publication, highlighting results from the MEF and G20 country groupings. The IEA assesses three core energy scenarios related to energy efficiency and emissions mitigation potential to 2050; these different climate scenarios result in average global temperature rises of 6°C to 2°C above pre-industrial levels. The 6DS is largely an extension of current trends. In the energy system described by the 2DS, climate science research suggests the emissions trajectory would allow at least a 50% chance of limiting the average global surface temperature increase to 2°C. The 2DS also identifies changes that would help ensure a secure and affordable energy system in the long run. It sets the target of cutting energy- and process-related CO_2 emissions by almost 60% in 2050 (compared with 2012) and ensuring that they continue to fall thereafter.

Energy consumption and savings forecasts

The IEA uses historical floor area per capita data and unique algorithms to derive future trends that were recently updated in collaboration with Tsinghua University (IEA, 2014c). Table 4 provides the population and floor area projections used in the modelling analysis. GDP forecasts are also critical to the development of energy forecasts (Annex F).

Table 4 • Forecasted population and floor area growth in MEF and G20 economies, 2012-50

Economy	Population (million) in 2012	Population (million) in 2050*	Change in population (%)	Floor area (million m^2) in 2012	Floor area (million m^2) in 2050**	Change in floor area (%)
World	7 030	9 475	34.8%	203 889	391 571	92.1%
MEF 17	4 439	5 057	13.9%	152 477	267 716	75.6%
Australia	23	34	46.4%	1 668	2 729	63.6%
Brazil	199	231	16.3%	3 937	9 384	138.4%
Canada	35	45	29.8%	2 644	3 865	46.2%
China	1 384	1 393	0.6%	49 583	83 642	68.7%
European Union	508	512	0.6%	27 917	34 001	21.8%
France	64	73	14.5%	3 461	4 594	32.7%
Germany	83	73	-12.4%	5 133	5 330	3.8%
India	1 237	1 620	31.0%	13 994	52 756	277.0%
Indonesia	247	321	30.2%	4 081	11 882	191.2%
Italy	61	60	-1.4%	3 182	3 762	18.2%
Japan	127	108	-14.9%	6 674	7 213	8.1%
Korea	49	51	4.1%	2 760	3 508	27.1%
Mexico	117	156	33.4%	5 560	10 331	85.8%
Russia	143	121	-15.6%	4 189	5 737	37.0%
South Africa	52	63	21.0%	1 209	2 834	134.4%
United Kingdom	63	73	16.5%	3 609	4 712	30.6%
United States	318	401	26.3%	28 263	39 834	40.9%
Remaining G20	143	186	30.1%	--***	--	--

Note: The IEA and Tsinghua University have done extensive research on residential floor area projections (IEA, 2014c).

* Population forecasts: UN DESA (2013), *World Population Prospects: The 2012 Revision, Medium-Fertility Variant.*

** Floor area forecasts used in IEA buildings model.

*** Floor area projections for G20 economies are currently only available at more aggregate regional levels.

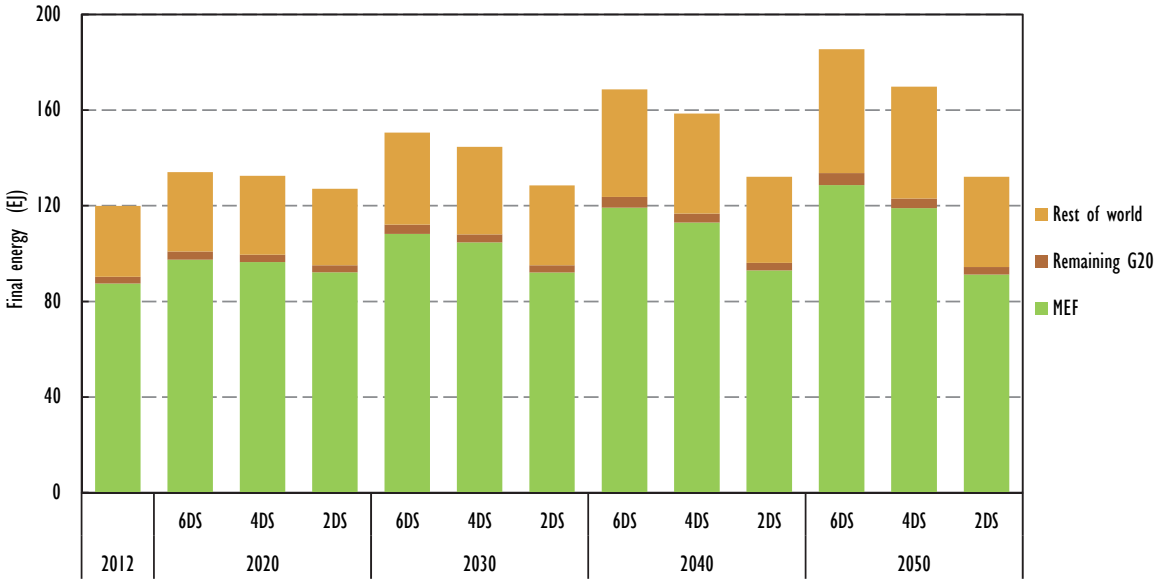
Source: IEA and Tsinghua University joint research forecasts.

For the period 2015 to 2050, the following energy consumption and savings potential are forecasted for buildings (Figures 25 to 28):

- Forecasts of energy savings potential show that in the IEA 2DS, the MEF as a whole could reduce annual building energy use by 37 EJ (a 30% reduction) by 2050 relative to the 6DS. The remaining G20 economies could achieve additional annual energy savings of 2 EJ by 2050.
- MEF member economies could account for approximately 70% of cumulative projected global building energy savings potential between 2015 and 2050. The remaining G20 economies could save an additional 4% of the global potential.
- Forecasts of electricity savings potential show that in the IEA 2DS, MEF economies could collectively reduce annual building electricity use by 18 EJ (a 33% reduction) by 2050 relative to the 6DS. The remaining G20 economies could achieve nearly 1 EJ of additional annual electricity savings by 2050.
- The MEF could account for 76% of cumulative projected global electricity savings potential between 2015 and 2050. The remaining G20 economies could save an additional 3% of the global potential.

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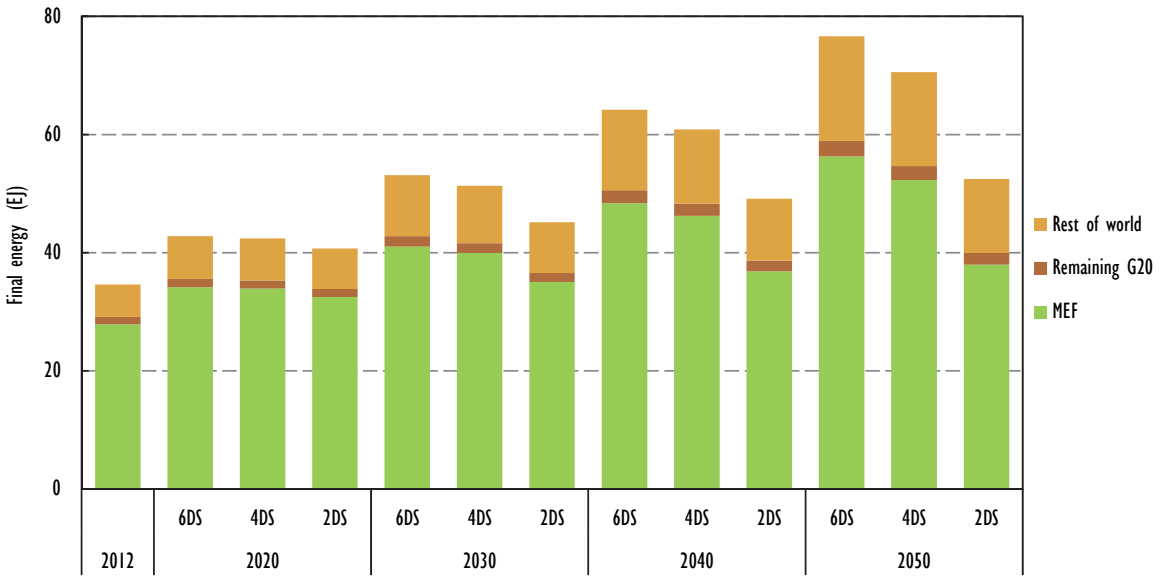
Figure 25 • Building energy scenario forecasts for world, MEF and G20 economies to 2050



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • MEF and G20 economies account for major portions of the projected world building energy use through 2050. Without new policy measures, total MEF building energy use could grow from 87 EJ as of 2012 to 129 EJ in 2050 under the 6DS.

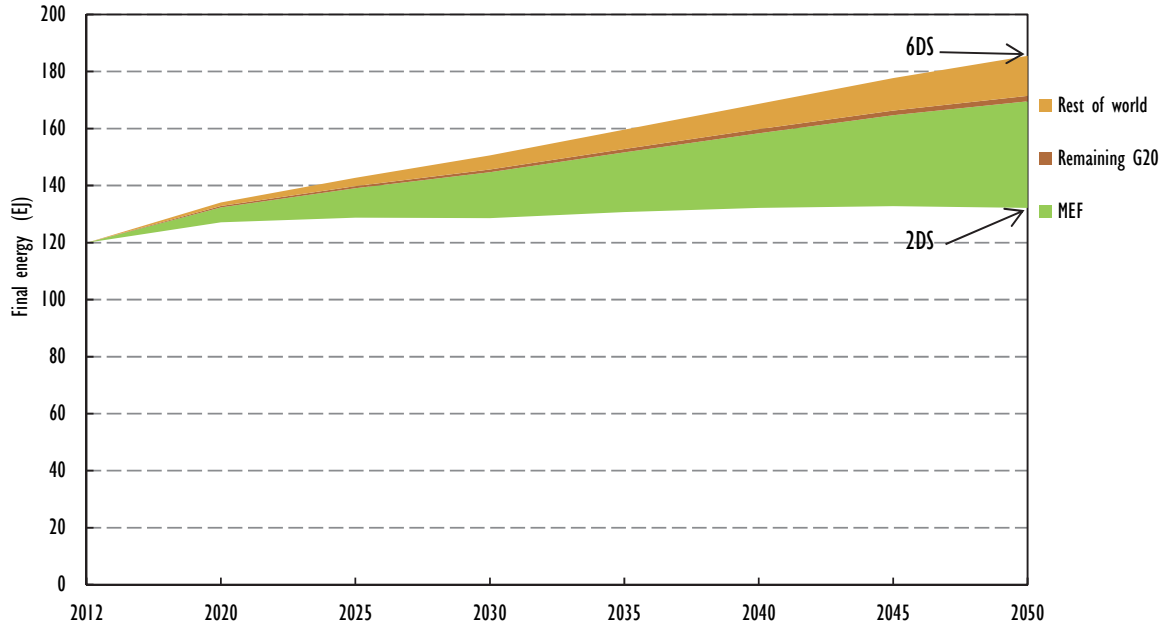
Figure 26 • Building electricity scenario forecasts for world, MEF and G20 economies to 2050



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • MEF and G20 economies account for major portions of the projected world building electricity use through 2050. Without new policy measures, total MEF building electricity use could grow from 28 EJ as of 2012 to 56 EJ in 2050 under the 6DS.

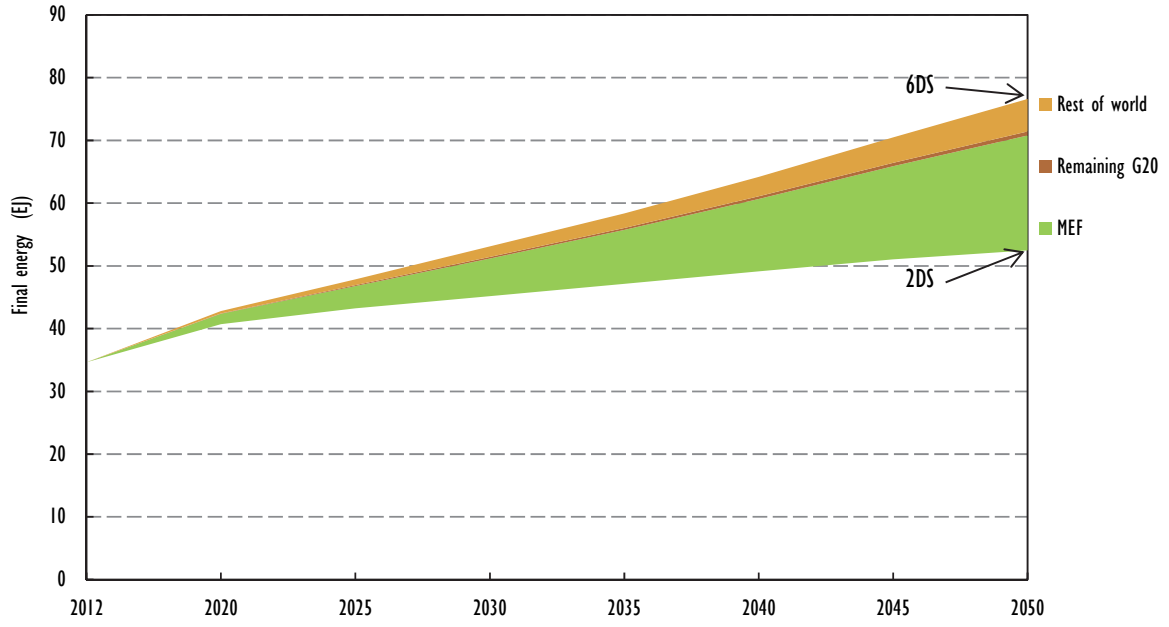
Figure 27 • Building energy savings for world, MEF and G20 economies, 6DS to 2DS to 2050



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • The annual energy savings potential (the difference between the 2DS and the 6DS) from the buildings sector for MEF and G20 economies is estimated to be 39 EJ in 2050, and with the rest of the world, total global savings reach 53 EJ in 2050.

Figure 28 • Building electricity savings for world, MEF and G20 economies, 6DS to 2DS to 2050



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Key message • The annual electricity savings potential (the difference between the 2DS and the 6DS) from the buildings sector for MEF and G20 economies is estimated to be 19 EJ in 2050.

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Advancing metrics for very low-energy buildings and deep energy renovations

Background

Lowering building energy use in both new and existing buildings is a high policy priority among MEF economies. In many mature, developed economies, 75% to 90% of existing building stock is likely to still be in service in 2050. In these countries, it will be essential to pursue policies for assertive energy renovations in existing stock to achieve large energy savings. Building codes for new constructions are needed in all G20 member countries, especially in fast-growing markets.

To achieve the full savings potential in buildings, some governments have started to set targets for VLEBs and DERs. Building energy codes for new constructions and for major building refurbishment are a critical policy lever for advancing VLEBs and DERs. A separate IPEEC BEET project focuses on priorities for international collaboration on building energy code implementation. In the present report, the focus is not on policy but instead on the key challenges and recommended steps to advancing VLEB and DER metrics.

During development of the BEET 2 report, government and non-government energy efficiency experts suggested that, beyond the broad metrics such as building energy use per capita and per floor area, metrics for understanding and tracking progress towards VLEB and DER goals would be useful, though further development and additional data are required for the elaboration of these metrics. While significant work on VLEB and DER development has been done in some MEF economies, there are significant differences in approaches and in the interpretation of terms from one country to the next.

There has been substantial policy activity related to VLEBs and DERs in some MEF economies. This is especially true in Europe, where mandates have been established for European member states to move rapidly towards “nearly zero-energy buildings” for all new building construction by 2021; for renovation plans established from 2014, the European Commission requires the “deep renovation” of existing buildings. In the United States and some other MEF economies, the focus has been on developing technologies and establishing high-efficiency markets for “net zero-energy” or “net zero-ready” new buildings. Another related term that is gaining popularity in some countries is “ultra-low-energy.” Because of these differences, the current BEET work uses the term “VLEB” to avoid any confusion with the different definitions tied to “zero-energy buildings.” Comparing relative progress from these policies is impossible, however, because there are no internationally recognised metrics based on consistent definitions.

Building energy performance policies and targets in Europe generally focus on thermal energy building loads which control heating and cooling. In some cases, lighting loads (mainly for commercial buildings) or domestic hot water loads (generally for residential) may also be considered. Policies and other initiatives encouraging VLEBs in the United States usually look at all energy end uses in the building, including plug loads. Understanding which end uses are included in a definition of energy performance is especially important because energy consumed in buildings is increasingly for end uses other than space heating and cooling. In the United States, for example, heating and cooling now represents well under 50% of building energy demand. Another key differentiation can be the “energy boundaries” for inclusion in reporting and energy targets.

Box 1 • VLEB implementation

In Europe, the recast Energy Performance of Buildings Directive (EPBD)* provides a framework definition for nearly zero-energy buildings (nZEBs). As determined by the general framework for the calculation of energy performance of buildings laid down in Annex I of the recast EPBD, nZEBs are buildings that have a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.

By the end of 2020, all new buildings in Europe must be nZEBs (by the end of 2018 for buildings owned and occupied by public authorities), and member states must stimulate the transformation of existing buildings into nZEBs through refurbishment. The specific requirements of what constitutes an nZEB must be developed by each of the member states, and include a numerical indicator of the primary building energy use, expressed in kilowatt hours per square metre per year (kWh/m²/y). Member states have already developed their nZEB roadmaps.

A study conducted in 2013 by the consulting firm Ecofys, for the European Commission, concluded that a very low level of energy for heating and cooling is a vital pre-condition for nearly zero primary energy buildings (Hermelink, A. et al., 2013). In that respect, by 2021, a cost-optimal, nearly zero-energy building could be defined as a building for which the energy need for heating and cooling is less than 30 kWh/m²/y.

Upon request by the European Commission, in October 2014 Ecofys prepared a report on the progress of member states in delivering on nZEB targets by 2019 and 2021 (Groezinger, J. et al., 2014). The report indicated progress had been made in providing the necessary definitions and guidance, but that significant work remained.

Similar overview work looking more broadly around the world was done as part of an IEA joint project between the Energy in Buildings and Communities Programme Annex 52, and the Solar Heating and Cooling Programme Task 40. The project studied current net zero-, nearly zero- and very low-energy buildings, and how to develop a harmonised international definitions framework, tools, innovative solutions and industry guidelines.**

Several MEF economies also participated in a recent Asia-Pacific Economic Cooperation (APEC) Energy Working Group project on "Nearly (Net) Zero-Energy Buildings," led by the China Academy of Building Research as Secretariat but with significant input from – and review of the state of activity in – the United States, Japan and Korea. The project found that Japan, Korea and the United States have issued policies and set up clear and aggressive goals for nZEBs, and Japan and Korea have established financial and taxation policies to stimulate development. The findings also noted different definitions among countries (and even within some of the APEC countries) for nZEBs, and highlighted current obstacles and barriers to wider market penetration of nZEBs.

Separately, in late 2014 the United States Department of Energy (US DOE) released for public comment a document proposing a common definition for zero-energy buildings (ZEBs) in the services sub-sector (commercial buildings).*** With increasing market attention on ZEBs (and "net" ZEBs, for which any energy needs for the building are provided by on-site renewable generation), along with a growing number of state and local policy initiatives aimed towards ZEB growth, the US DOE hopes to set a national definition to avoid the confusion entailed by the variety of interpretations of ZEBs. It remains to be seen whether that definition will be adopted beyond the United States.

* European Commission Directive 2010/31/EU.

** More information about this project is available at www.task40.iea-shc.org.

***"A Common Definition for Zero Energy Buildings", November 2014, US Dept. of Energy Building Technologies Office.

Some MEF member countries have noted that, while the need for common metrics in the European Union is understandable, the benefit for other MEF (or G20) countries of measuring and tracking progress towards these evolving policies is still unclear (though this may change as more countries develop and adopt VLEB and DER policy frameworks).

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Box 2 • DER implementation

While there is interest in DER around the world, policy activities are most advanced in Europe. Actions by the European Commission to mobilise investment in deep renovations are mandated in accordance with Recital 16 of the Energy Efficiency Directive, which states that "cost-effective deep renovations lead to a refurbishment that reduces both the delivered and final energy use of a building by a significant percentage compared with the pre-renovation levels leading to a very high energy performance." * Such deep renovations could also be carried out in stages.

The EU member states' long-term strategies for mobilising investment in the renovation of the national building stock (Article 4 of the Energy Efficiency Directive) must encompass policies and measures to stimulate cost-effective deep renovations of buildings, including staged deep renovations.

In parallel with the incentive to stimulate investments in deep renovation, the recast EPBD (Directive 2010/31/EU) provides a definition for major renovation. Member states must set minimum energy performance requirements for buildings that undergo a major renovation with the view to achieving cost-optimal levels.** Member states must take all necessary measures to ensure that when a building undergoes a major renovation, these minimum energy performance requirements are met.

* European Commission Directive 2012/27/EU.

** The EPBD Recast (Directive 2010/31/EU) defines the "cost-optimal level" as "the energy performance level which leads to the lowest cost during the estimated economic lifecycle."

VLEB and DER metrics issues

Metrics based on universal definitions for types of VLEBs and DERs would be useful for understanding progress towards policy goals; however, widely differing definitions prevent meaningful comparison metrics at present. Even in the European Union, where discussion is the most advanced (and the EPBD has mandated member states to prepare national implementation plans defining key terms), there is a wide variety of definitions among member states – as revealed in the recent report by Ecofys on nZEBs (Figure 29). However, a better understanding of what is meant by DER in the European Union should be possible when analysis of the renovation strategies submitted by member states is finalised.

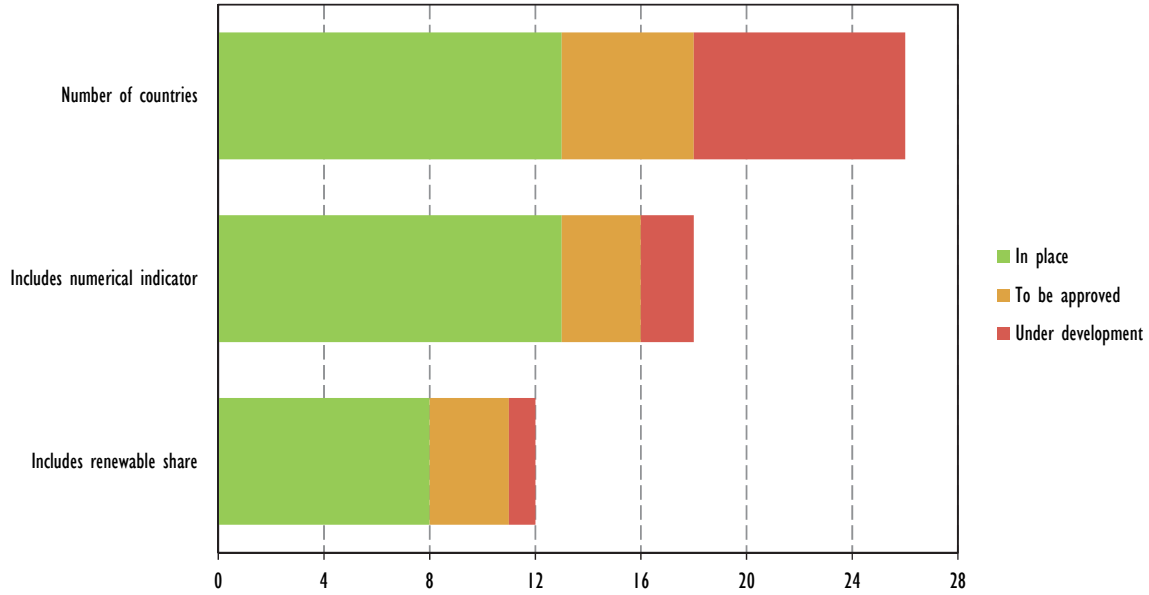
Without common definitions for nZEBs or ZEBs in place in all countries or regions, or even among EU member states, it seems premature to consider VLEB and nZEB metrics that could compare progress in different regions. At the moment, however, the timelines needed to achieve nZEBs and DERs can feasibly be compared.

The development of common metrics for DERs would also further work on definitions. While there is great interest in the energy savings potential of "deep" renovations (or retrofits), there are varying levels of stringency and scope in definitions among MEF economies. As an example, in many European countries the expectation is that a "deep" retrofit reduces energy use by 60% to 90% (BPIE, 2013), while in the United States it is more widely considered that a deep retrofit reduces building energy use by 45% (though in Europe the savings are often just in heating and cooling energy, while in the United States it means savings in the whole building's energy use, including all end uses). That is a significant difference, and one that makes deep retrofits seem much more difficult to certain stakeholders. Moreover, energy use reductions may be based on different end uses, further complicating evaluations of progress from policies in different countries.

In 2013, the Global Buildings Performance Network (GBPN) conducted a global survey of building energy experts and prepared a comprehensive summary report entitled "What is a Deep Renovation Definition" (GBPN, 2013). The project concluded that there is the need for a better, clearer and more harmonised definition of deep renovation (DR). The expected conditions and general definition of a DR vary significantly among the regions, especially between the European Union and the United States.

Given the variety of definitions, and lack of any sign that key definitions will be harmonised in the near future, developing metrics to measure and track progress towards VLEB and DER policy implementation and market penetration seems unrealistic until there is more consistency in terminology, or metrics have been designed to quantify and translate energy savings from VLEB and DER policy activity.

Figure 29 • Status of EU member state definitions for nZEBS as of 2014



Note: Two EU countries have not provided a report to the European Union.

Source: Adapted from Groezinger, J. et al. (2014), "Overview of member states information on nZEBs; working version of the progress report – final report", Ecofys, October.

Key message • As of 2014, EU member state definitions for nZEBs varied, with some specifically including renewable energy and numerical indicators and others not including these elements.

Potential collaboration on VLEB and DER issues

Although the proper development and tracking of common metrics for VLEBs and DERs requires harmonised definitions and consistent measurement approaches, the growing level of activity in this area suggests opportunities for future collaboration. Collaboration activities to be considered include:

- mapping the definitions of VLEBs and DERs used in all MEF and G20 economies
- mapping policies and measures, including those proposed and implemented in MEF and G20 economies, encouraging the construction of VLEBs
- from this mapping, developing a better understanding of how to quantify relative energy savings from VLEB and DER policy activity
- collaborating on tracking the progress of policy implementation, and evolving common metrics (possibly in ISO standards)
- mapping progress in VLEB and DER market penetration in government buildings, where compliance is often required earlier than in the broader private building marketplace.

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Recommendations for future work

Focus areas

Through analysis and project input from government representatives and non-governmental experts, a number of opportunities for further work were identified. These follow-up activities could further support governments in formulating, implementing, and evaluating policies that will help realise the energy savings potential in the buildings sector. Enabled by the international sharing of best practices and collaborative capacity-building, countries could take the following actions:

Improve data availability and quality

- Enable the development of more robust metrics by building capacity in the governance and management of building energy data.
- Improve the measurement of progress and opportunities in building energy performance through increased collection, analysis and sharing of data.
- Improve building energy data consistency and comparability through working groups aimed at co-ordinating better data collection and collaborating on the development of common definitions for key metrics.
- Improve the quality of benchmark and energy performance disclosure, and establish processes to evaluate efficiency improvements and policy effectiveness.

Develop and track additional metrics

- Demonstrate leadership by developing and tracking energy performance metrics for government buildings.
- Establish processes for tracking the spread of VLEBs and DERs and associated energy savings.
- Develop building sector metrics for primary energy use and associated carbon emissions.
- Quantify the multiple benefits of improved energy efficiency in buildings (e.g. financial, economic, health, and environmental benefits).
- Develop building energy performance metrics to inform policy design and implementation at the level of end uses (e.g. space heating and cooling, lighting and electronics), building types (e.g. office buildings), and building products and materials.

Model future energy use

- Identify key areas for improvement in building energy performance by modelling the energy savings associated with major policy interventions and technology adoption.
- Improve the analytical basis of building energy policy design and implementation by improving the quality of forecast modelling tools and data.
- Quantify the potential reductions in carbon emissions associated with the building sector for future policy and technology scenarios.

IEA and IPEEC support for implementation

MEF and G20 economies working together could expand the IEA's current EEI work to ensure greater support for the development and tracking of building energy performance metrics. Each country could provide technical staff to work on its specific data availability and quality issues, and participate in collaborative international projects in the focal areas mentioned above.

IPEEC and the IEA should also continue to facilitate dialogue and data exchanges with other organisations and initiatives to advance the development of metrics. Endeavours in this area include the IPEEC Improving Policies through Energy Efficiency Indicators (IPEEI) Task Group, the Asia-Pacific Economic Cooperation Expert Group on Data and Analysis, the Asia Pacific Energy Research Centre (APERC), EUROSTAT and its energy community group, the European Union's ODYSSEE database, and the World Energy Council (WEC).

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Annex A. Data availability and quality

The development of building energy performance metrics for countries and regions is challenging, with a variety of data availability and quality challenges. Metrics can be very useful for revealing trends and opportunities for savings, but the reliability of some data sources needs to be considered.

The data challenges presented below highlight current limitations and areas for future collaborative work.

Energy use data

- The IEA collects extensive energy balance data globally that has fuel share proportions for the residential and services sub-sectors. While this data collection involves extensive interactions with government agencies and validation, in some cases in which data is lacking, especially in smaller emerging markets, fuel and sub-sector shares are derived using a variety of statistical methodologies.

Floor area

- Globally, there is a lack of common definitions; the IEA international repository for collection and review currently has limited resources and only a portion of its members participating. For this project, the IEA energy efficiency indicator (EEI) programme has been the source for floor area data. Information for the EEI programme is supplied by IEA member countries and the ODYSSEE-MURE database, and is supplemented by IEA estimates when data are missing or obviously incorrect.
- The information collected and reported from different countries is inconsistent, and most countries lack good time-series floor area data. Uniform sources of data from individual countries can be valuable to compare trends, even if differing definitions of floor area make it less appropriate to compare among countries.
- Floor area estimates are most problematic for the services sub-sector; while periodic census data in most countries reflects reasonable residential floor area estimates, most countries have no consistent way of measuring and collecting non-residential floor area data. Significant improvement in data collection and comparability is needed for the services sub-sector's energy per floor area to be a more useful metric.

Number of households

- There is no common international reporting format that provides comparable estimates of occupied relative to unoccupied households, which can skew this metric as unoccupied buildings generally use significantly less energy than occupied buildings. This discrepancy is compounded for economies which have a large number of second/vacation homes per family, which are only occupied and/or air-conditioned a portion of the year.
- In some emerging economies, only a portion of the housing stock is electrified, which also has a large impact on per household metrics. Similarly, in some moderately temperate climates, only a portion of residences are fully space-conditioned (with heat and/or cooling throughout the building); this is another factor that can impact per household metrics.

Normalisation factors for service sub-sector building energy use

- While the number of households or the overall population are good normalisation factors for residential energy use, relying on only these factors masks major structural differences in economic activity and splits between service sub-sector building use and other sectors of the economy (especially level of industrial energy use), making non-residential energy use per capita or household not particularly meaningful.
- Potential normalisation factors, such as number of service sub-sector employees or services' GDP or value-added, are more relevant, but no common data collection or reporting methodology, or repository, exists. Additional research to attain better data on these other factors could be very helpful in understanding progress in the non-residential sub-sector.
- Relative to the residential sub-sector, there is sometimes a lack of consistency on what is included in the services sub-sector: some economies include street and other outdoor lighting as part of services, while others do not. Again, more clarity on what is included, and what can therefore be compared, would be helpful.

Detailed metrics based on end uses

- Metrics based on end uses can provide valuable information on potential energy savings, though virtually all end-use breakdowns are estimates (not measured or metered). As such, there is very little true comparability or consistency in the methodology or estimations. Because precise metrics can provide better detail about the impacts of specific policies, additional work to make the detailed metrics more relevant could be very useful.

Because of these (and other) data quality challenges, some of the metrics presented in this report may encompass different data from that presented by other sources. All of the data presented in this report are based on the IEA energy balance and energy efficiency indicator information collected in collaboration with IEA member and partner countries.

Where there were known data quality problems (e.g. Russia and South Africa), those data were not included in the figures to avoid showing inconsistent information. During this project, the IEA conducted extensive peer reviews and continues seeking input to improve the quality of the data. As necessary, data are adjusted by the IEA.

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Annex B. Metrics framework

Conceptual building energy performance metrics framework

To understand the development of building energy performance metrics, a simple conceptual framework is instructive. The framework uses four basic metric parameters: input, output, scope, and normalisation factors (Table B1). The input is the amount or cost of the energy by fuel source; this could be expressed as final (also known as delivered or site) energy, or as primary energy, or as the cost of energy. The output reflects the service provided by the energy, and can include the building space (floor area) served, the number of people or number of buildings served, or the amount of cooling and heating provided. The scope is a classification of the metric, such as the portion of the buildings sector under consideration (e.g. the entire buildings sector, or certain building types, or energy end uses). Finally, the normalisation factors are used to modify the basic input-per-output metric values, such as economic purchasing power differences among regions, climate differences that impact heating and cooling energy use, and change in time relative to a reference or base year (for additional detail, see the description of normalisation below).

Table B1 • Conceptual framework for the development of building energy performance metrics with examples for metric parameters

Inputs	Final energy (total, electricity, gas, etc.) Primary energy (total, electricity, gas, etc.) Energy cost (total, electricity, gas, etc.)
	Per
Outputs	Persons served (total population, occupants, employees, etc.) Floor area served (total, occupied, heated, cooled, enclosed) Buildings served (total, grid-connected, etc.) Service level provided (amount of heating, cooling, lighting, etc.) Economic value (GDP, property value, etc.)
	For
Scope	Sector (all buildings, residential sub-sector, services sub-sector [commercial and public]) Building types (single-family, multi-family, office, healthcare, etc.) End uses (heating, cooling, water heating, lighting, appliances, cooking, etc.) Region (country, state, city, etc.)
	Normalised by
Normalisation factors	Climate (ground temperature, heating degree days, cooling degree days) Economic indicators (purchasing power parity, currency, etc.) Time (percent change from baseline date, lifecycle)

Normalisation

Normalisation factors are used in addition to the basic input-per-output metrics to better understand how building energy performance is impacted by additional factors that affect energy inputs or outputs. The most commonly used normalisation is weather normalisation, either (1) temperature correction (also known as weather correction), comparing multiple years for a single region, or (2) climate normalisation, comparing multiple regions. In addition to weather normalisation, this framework shows examples of economic and time-based normalisation factors.

Temperature correction vs. climate normalisation

The temperature correction for a single region is described in detail in Annex C of the IEA *Energy Efficiency Indicators: Fundamentals on Statistics*.[12] The climate normalisation used to compare multiple regions in the US Environmental Protection Agency's "ENERGY STAR Portfolio Manager: Technical Reference – Climate and Weather" is described by the US EPA as accounting for climate (for climate normalisation) and for weather (for temperature correction).[13]

Temperature correction

The purpose of temperature correction is to be able to reduce the impact of varying seasonal outside air temperatures when calculating energy consumption; comparisons are based on the average temperature for a specific or regional location. This temperature correction is typically done through the use of heating degree days (HDD)[14] or cooling degree days (CDD). In this report, we adjusted seasonal space heating consumption by applying the variation of HDD when data was available. For example, if a year has 3 000 HDD and the annual 30-year average HDD is 2 700, the temperature-corrected energy consumption for space heating would be divided by the ratio of 3 000/2 700. This would result in the amount of heating energy consumption figured into the historical energy calculation being only 90% of the actual energy consumption for that year.[15]

Climate normalisation

For climate normalisation, the variation in HDD and CDD between regions is compared. For example, if the first region has an average of 5 000 HDD and the second region has an average of 2 500 HDD, climate normalisation would expect the first region to have double the heating energy consumption of the second region. When comparing the two regions after climate normalisation, the heating energy consumption of the first region would be reduced by 50% compared to that of the second region; this comparison helps analysts understand how much heating energy consumption is occurring with equivalent HDD. This report does not include climate normalisation; however, in Annex C, it does present an example of a detailed metric that shows residential energy consumption that excludes space heating and cooling.

Ground temperature normalisation

Ground temperature normalisation is similar to climate normalisation, except that ground temperature normalisation is used for water-heating energy normalisation.

Economic normalisation

Economic normalisation can be used to understand how differences in economic factors between regions impact the basic input-per-output metrics. Examples include the commonly used purchasing power parity (PPP), which is used to normalise historic data or forecasts with respect to economic spending capacity (relative to a set purchasing power). Other economic factors can be used, such as currency valuation; however, PPP is the most common economic normalisation and is used by the IMF for the GDP data that is sourced in this report.

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[12] www.iea.org/publications/freepublications/publication/IEA_EnergyEfficiencyIndicatorsFundamentalsonStatistics.pdf.

[13] https://portfoliomanager.energystar.gov/pdf/reference/Climate%20and%20Weather.pdf.

[14] HDD refers to the total seasonal heating requirements needed to maintain a desired temperature setting, compared to the average daily temperature (either actual or historical average). Desired or set temperatures vary by preference and consumer behaviour, but design engineers usually follow a standard protocol by country or region. For example, if a desired temperature were 20°C and the average daily temperature was 5°C, there would be 15 HDD for that day. All days with a heating load are summed up to derive total HDDs for the heating season that have large variations based on climate.

[15] www.iea.org/publications/freepublications/publication/IEA_EnergyEfficiencyIndicatorsFundamentalsonStatistics.pdf.

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Time-based normalisation

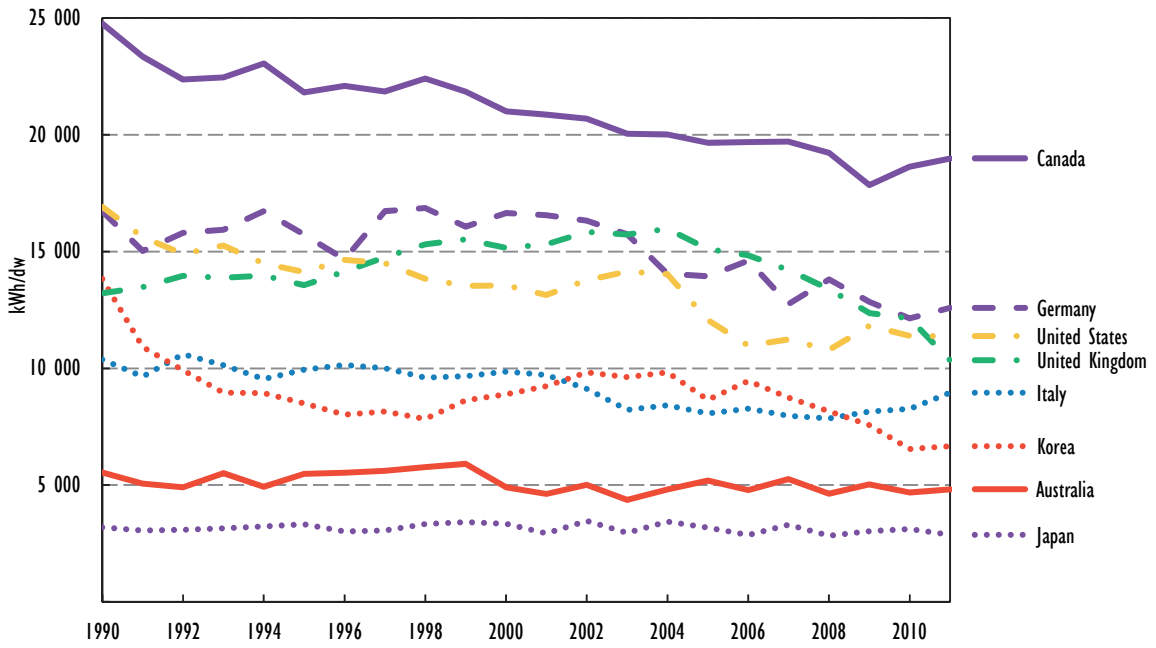
Time-based normalisation can be used to understand how energy use has changed relative to a baseline year, as is done in this report. Another option that has not been used is to normalise the basic input-per-output metric with a lifecycle valuation of energy impacts of the policy decision being analysed.

Annex C. Detailed metrics

Using additional metric parameters from Table B1 in Annex B, other detailed metrics can be developed. This section includes examples of detailed metrics using end-use energy data: residential space-heating energy per dwelling (Figure C1), residential water heating per dwelling (Figure C2), and residential energy use excluding space heating and space cooling (Figure C3). This last example illustrates one approach to removing the components of energy use that are most strongly tied to climate. Residential water heating use is also somewhat dependent on climate, for example because of thermal comfort demands and impacts on the temperature of the water entering the home.

Another metric comparison approach for climate impacts on energy use would be to cross-reference the climate-dependent energy use data with the climate data. This additional comparison has not been completed for this report; however, it could be done in future work. The cross-referencing of climate-dependent energy use could include using heating energy versus HDD per country, and cooling energy versus CDD per country. With large countries such as the United States and China, additional disaggregation of the data would be needed to make a meaningful comparison, such that the energy used within the hot regions of the country would be analysed separately from the energy used in the mixed or cold regions of the country. In future work, this analysis could use climate zone definitions, along with metropolitan-level data, to compare energy use across various climates. For smaller countries in which the climate is consistent, analysis could apply to the country as a whole.

Figure C1 • Residential space-heating energy use per dwelling

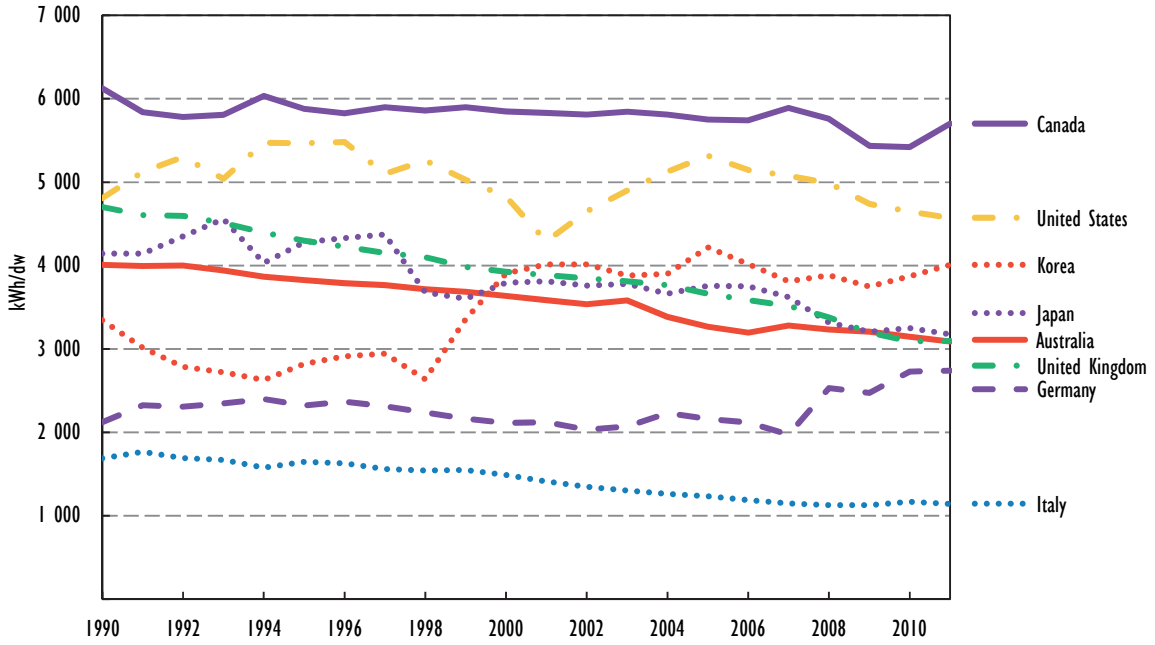


Note: dw = dwelling.

Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

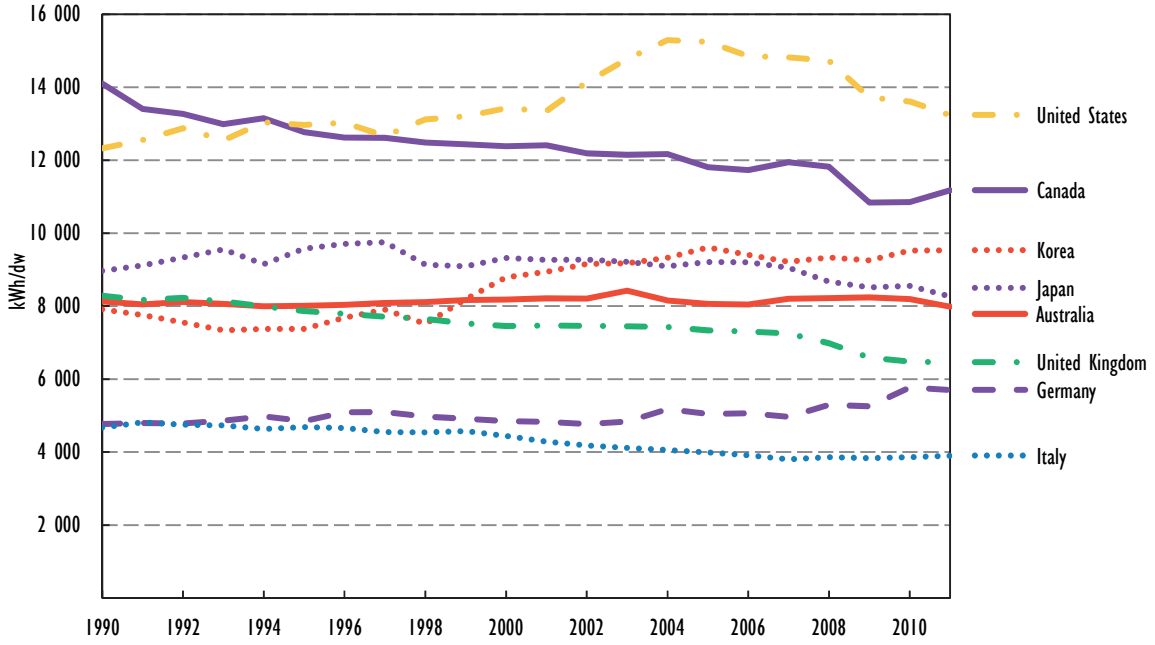
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Figure C2 • Residential water-heating energy use per dwelling



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

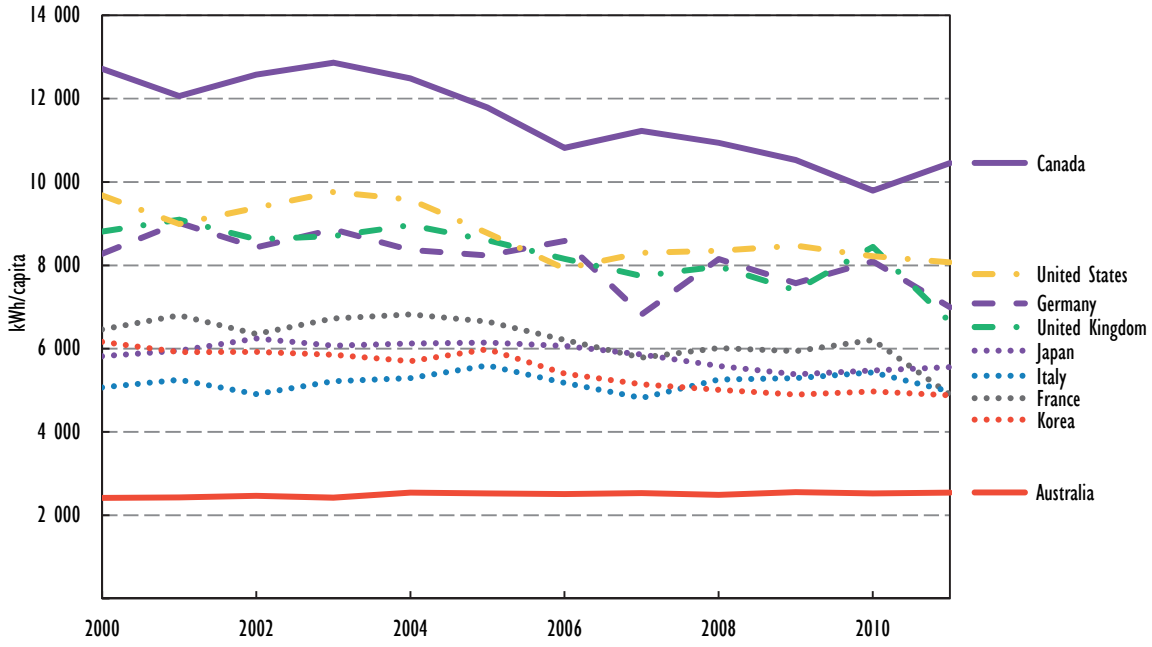
Figure C3 • Residential energy use per dwelling excluding space heating and cooling



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

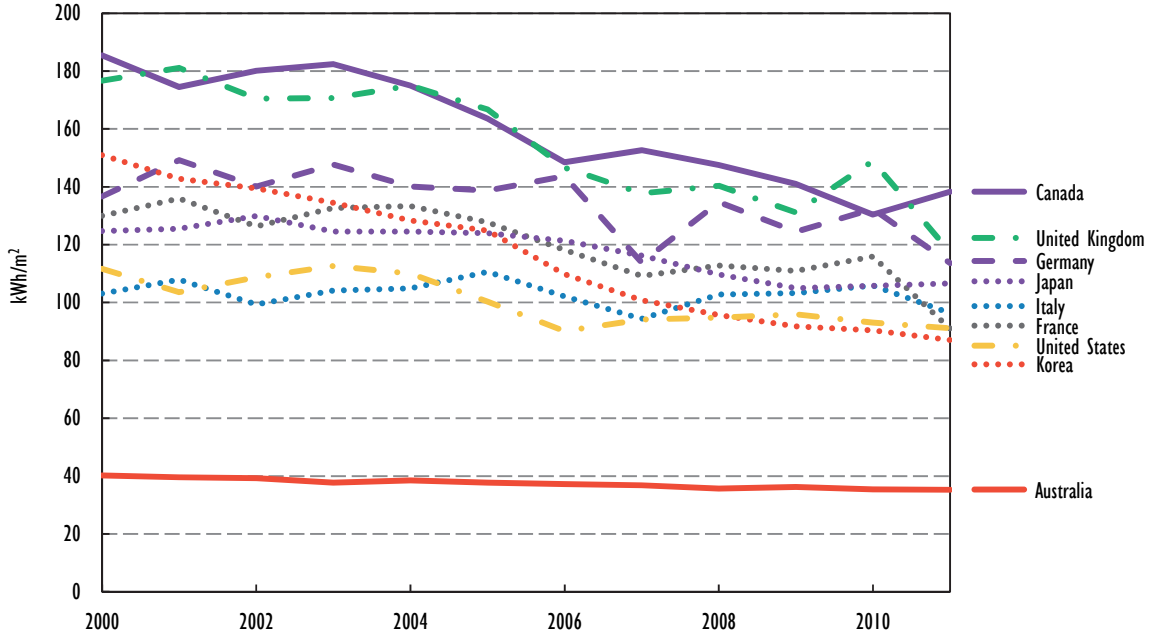
Another type of detailed metric could address different types of fuel use, such as fossil fuel energy use per capita (Figure C4). However, as noted above, this type of metric should also be correlated to heating demand requirements or climate.

Figure C4 • Residential fossil fuel energy use per capita



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure C5 • Residential fossil fuel energy use per floor area



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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Annex D. Residential building energy trends and metrics

In this annex, building energy use and performance metrics are shown for the residential buildings sub-sector; Annex E addresses the service buildings sub-sector. These two annexes provide valuable information for policy makers about differences in trends between the two sub-sectors, and specific opportunities for energy efficiency improvement.

For the period 2000 to 2012, the following features and trends for the residential sub-sector are observed:

- In many of the MEF economies, total final residential sub-sector energy use has held relatively constant. It is growing in most of the emerging economies due to increases in wealth, with additional population, floor area and other drivers pushing up total consumption. In some OECD countries, especially the United Kingdom, Germany, France and Japan, total final residential energy use decreased over the period. In some European countries and Japan, total residential energy consumption has declined, while in emerging economies growth has been relatively steep.
- While residential total final energy use has held steady or declined for some developed economies, this is not the case for residential electricity consumption: all countries have seen electricity consumption rise over the period. The pace of growth is steepest for emerging economies.
- Residential electricity use has grown in all countries over the period, though in some countries the trend slows significantly from 2008 through 2012. Rapidly growing economies such as China, India and Indonesia record the steepest increase in residential electricity use.

Regarding energy and electricity use per capita:

- Residential energy use per capita varied considerably among MEF economies. Several developed economies show a significant downward trend, while emerging economies have relatively steep growth.
- Electricity consumption per capita is declining in some countries despite large growth globally. As expected, emerging economies have very high rates of growth for electricity consumption per capita, but it also increased in some developed economies.

Regarding energy and electricity use per unit of floor area:

- Residential total energy use per floor area is decreasing in nearly all MEF economies. Some of this can be attributed to efficiency improvements, though in some countries the increase in average house size can result in reduced energy per floor area, as total energy use is divided by a larger floor area.
- Residential total final energy per unit of floor area has dropped in all except one MEF economy (Italy). This reduction is driven in part by substantial improvements in energy efficiency, especially in space-heating energy use.
- Canada has very high residential electricity consumption per floor area, which could be somewhat related to its cold climate, since electricity has a modest fuel share for space heating and water heating. It does appear to be on a significant downward trend.
- Residential electricity use per unit of floor area shows a different trend than total residential energy use. In many countries (especially emerging economies), electricity use per floor area is growing due to increases in electricity-consuming products, as well as increased penetration of air-conditioning equipment. Some of the more advanced economies, where appliance and air-conditioning saturation is already very high, have shown reduced floor area intensity over the period.

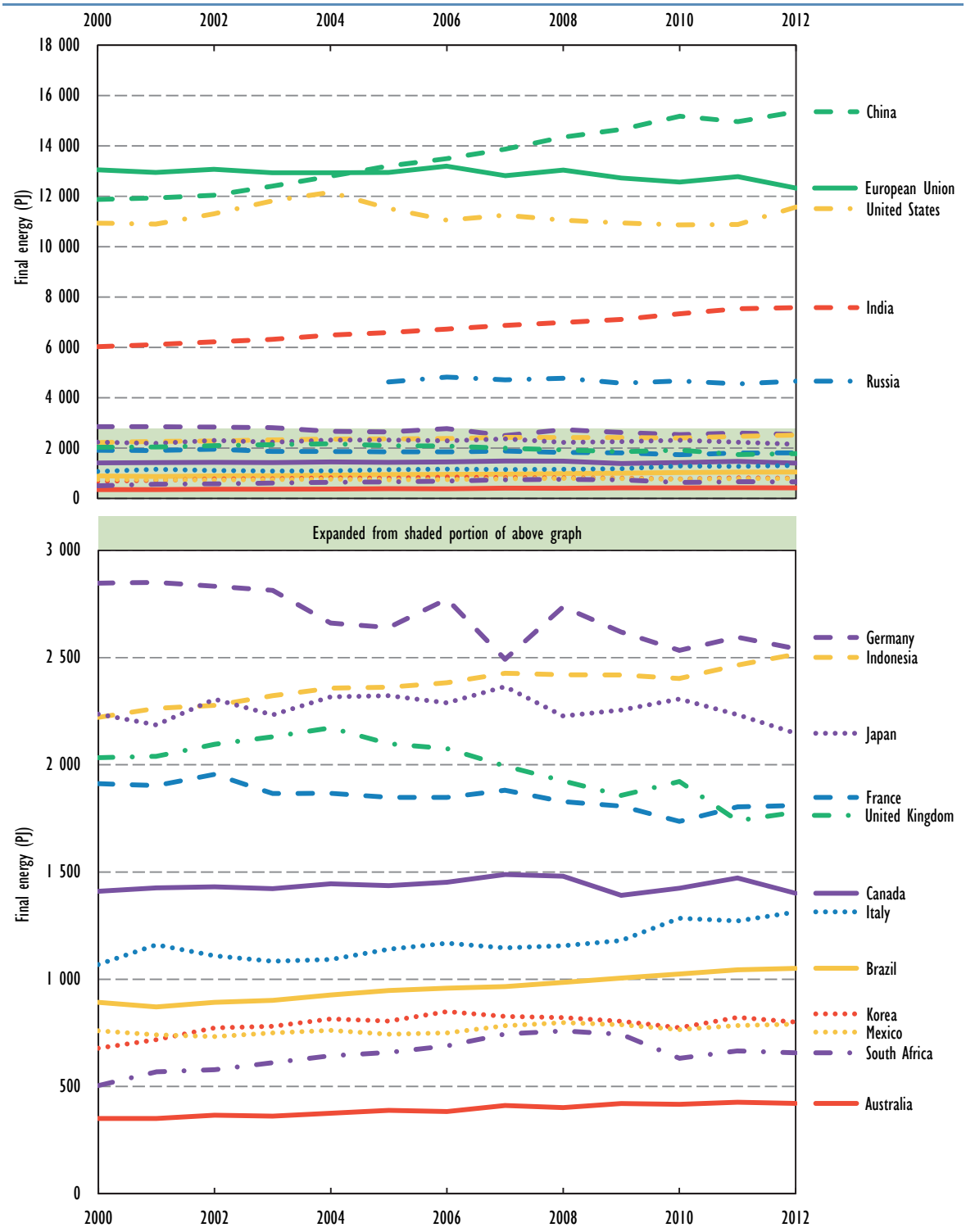
Regarding energy and electricity use per household:

- Residential electricity use per household is quite high in North America, due in part to a substantially larger dwelling size per household than that of most of the world, and significantly larger major appliances and more electric space heating and cooling than other countries. Electricity use per household is growing in emerging economies, but is still only a fraction of the use per household of most other countries.
- In emerging economies, residential electricity use per household is growing substantially, with increasing saturations of a variety of electric appliances and a growing saturation of air conditioning (despite higher equipment efficiency levels). Some European and North American countries which already have near-total saturation of most appliances show reductions in electricity use per household as a result of improved equipment efficiency.

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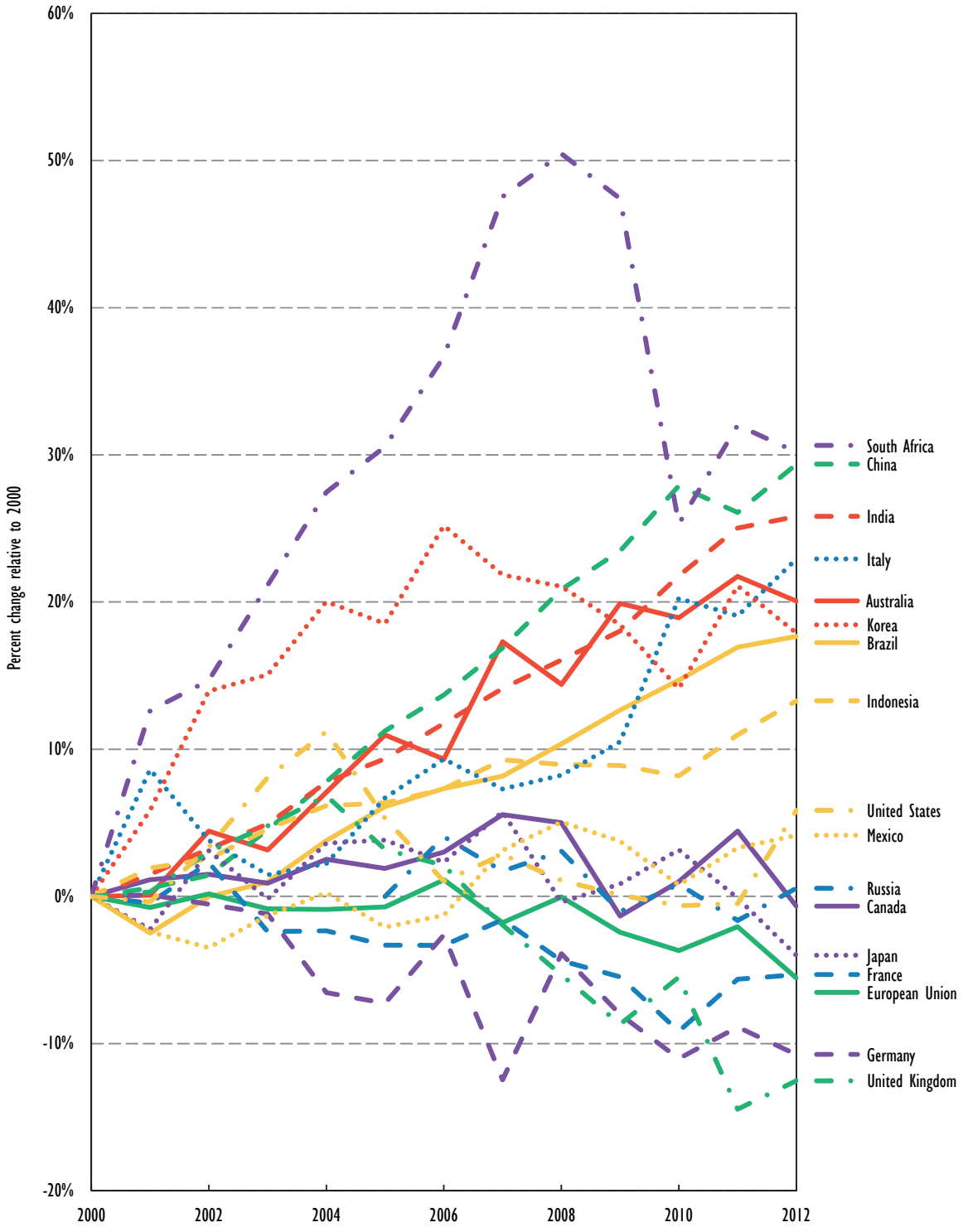
Residential building energy use

Figure D1 • Residential energy use in MEF economies, 2000-12



Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D2 • Change in residential energy use in MEF economies, 2000-12

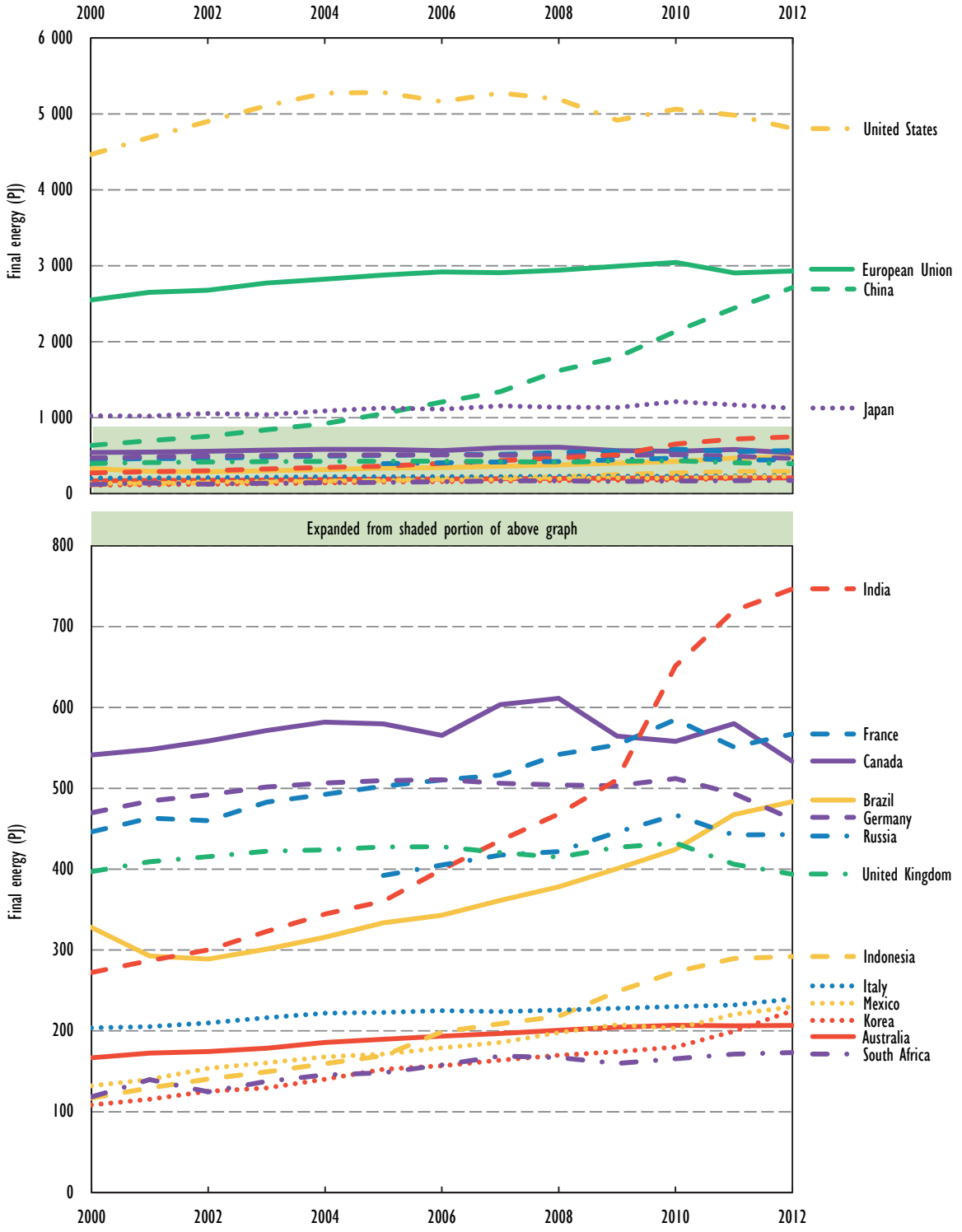


Note: South Africa energy balance data show large variations that may be attributable to significant year-to-year differences in coal reporting for the buildings sector. The IEA has a long-term co-operation initiative with South Africa to improve collection and reporting of energy balances data. Because of this, corrections to present and future data sets can be expected.

Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

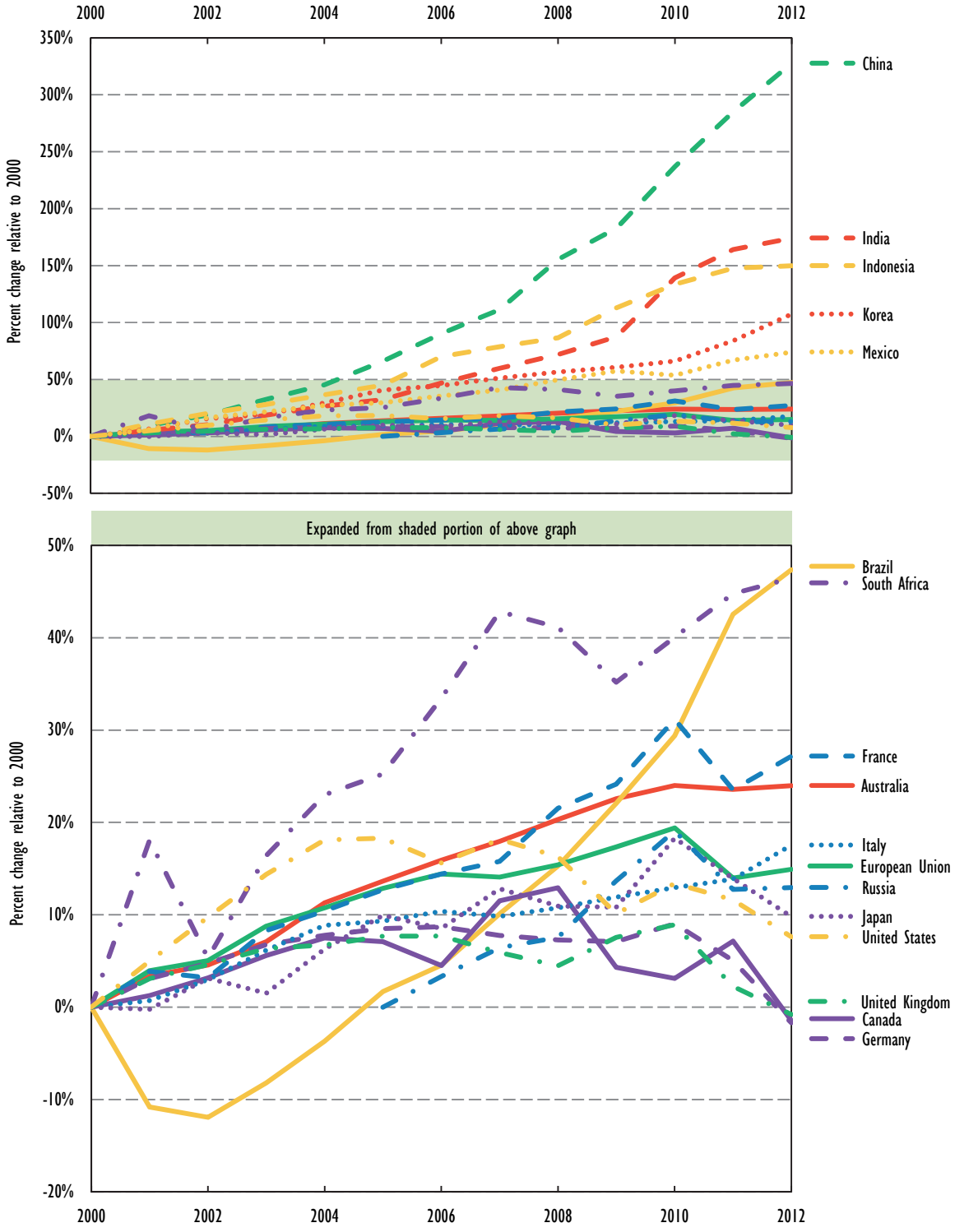
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Figure D3 • Residential electricity use in MEF economies, 2000-12



Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D4 • Change in residential electricity use in MEF economies, 2000-12



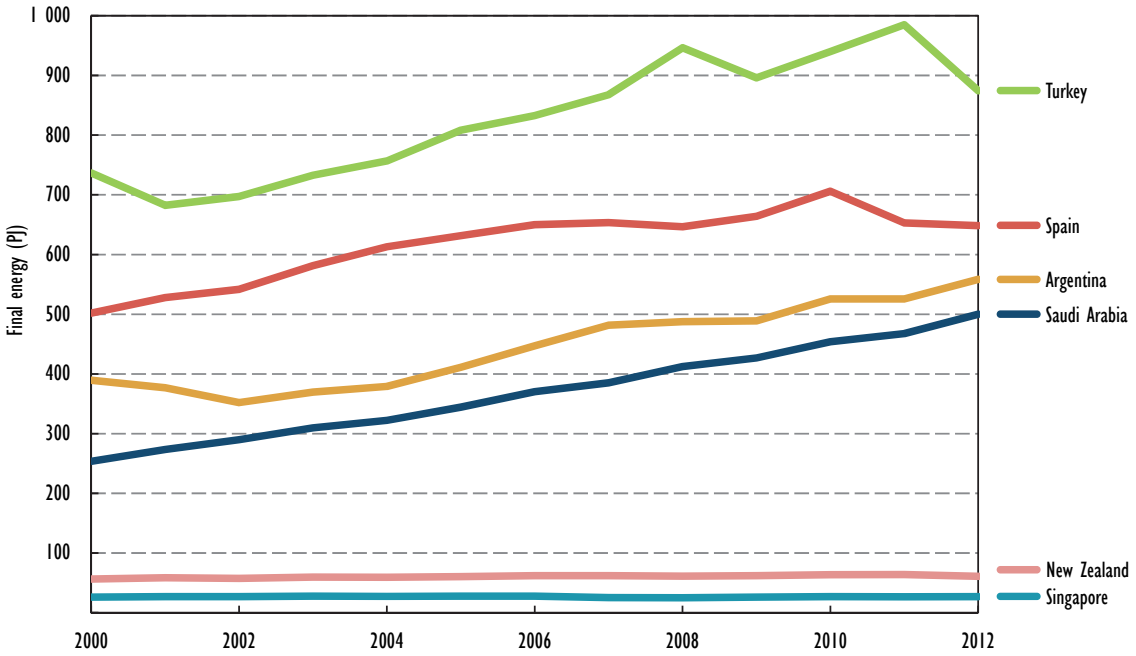
Note: South Africa data has data quality issue; see Figure D2 note for more information.

Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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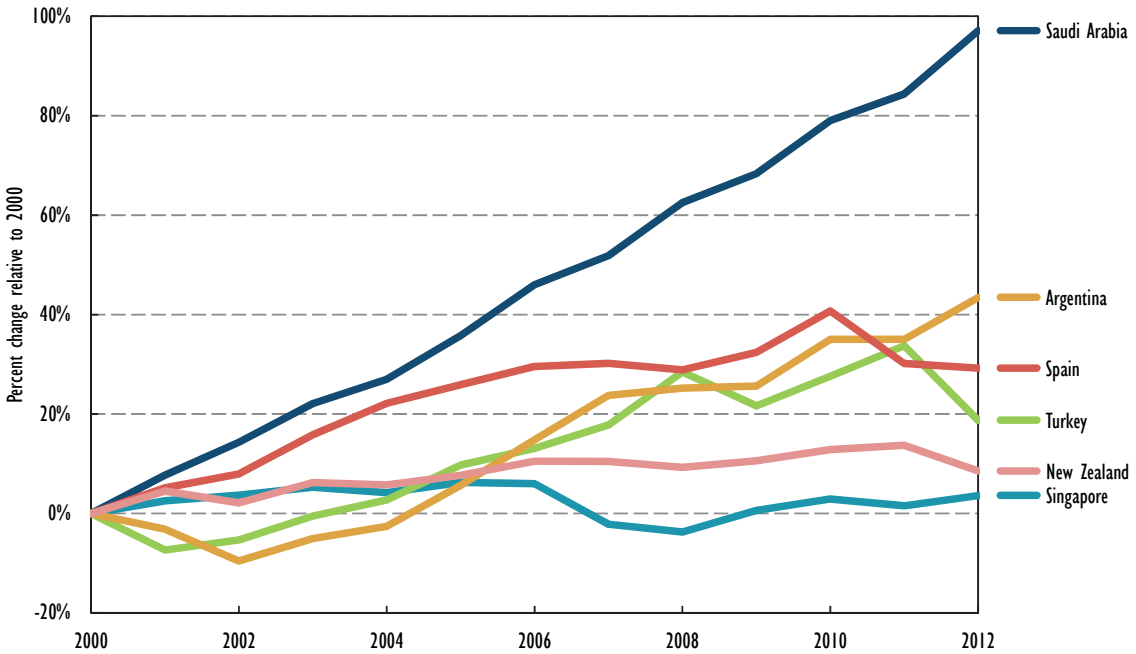
G20 members and guests

Figure D5 • Residential energy use in G20 and guest economies, 2000-12



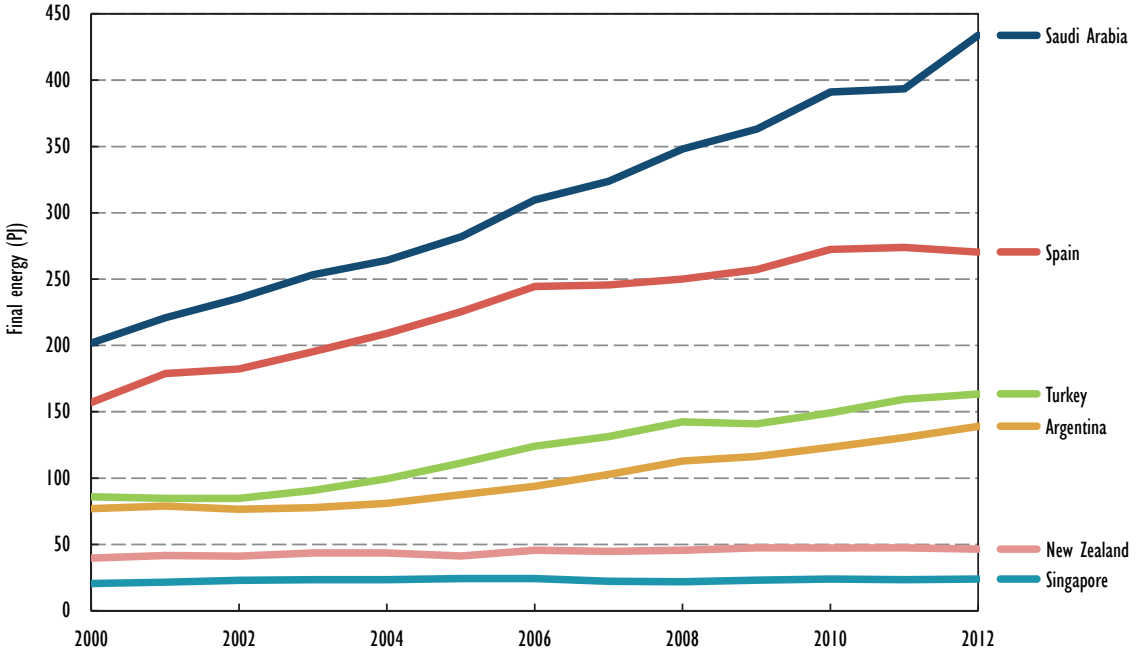
Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D6 • Change in residential energy use in G20 and guest economies, 2000-12



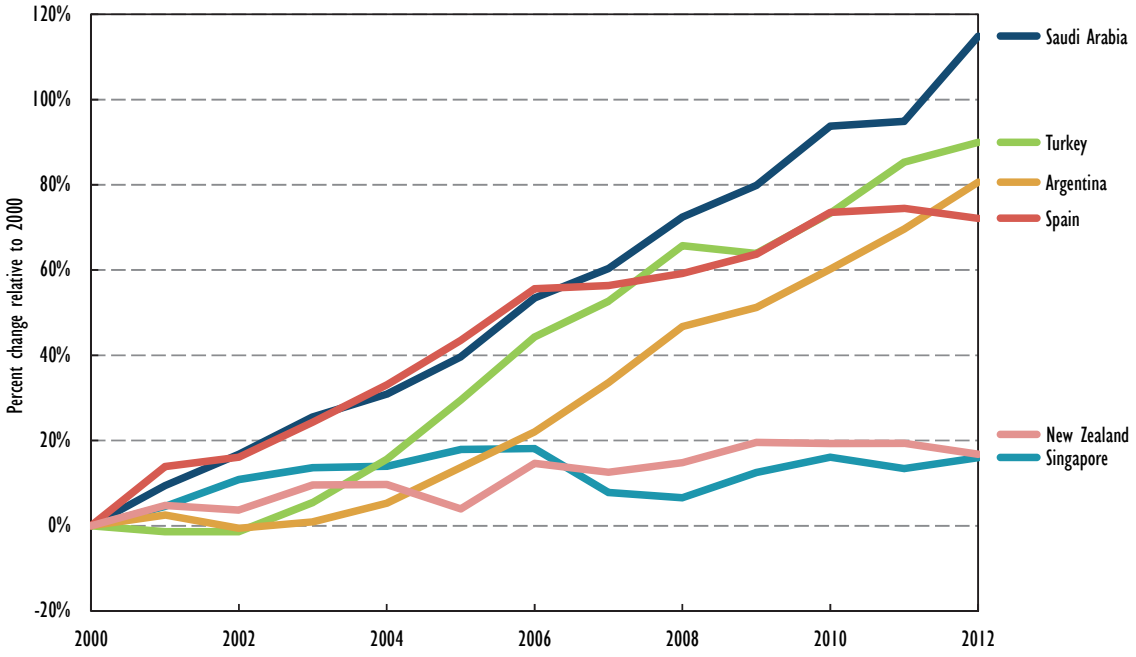
Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D7 • Residential electricity use in G20 and guest economies, 2000-12



Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D8 • Change in residential electricity use in G20 and guest economies, 2000-12



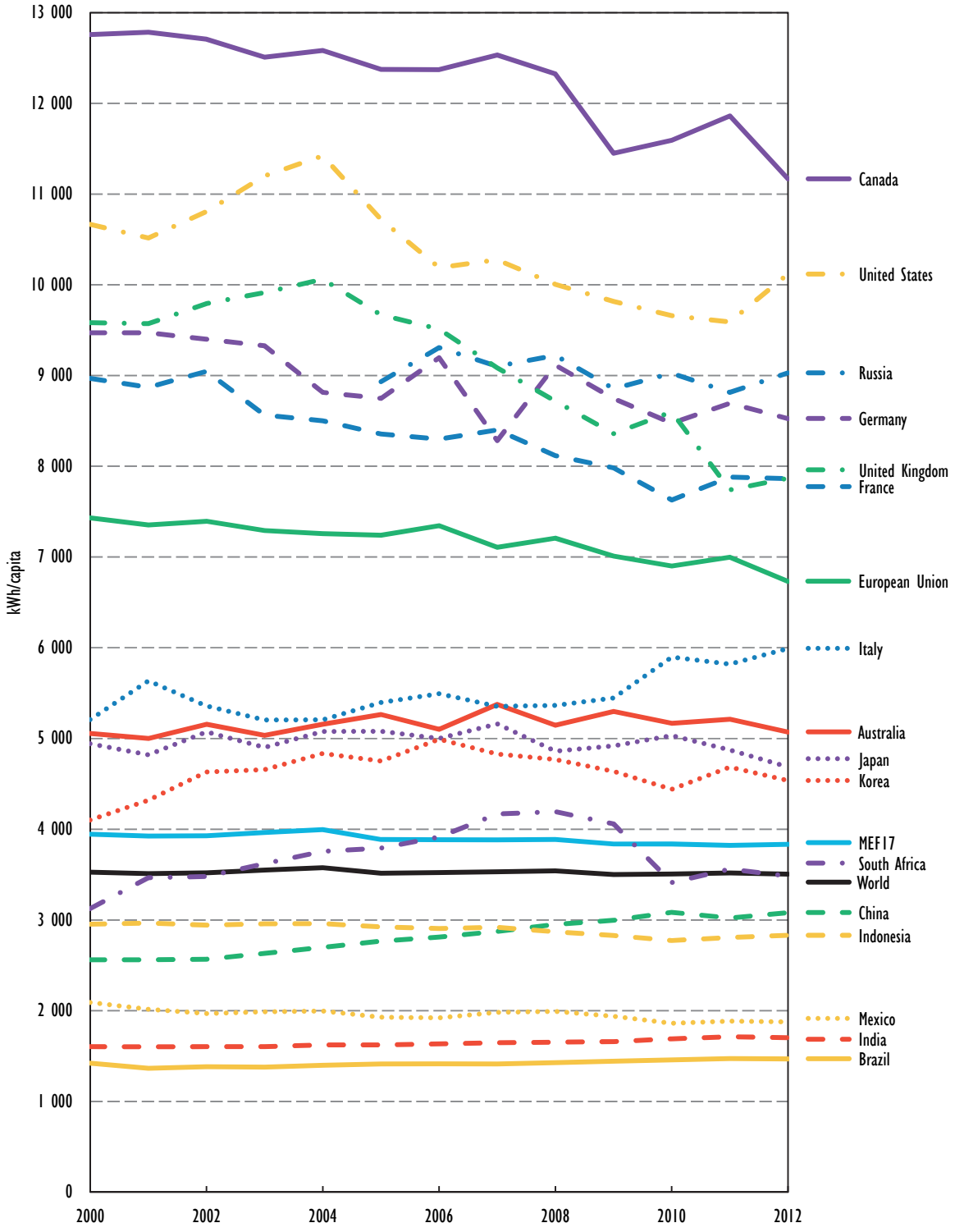
Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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Residential building energy metrics

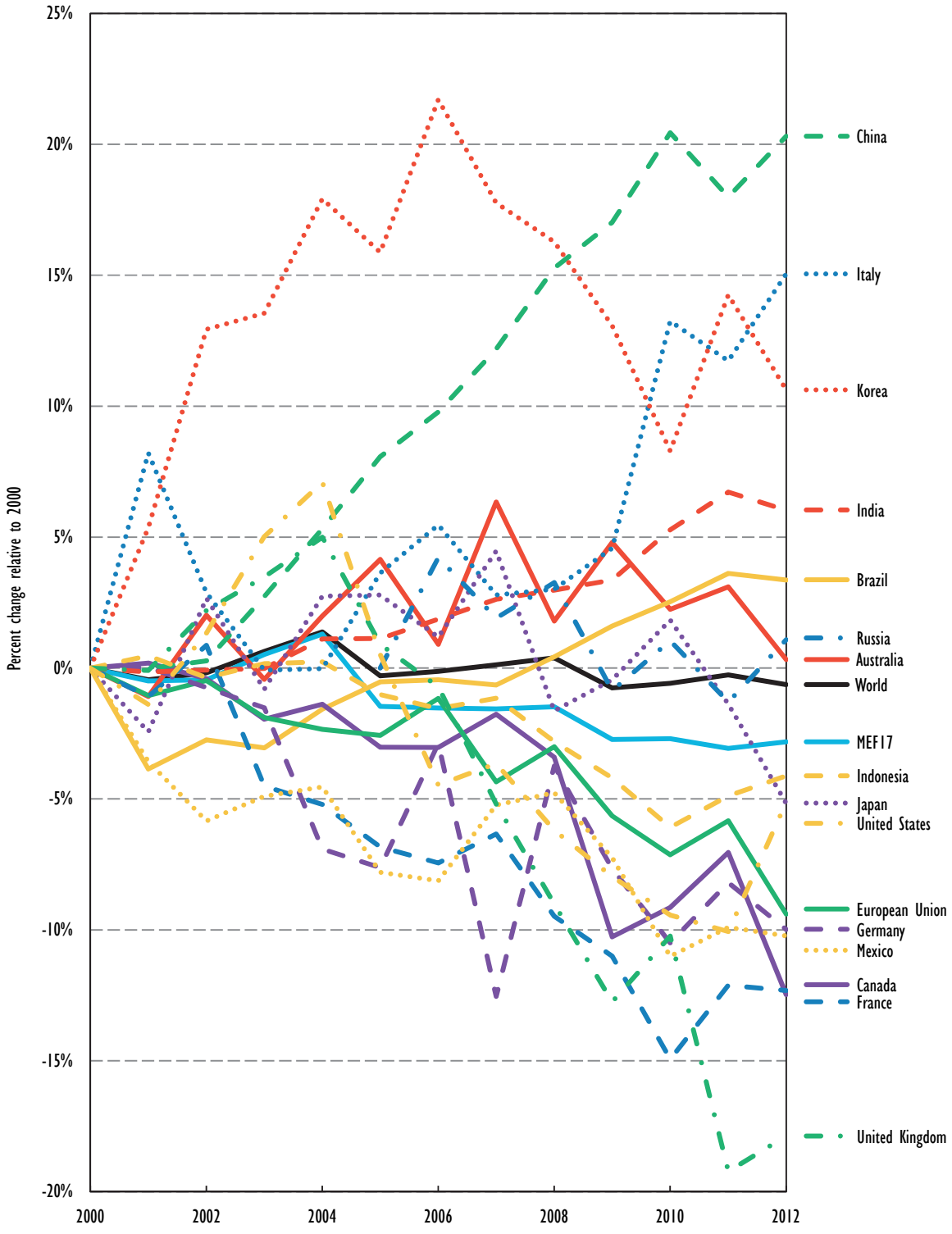
Per capita intensity

Figure D9 • Residential energy use per capita in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D10 • Change in residential energy use per capita in MEF economies, 2000-12

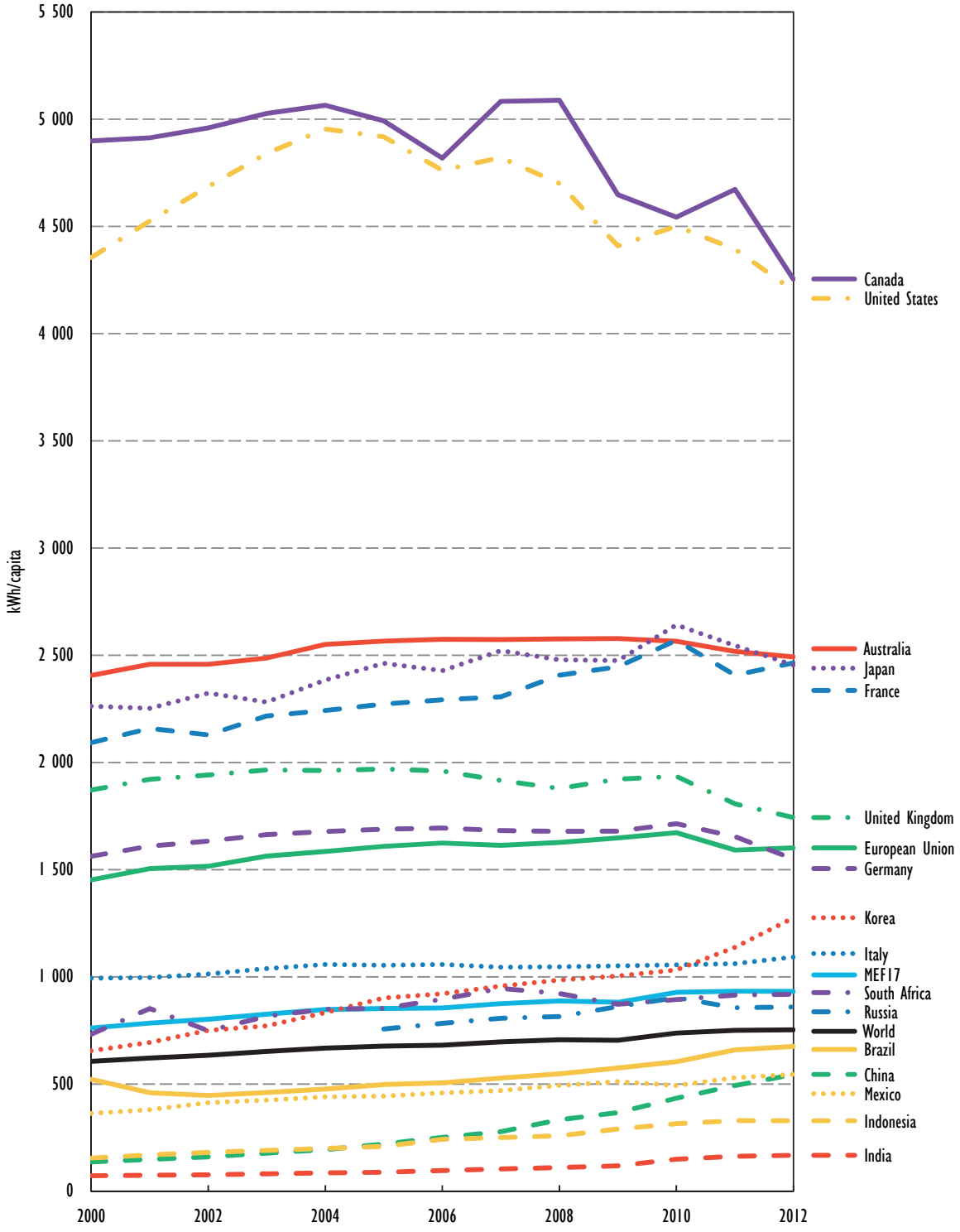


Note: South Africa data are not shown due to data quality issue; see Figure D2 note for more information.

Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

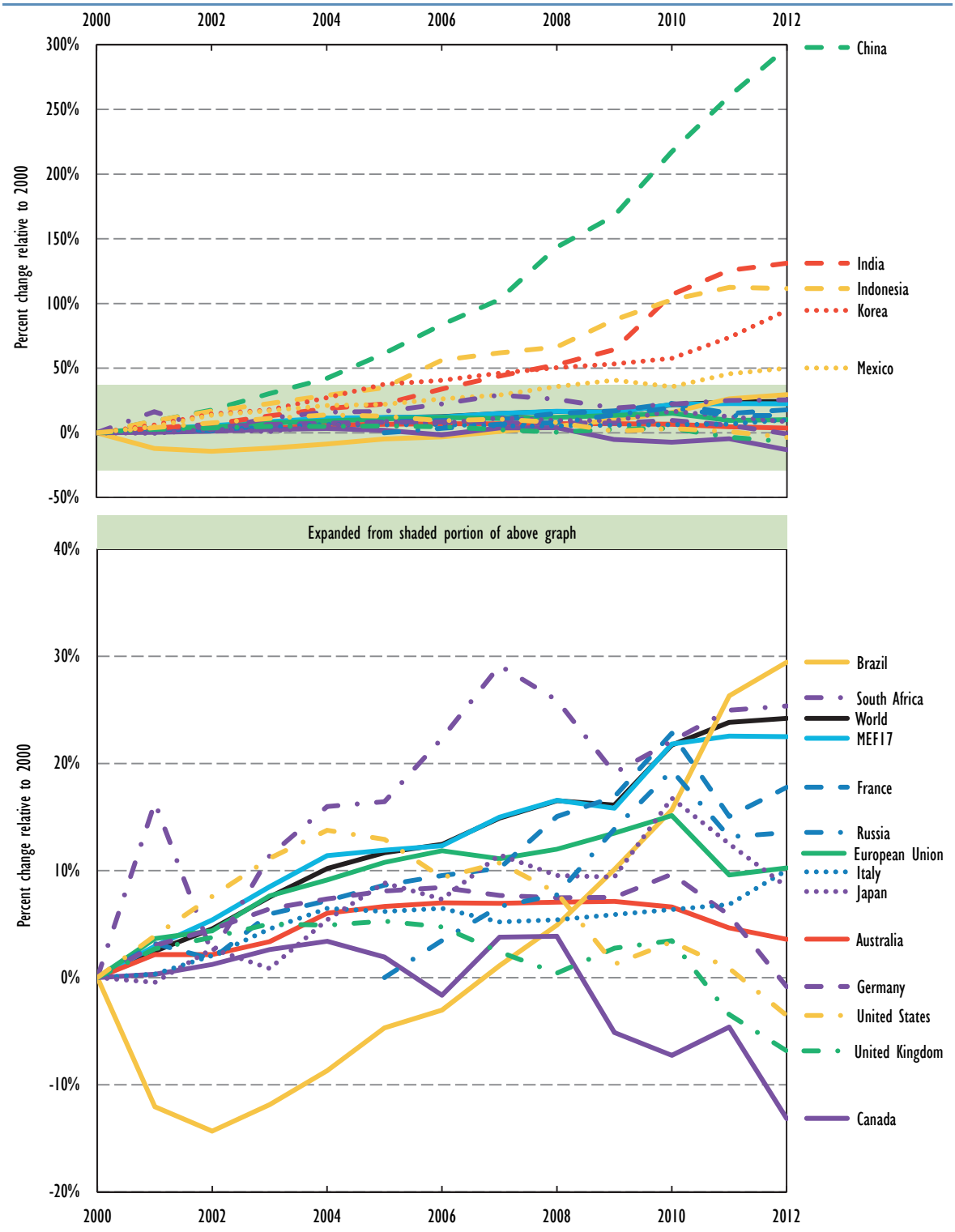
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Figure D11 • Residential electricity use per capita in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D12 • Change in residential electricity use per capita in MEF economies, 2000-12



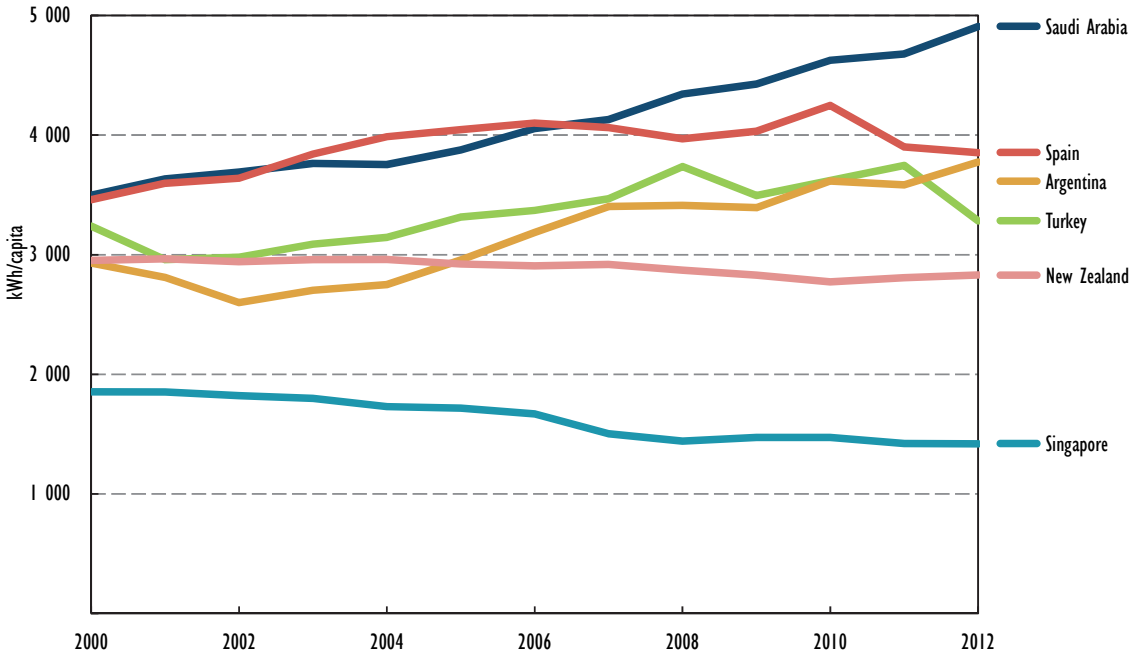
Note: South Africa data has data quality issue; see Figure D2 note for more information.

Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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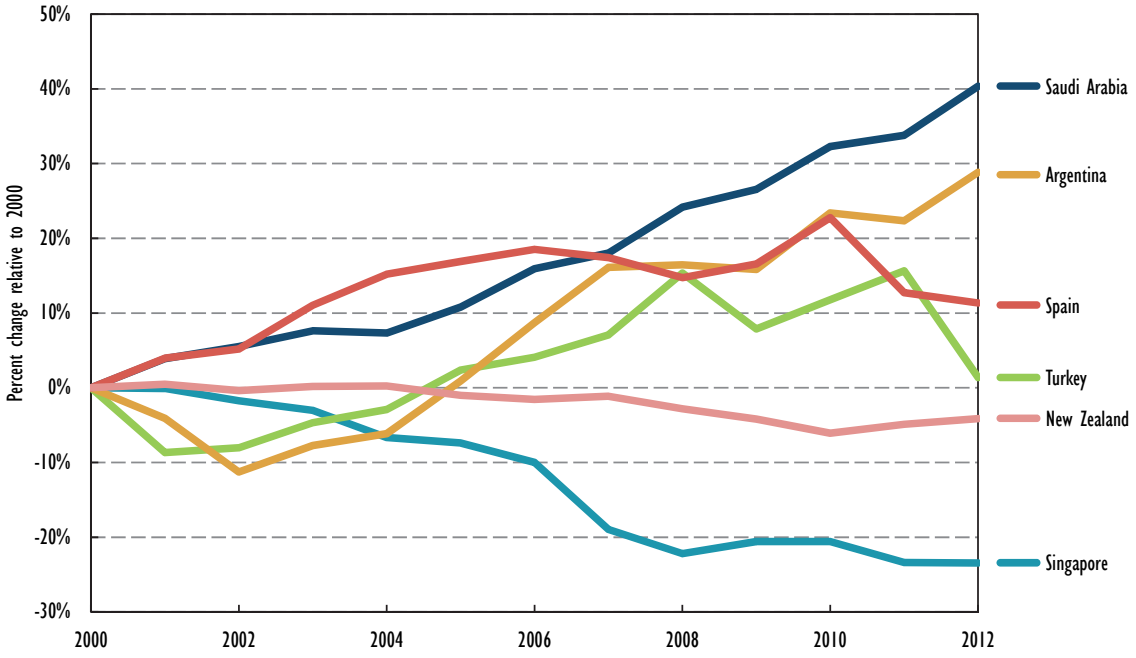
G20 members and guests

Figure D13 • Residential energy use per capita in G20 and guest economies, 2000-12



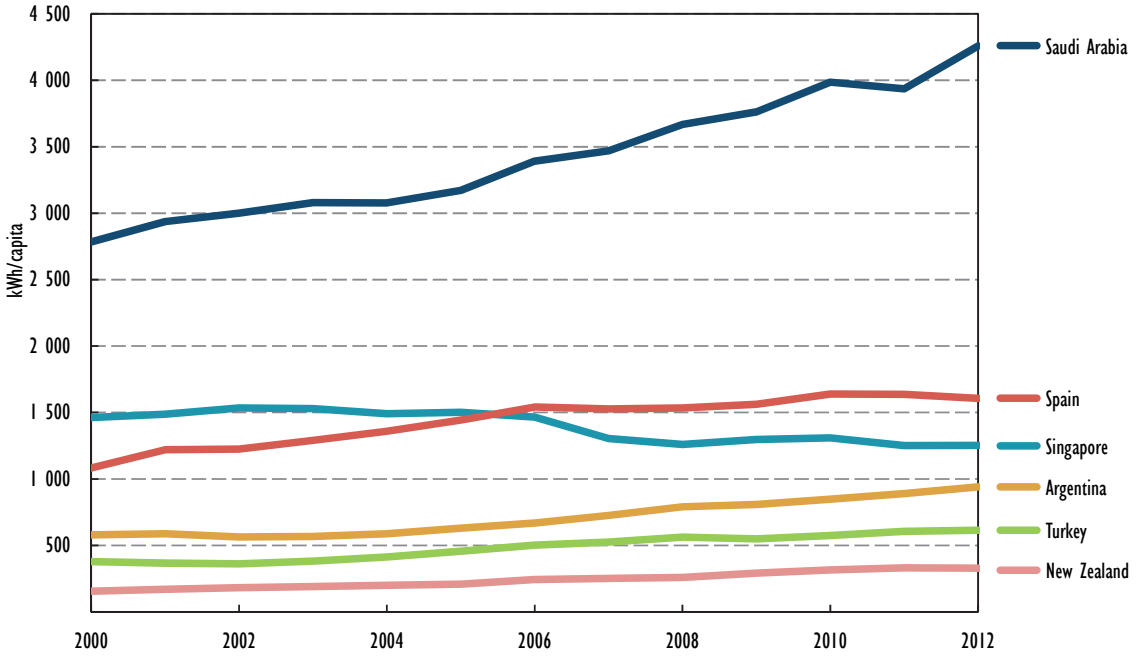
Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D14 • Change in residential energy use per capita in G20 and guest economies, 2000-12



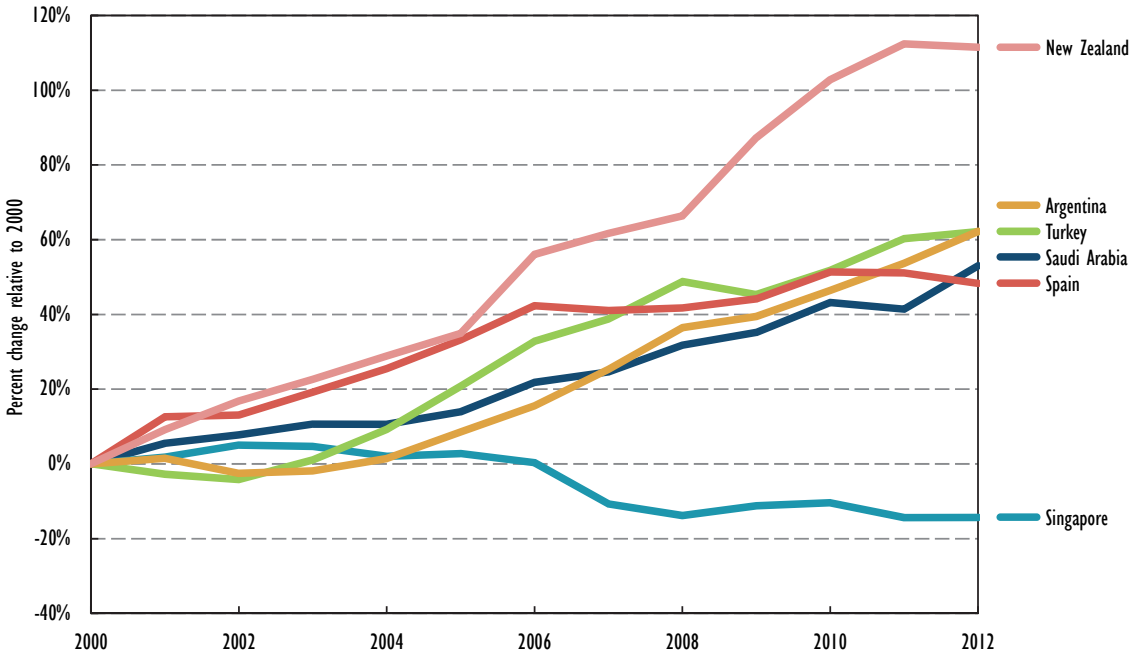
Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D15 • Residential electricity use per capita in G20 and guest economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D16 • Change in residential electricity use per capita in G20 and guest economies, 2000-12

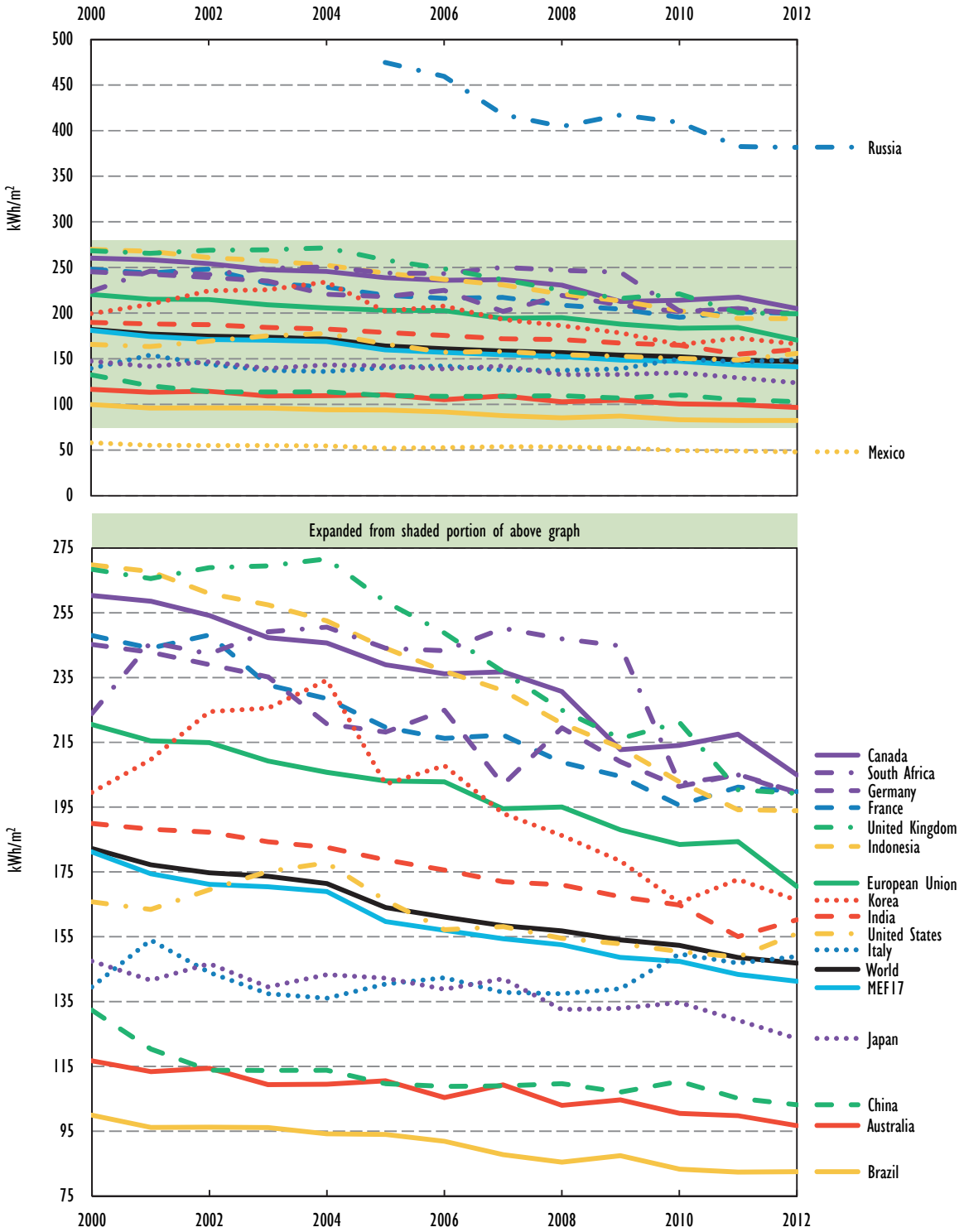


Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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Floor area intensity

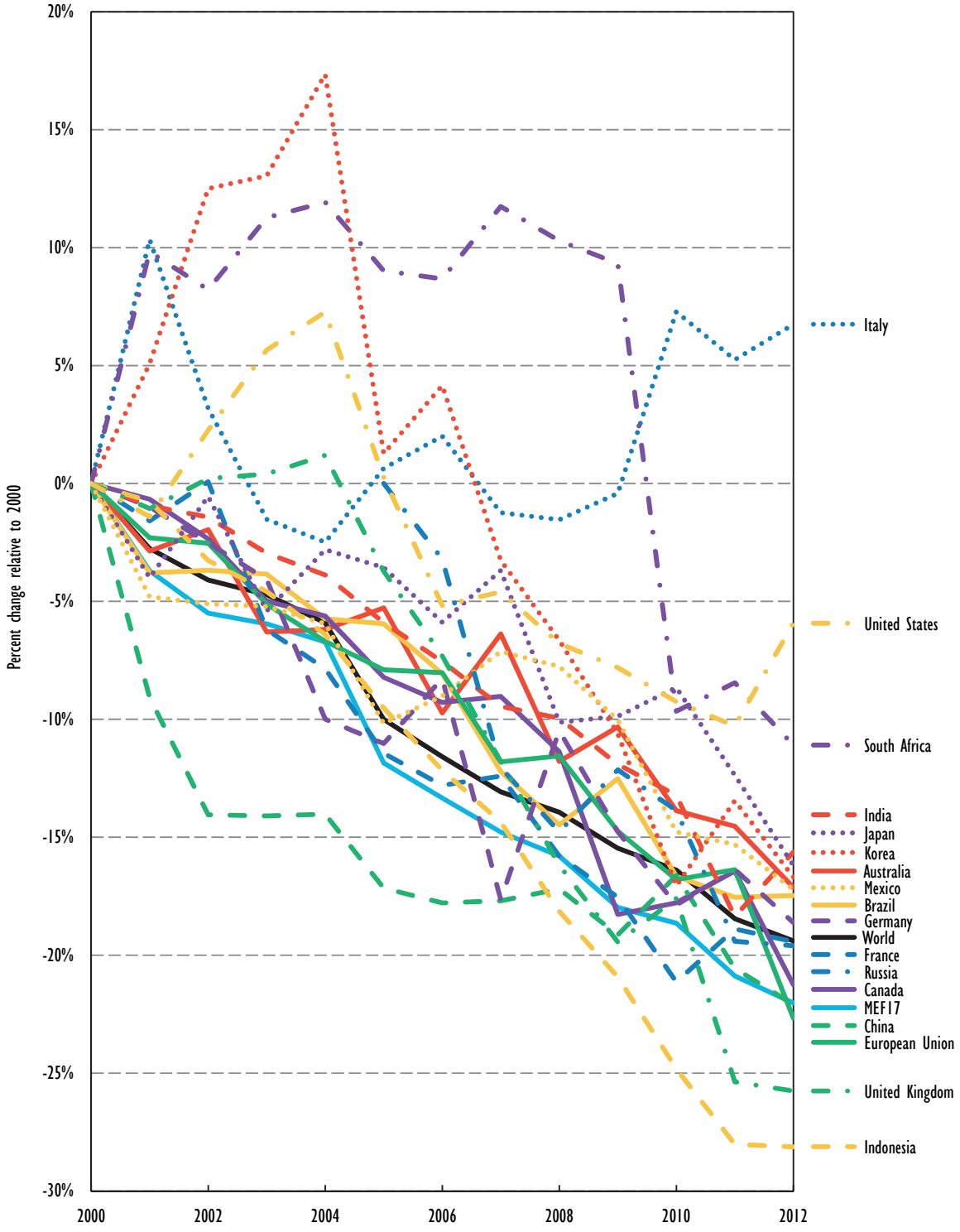
Figure D17 • Residential energy use per floor area in MEF economies, 2000-12



Note: South Africa data has data quality issue; see Figure D2 note for more information.

Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D18 • Change in residential energy use per floor area in MEF economies, 2000-12

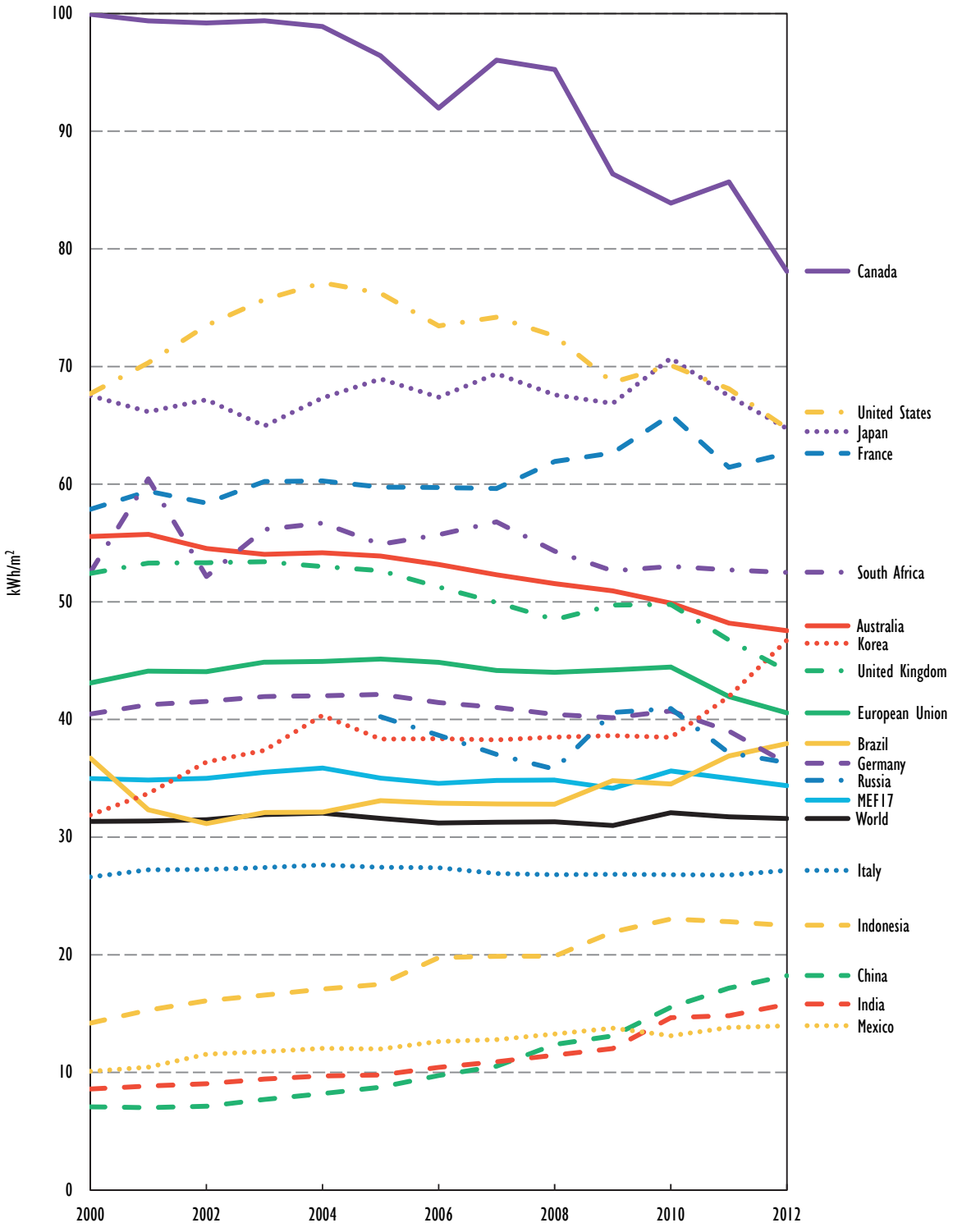


Note: South Africa data has data quality issue; see Figure D2 note for more information.

Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

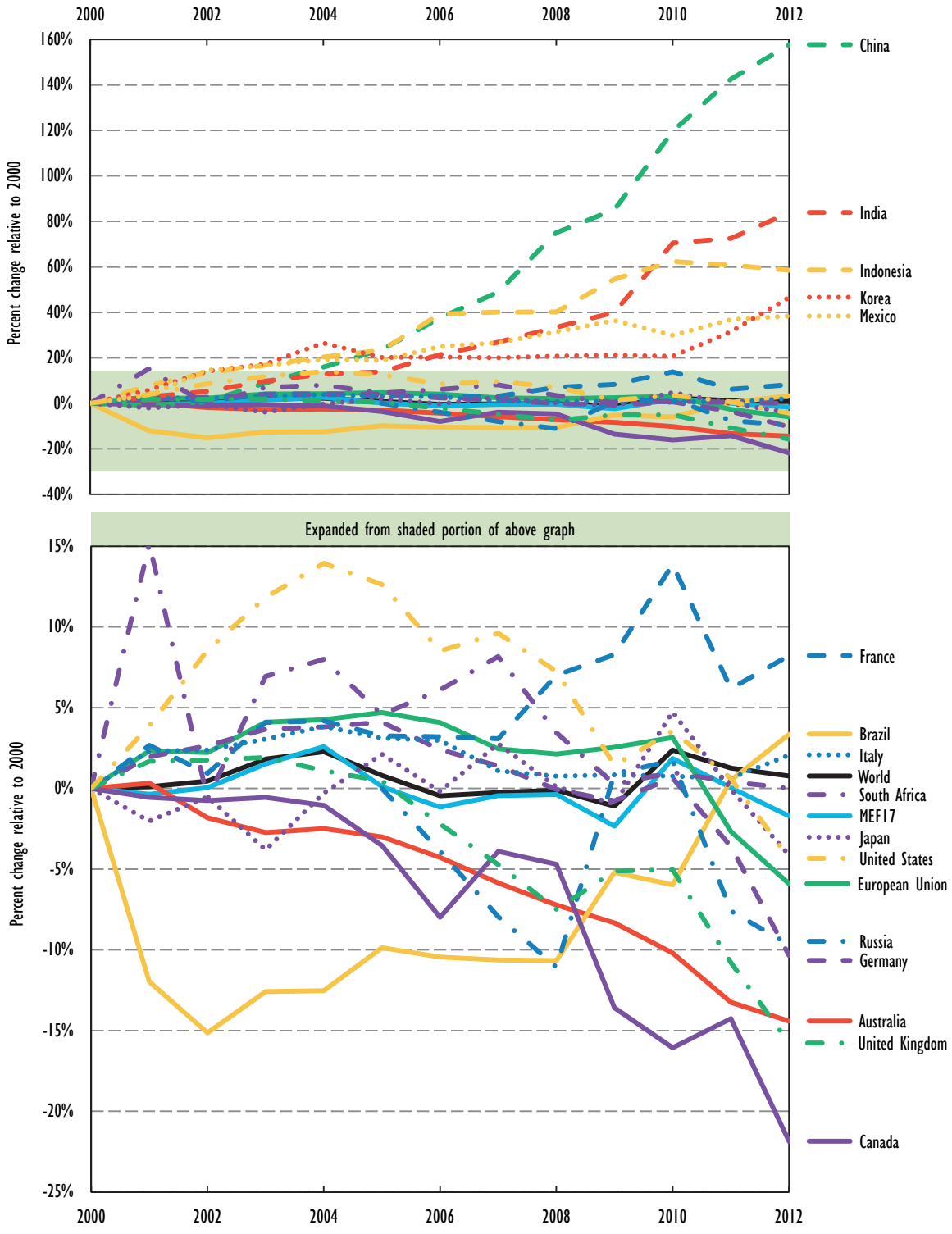
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Figure D19 • Residential electricity use per floor area in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D20 • Change in residential electricity use per floor area in MEF economies, 2000-12

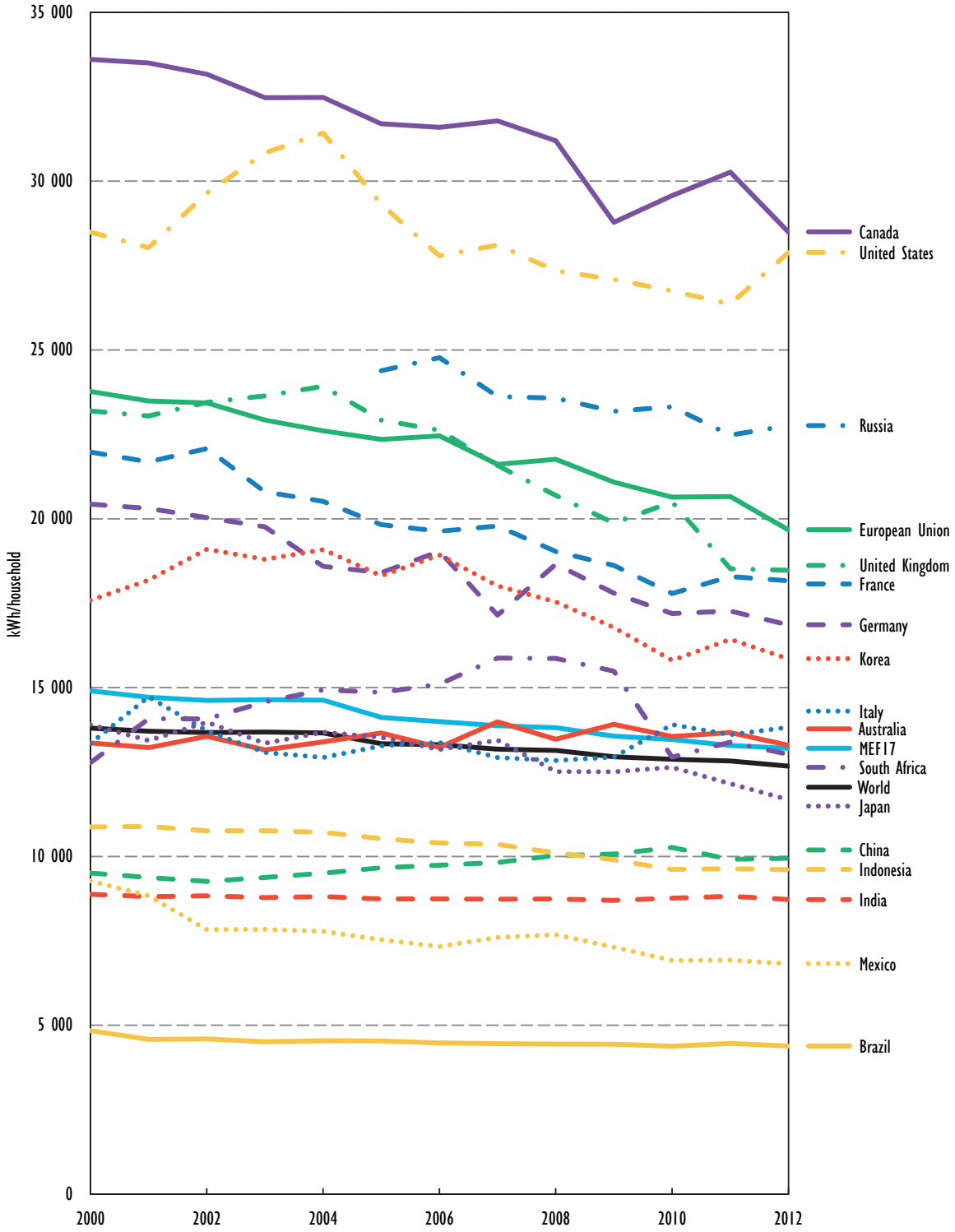


Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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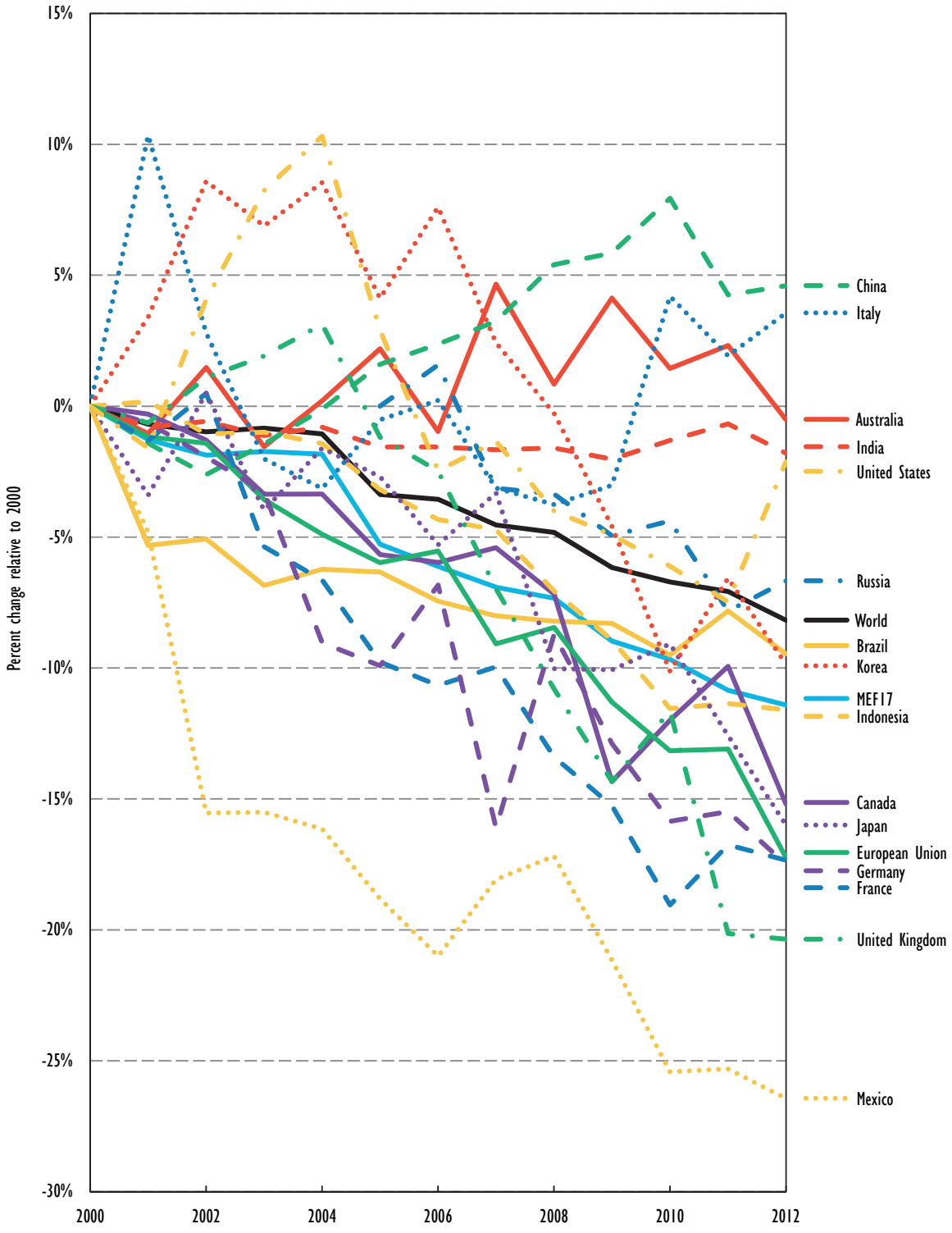
Residential household energy intensity

Figure D21 • Residential energy use per household in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D22 • Change in residential energy use per household in MEF economies, 2000-12

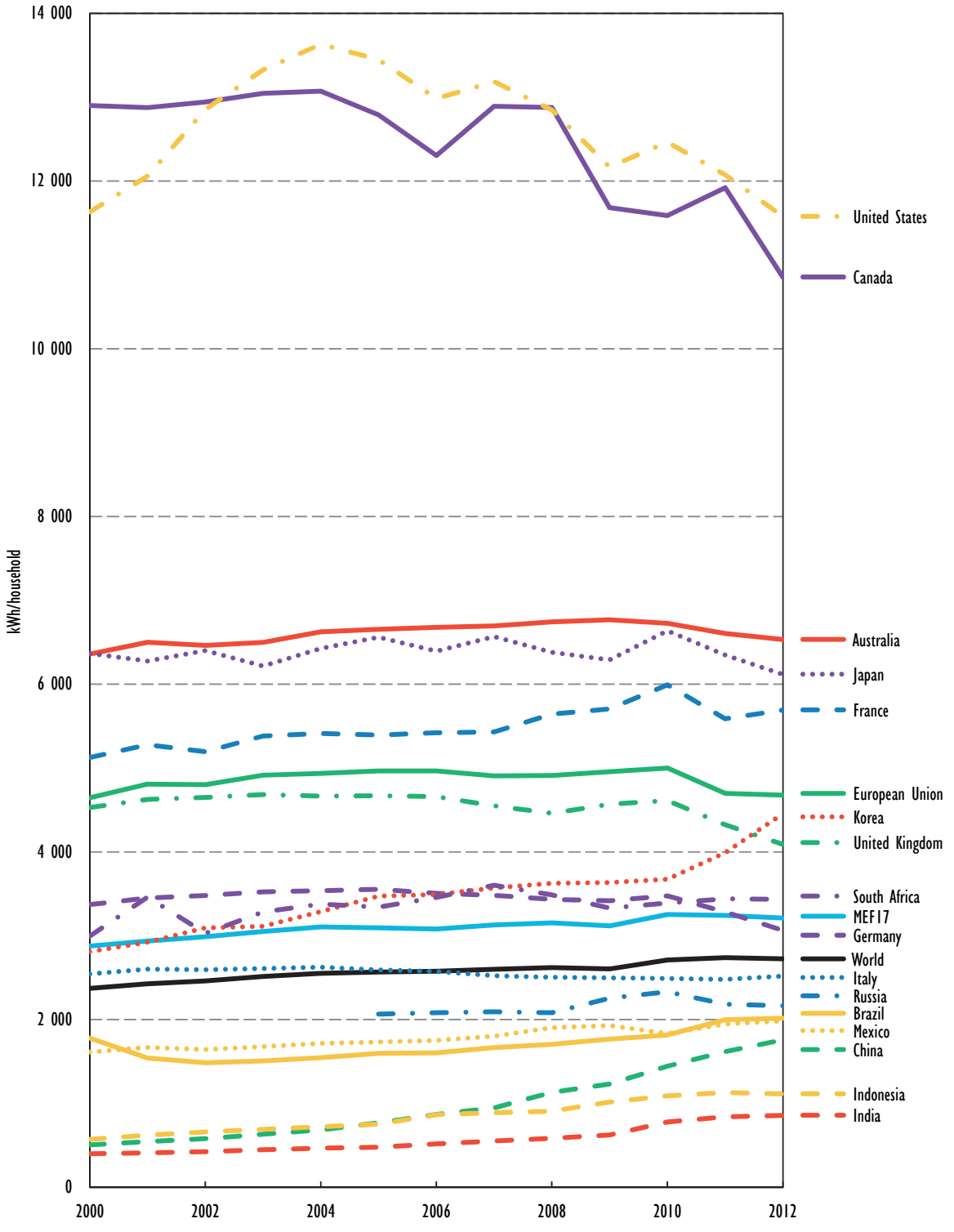


Note: South Africa data are not shown due to data quality issue; see Figure D2 note for more information.

Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

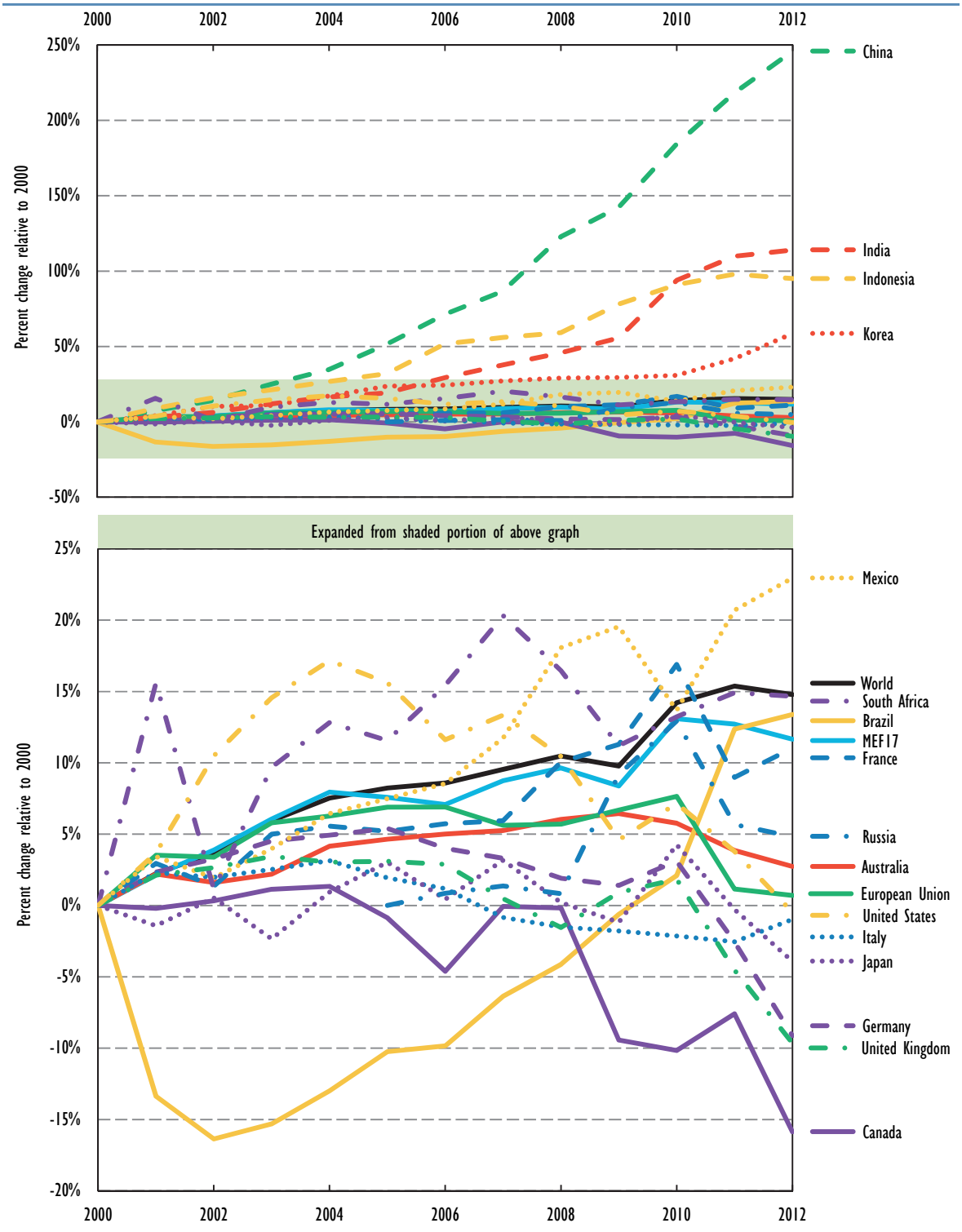
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Figure D23 • Residential electricity use per household in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure D24 • Change in residential electricity use per household in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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Annex E. Service building energy trends and metrics

In this section, building energy use and performance metrics are shown for the service buildings sub-sector. Metrics data at the sub-sector level provides valuable information for policy makers about differences in trends across sub-sectors and specific opportunities for energy efficiency improvements.

However, it is important to note several data quality and availability challenges associated with metrics for the services sub-sector. For example, as noted in Annex A ("Data quality and availability"), floor area data quality is an issue. While periodic census data reflect reasonable residential floor area estimates, most countries have no consistent way of measuring and collecting services floor area. Significant effort is needed to improve and make more consistent the collection of floor area data. Furthermore, other possible service sub-sector metrics such as energy use per number of services sector employees, or per-services GDP or value-added, would be relevant, but no common data collection or reporting methodology, or repository, exists across all MEF economies. Additional work to research and collect better data on these other factors could be very helpful in understanding progress in the services sub-sector. Finally, the value of per capita metrics for the services sub-sector is unclear, in part because country population is an imperfect proxy for the number of persons served by energy used in the services sub-sector (i.e. due to imports and exports of services, tourism, etc.).

For the period 2000 to 2012, the following features and trends for the services sub-sector are observed:

- Services sub-sector energy use increased for all MEF economies, with the exception of the United Kingdom. As in the residential sub-sector, energy demand growth has slowed in recent years for several economies, especially Japan, France and the European Union. In general, however, total energy consumption for services is growing at a relatively fast pace, especially in emerging economies.
- Services sub-sector electricity use grew in all MEF economies, in many at a rapid pace. The rate of change is greatest in the emerging economies of India, Indonesia, China and Korea, but is still climbing relatively quickly in some European countries where population, GDP and floor area are not changing rapidly.

Regarding services energy and electricity use per capita:

- Services sub-sector energy consumption per capita varies significantly among MEF economies. In emerging economies, services energy use per capita is growing quickly as commercial entities respond to increased economic demand from consumers. In some wealthier economies, the trend is downward.
- As of 2012, the United States and Canada had the highest services electricity use per capita, while India and Indonesia had the lowest. In part because of their very low starting level, India and Indonesia have had very fast growth, probably indicative of much greater use of air conditioning in services buildings. For a mature economy like Italy's, the growth is higher than would have been expected, but it started at a very low level and, after such large increases, total services energy consumption appears to have stabilised. Italy's electricity consumption is still below that of other EU countries.

Regarding services energy and electricity use per unit of floor area:

- There is a very wide range of services total final energy use per floor area among MEF economies, with variations of more than a factor of ten. Most MEF economies have reduced services energy use per floor area, with the notable exceptions of Italy and Germany, which both increased about 30%. In some countries with rapidly expanding services sub-sectors,

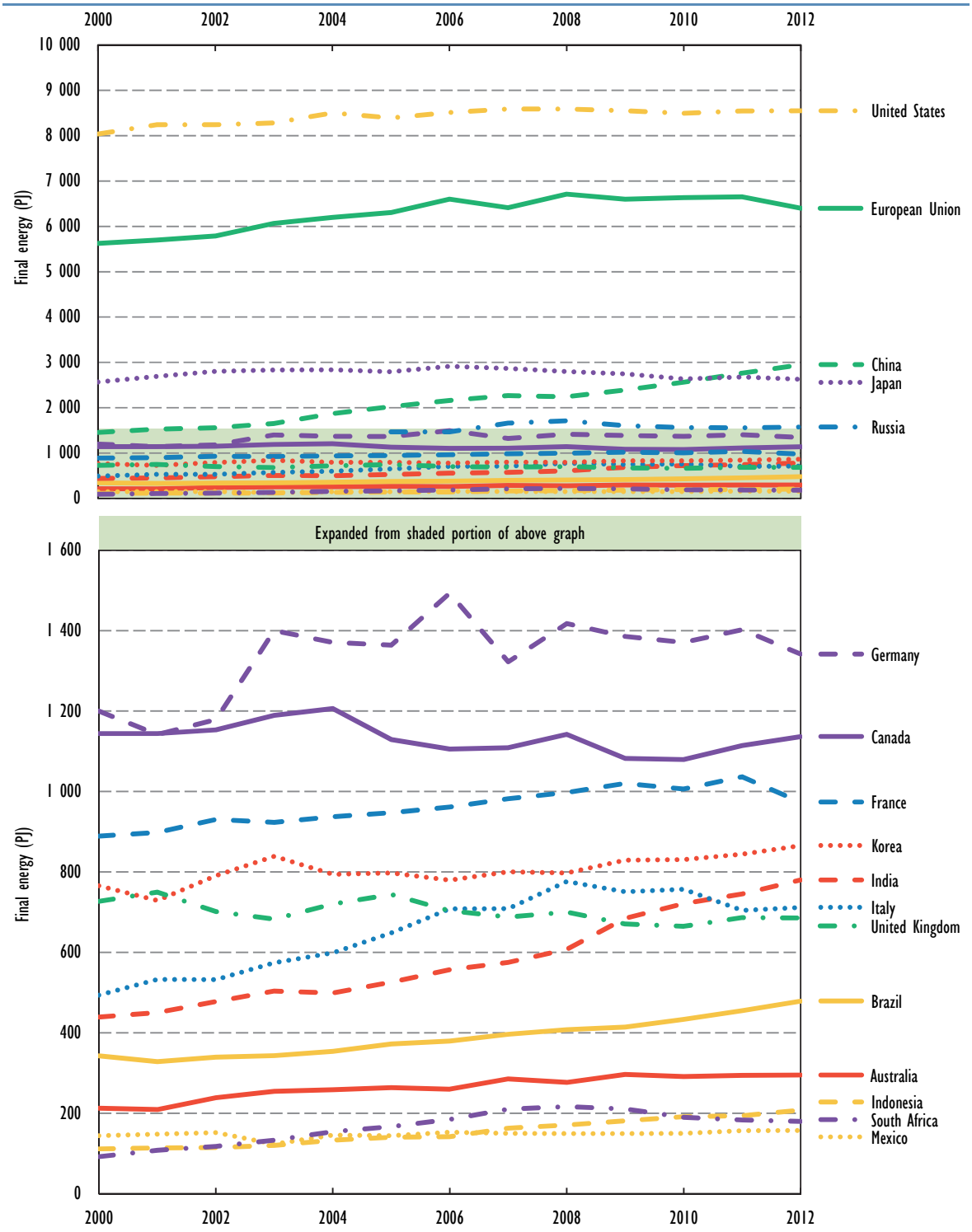
such as Indonesia and India, services energy use per floor area decreased substantially due to very strong growth in the services-built floor area during the period.

- The trend in services electricity use per floor area is much more mixed, with about half of MEF economies showing increases and the other half reductions. Several large European countries (Italy, Germany and France) have significant increases in their services electricity use per floor area, resulting in an increase overall for the European Union, while levels in MEF economies and in the world overall have decreased. South Africa, the United Kingdom and China show the most significant reductions in services electricity use per floor area, though the picture is mixed for China with an early decrease and then a substantial increase in the last four years of the period.

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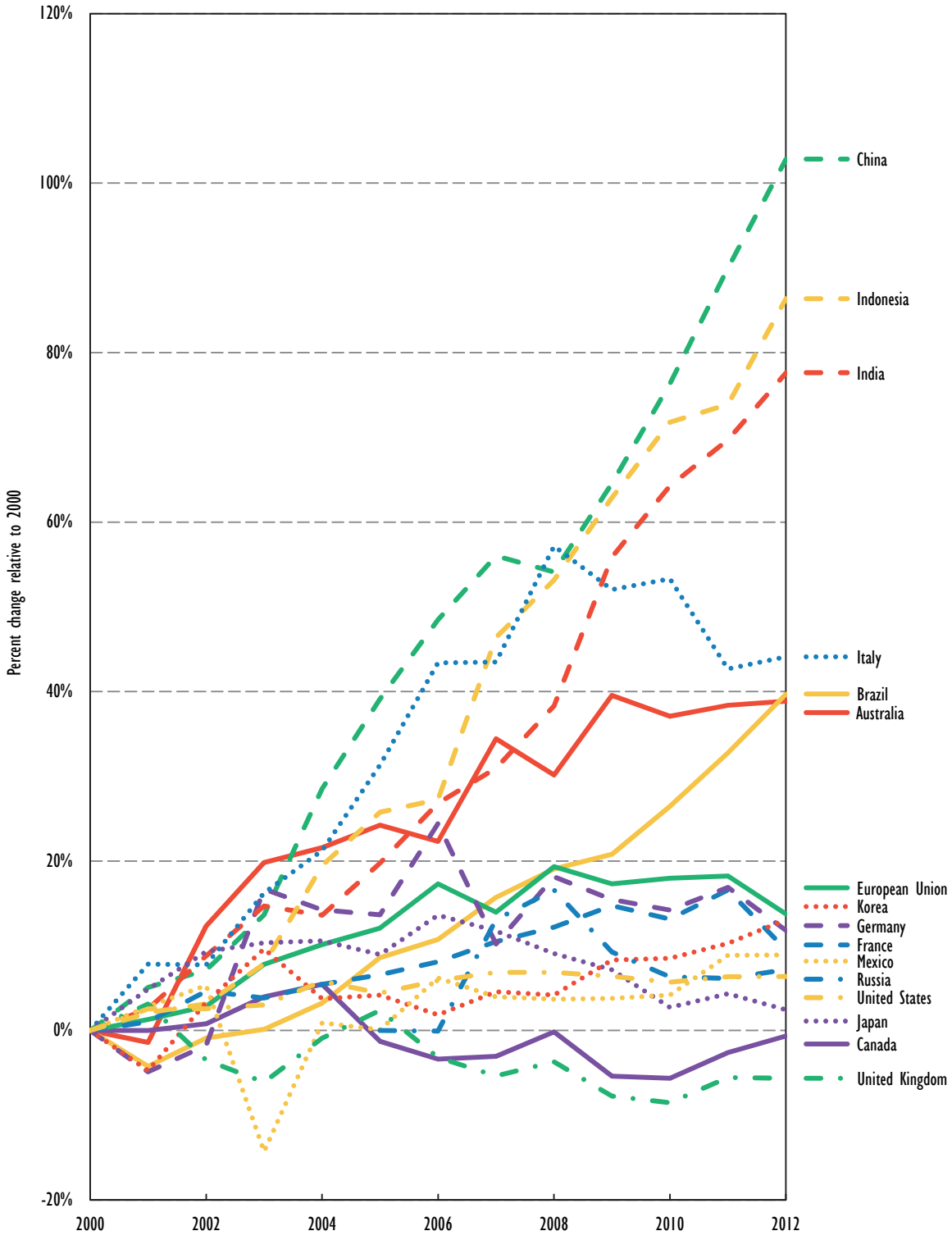
Services building energy use

Figure E1 • Services energy use in MEF economies, 2000-12



Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure E2 • Change in services energy use in MEF economies, 2000-12

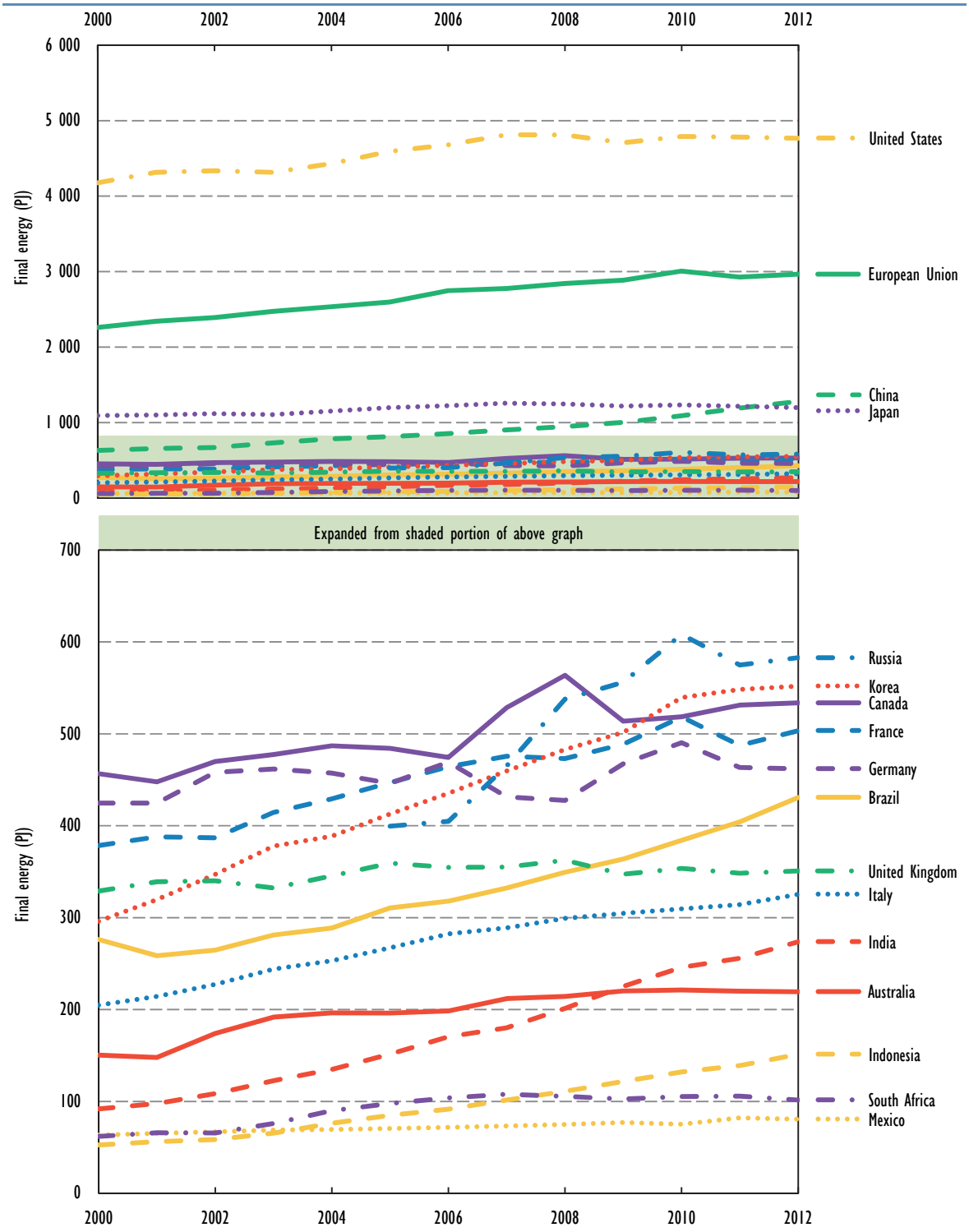


Note: South Africa data are not shown due to data quality issue; see Figure D2 note for more information.

Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

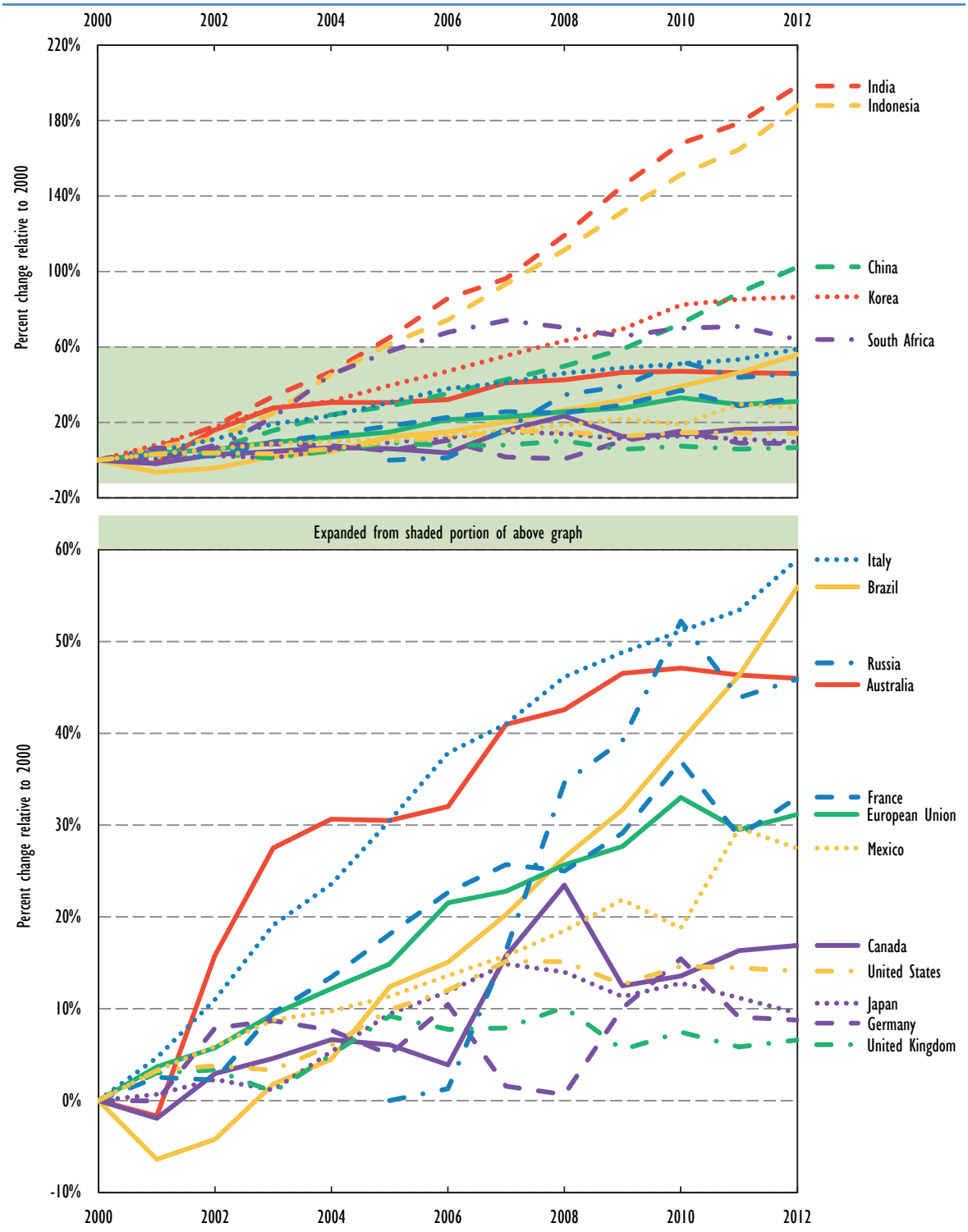
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Figure E3 • Services electricity use in MEF economies, 2000-12



Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure E4 • Change in services electricity use in MEF economies, 2000-12

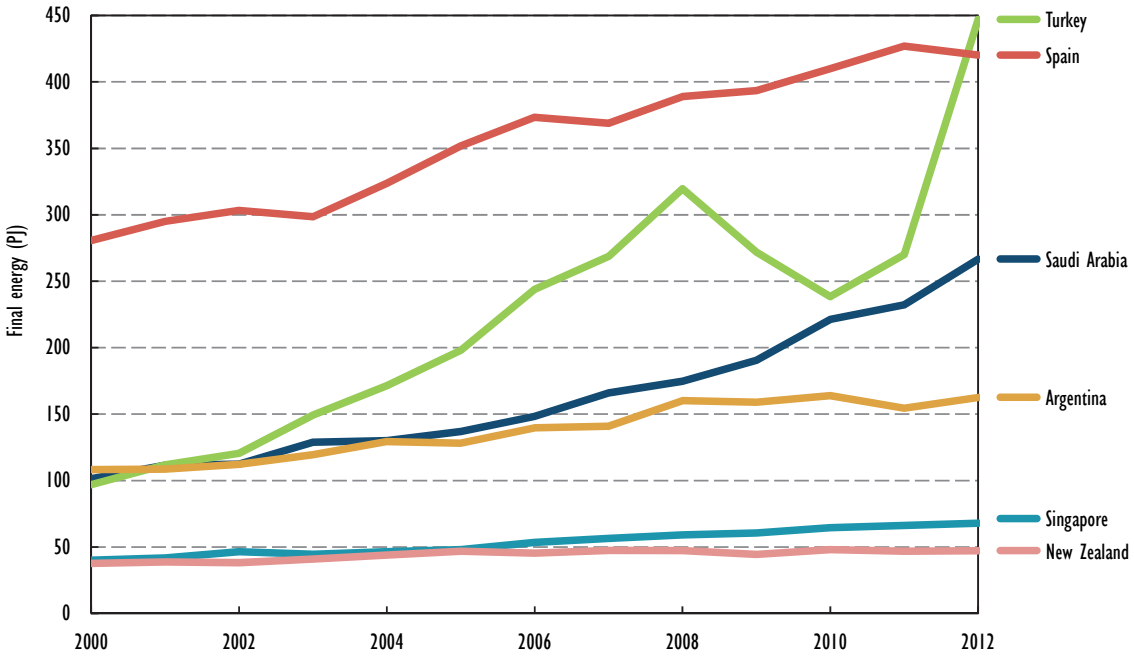


Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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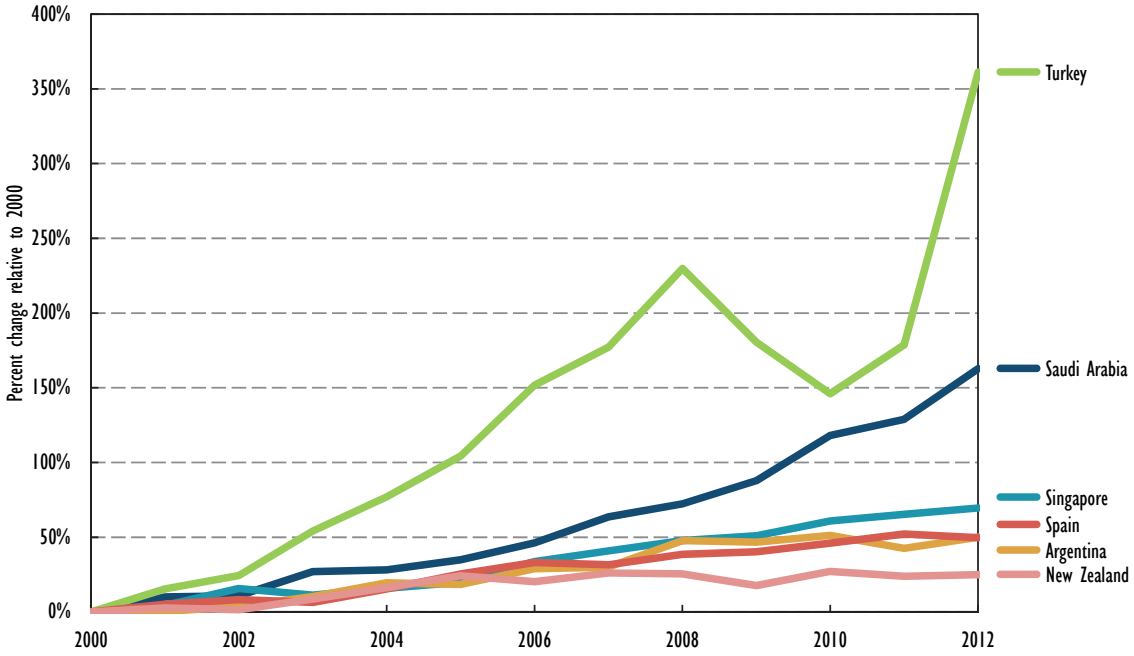
G20 members and guests

Figure E5 • Services energy use in G20 and guest economies, 2000-12



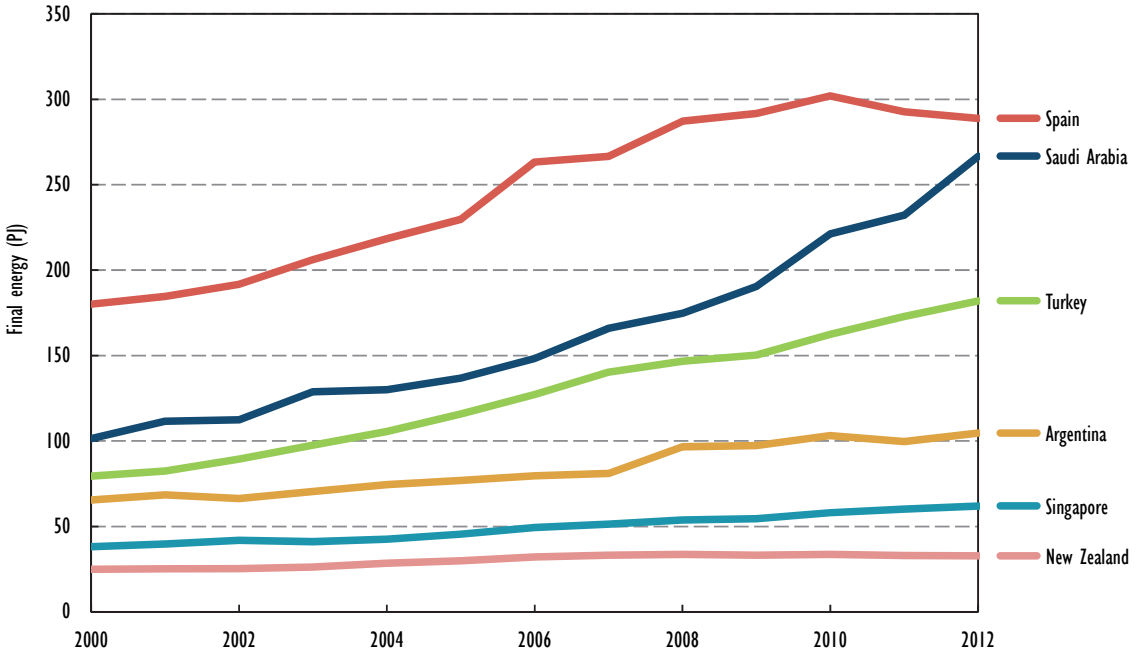
Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure E6 • Change in services energy use in G20 and guest economies, 2000-12



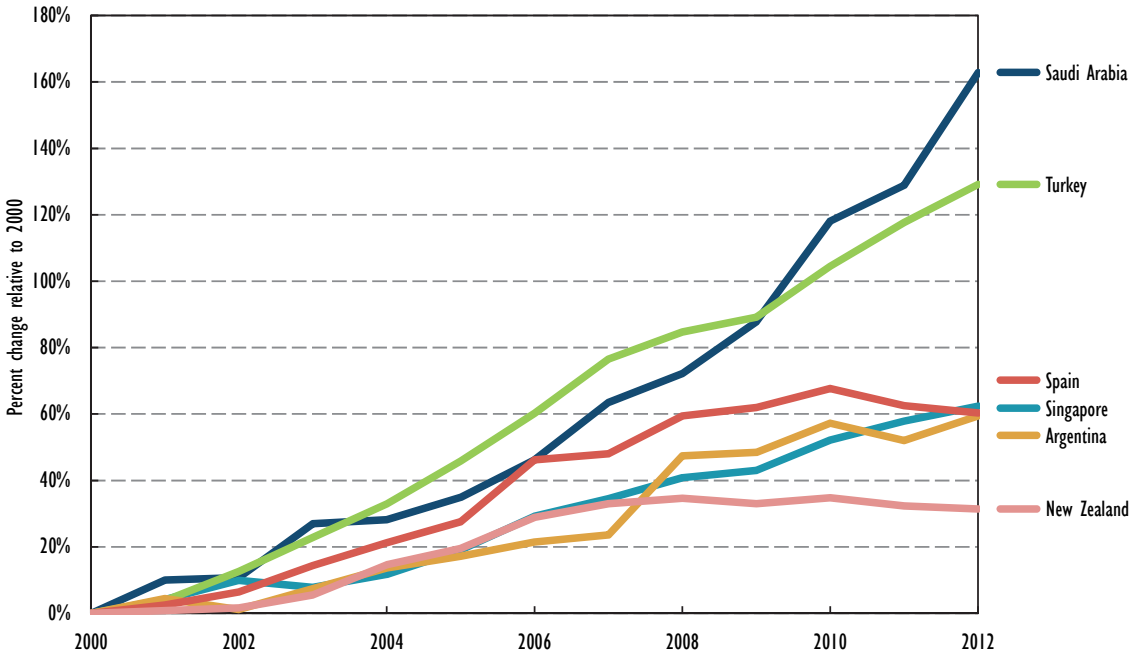
Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure E7 • Services electricity use in G20 and guest economies, 2000-12



Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure E8 • Change in services electricity use in G20 and guest economies, 2000-12



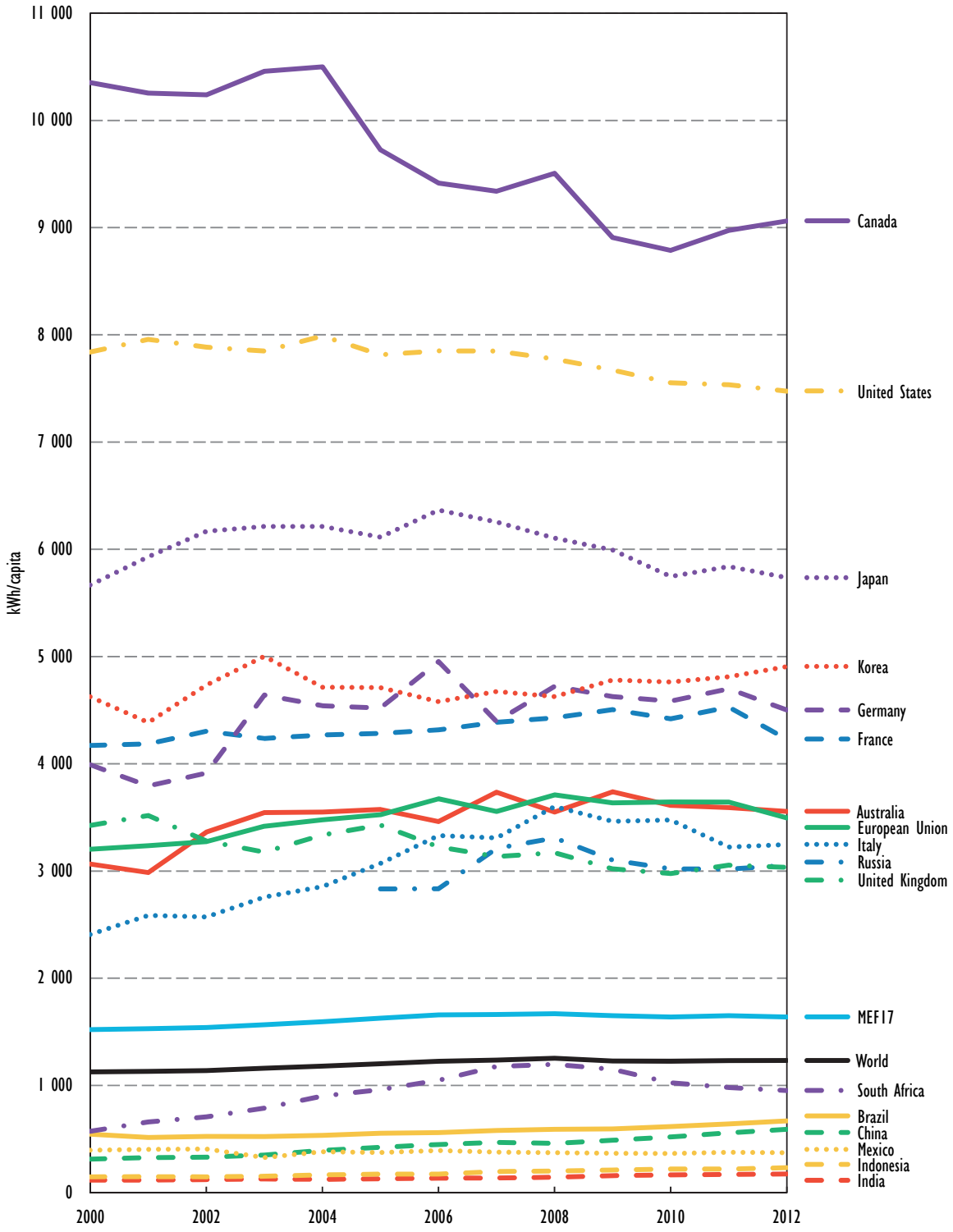
Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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Service building energy metrics

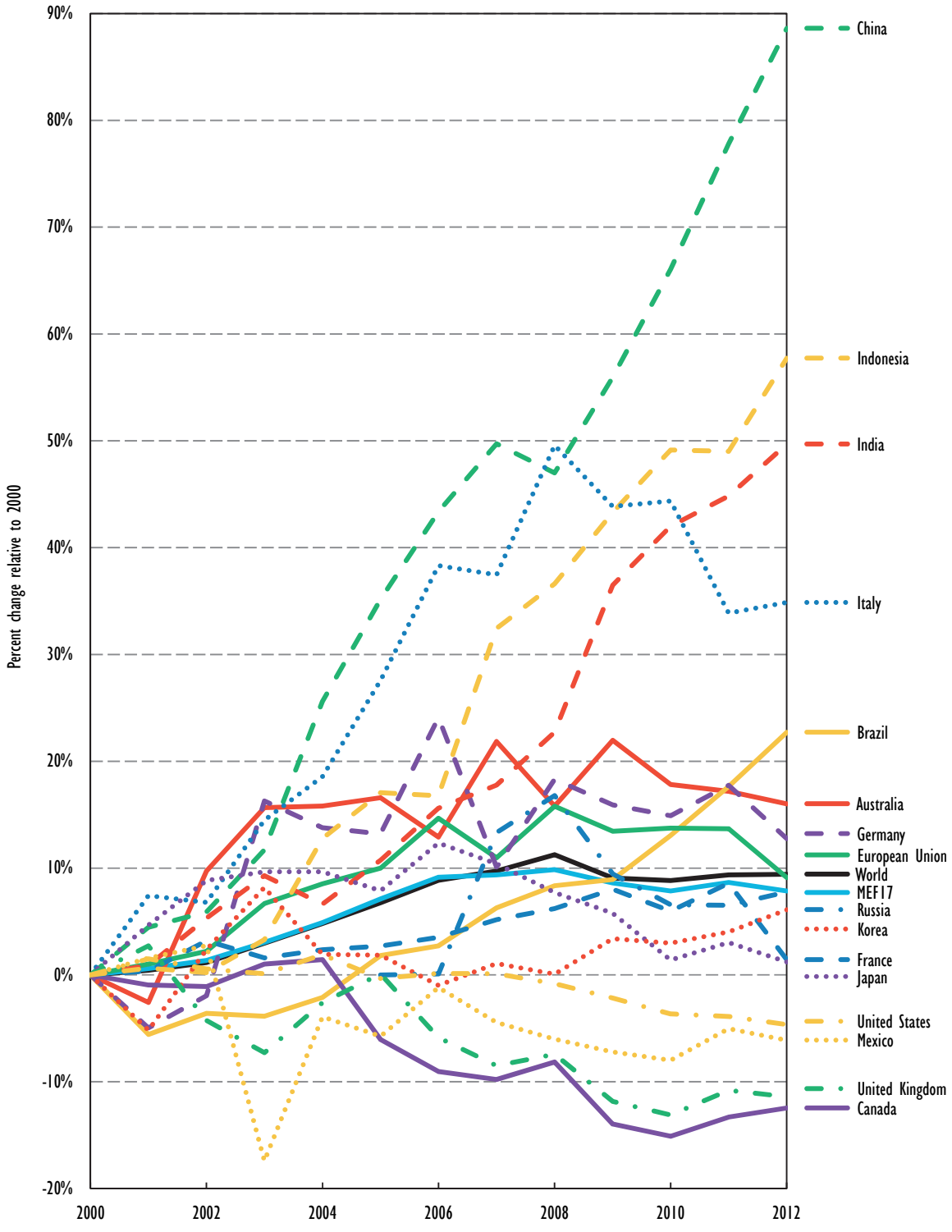
Per capita intensity

Figure E9 • Services energy use per capita in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure E10 • Change in services energy use per capita in MEF economies, 2000-12

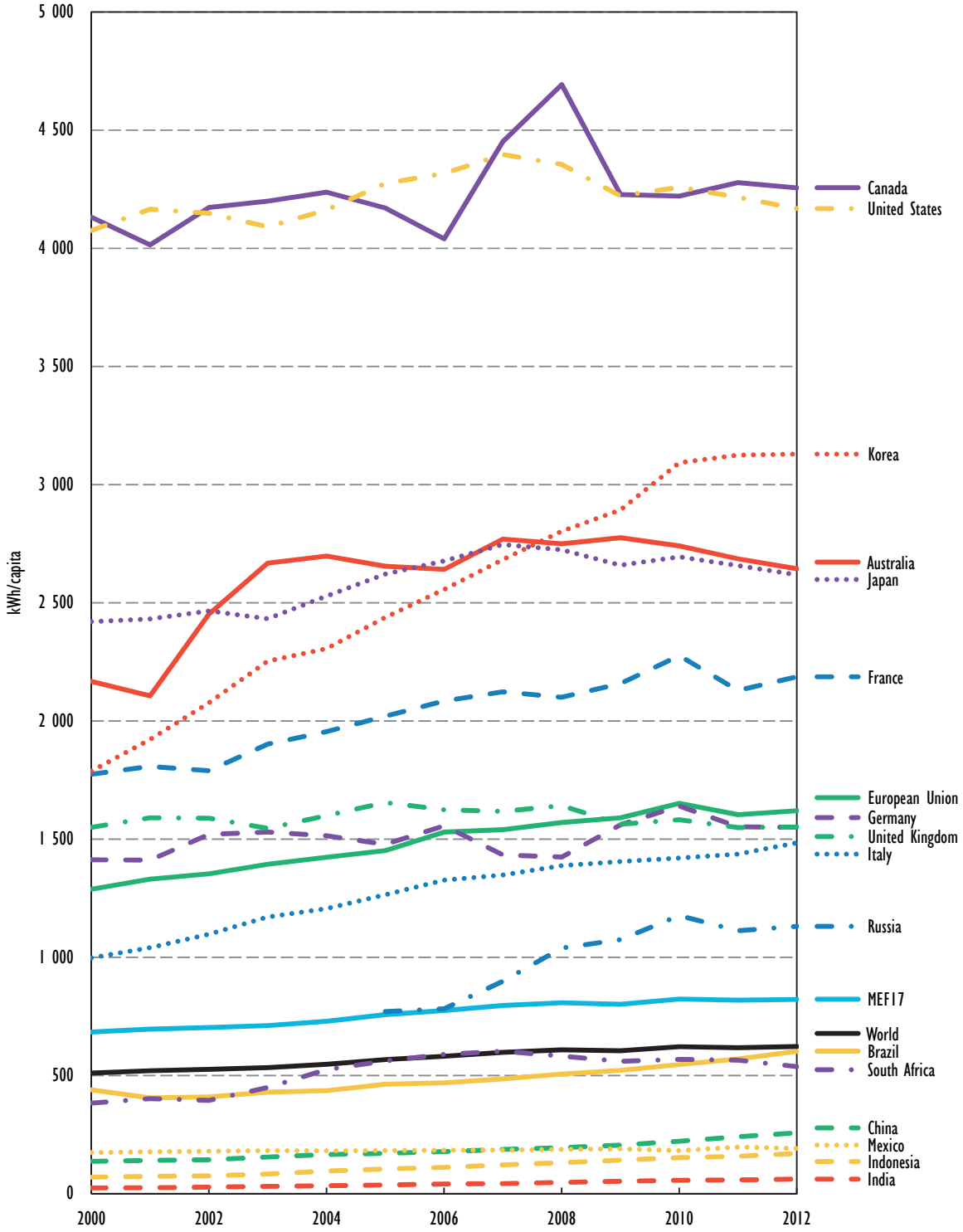


Note: South Africa data are not shown due to data quality issue; see Figure D2 note for more information.

Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

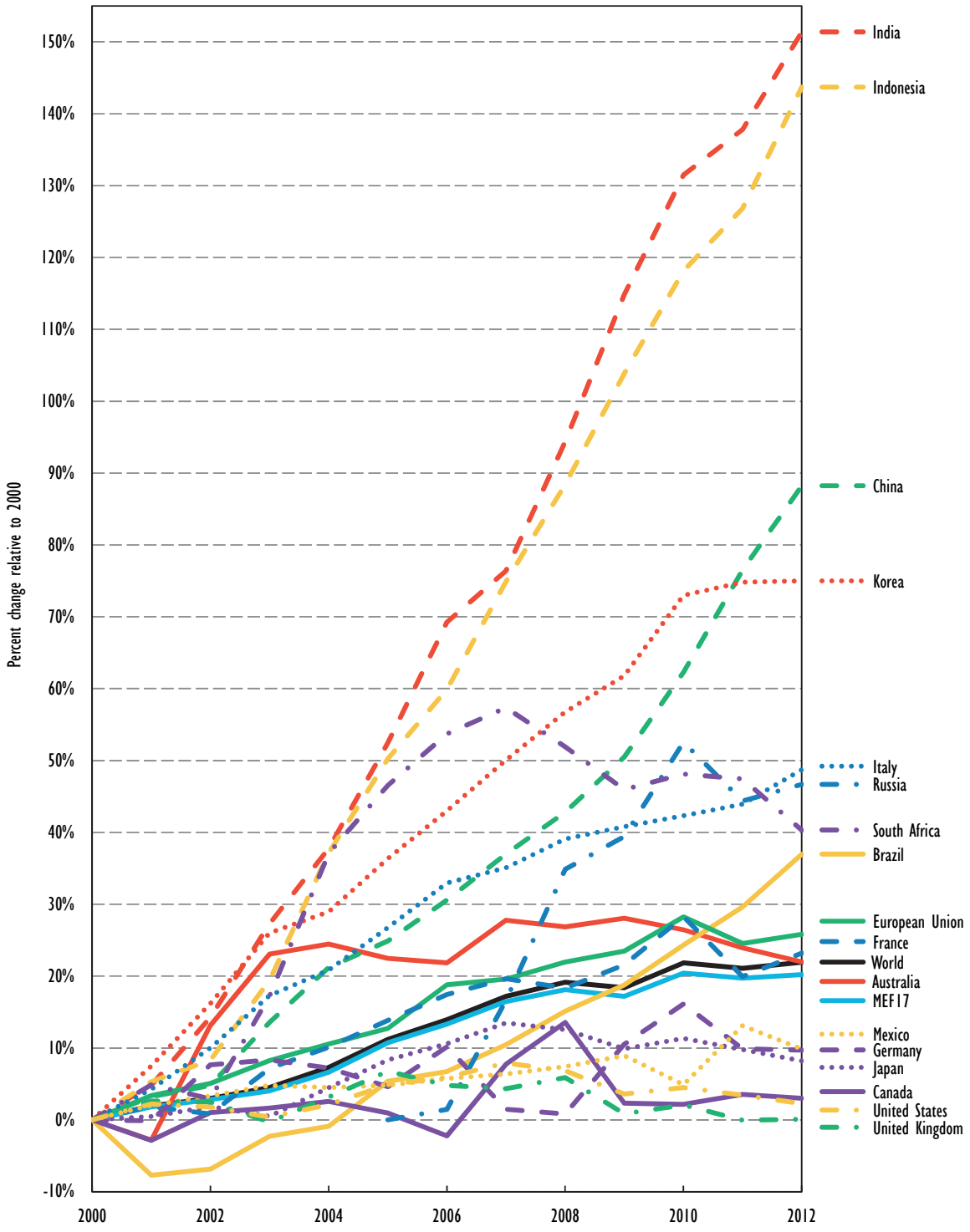
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Figure E11 • Services electricity use per capita in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure E12 • Change in services electricity use per capita in MEF economies, 2000-12

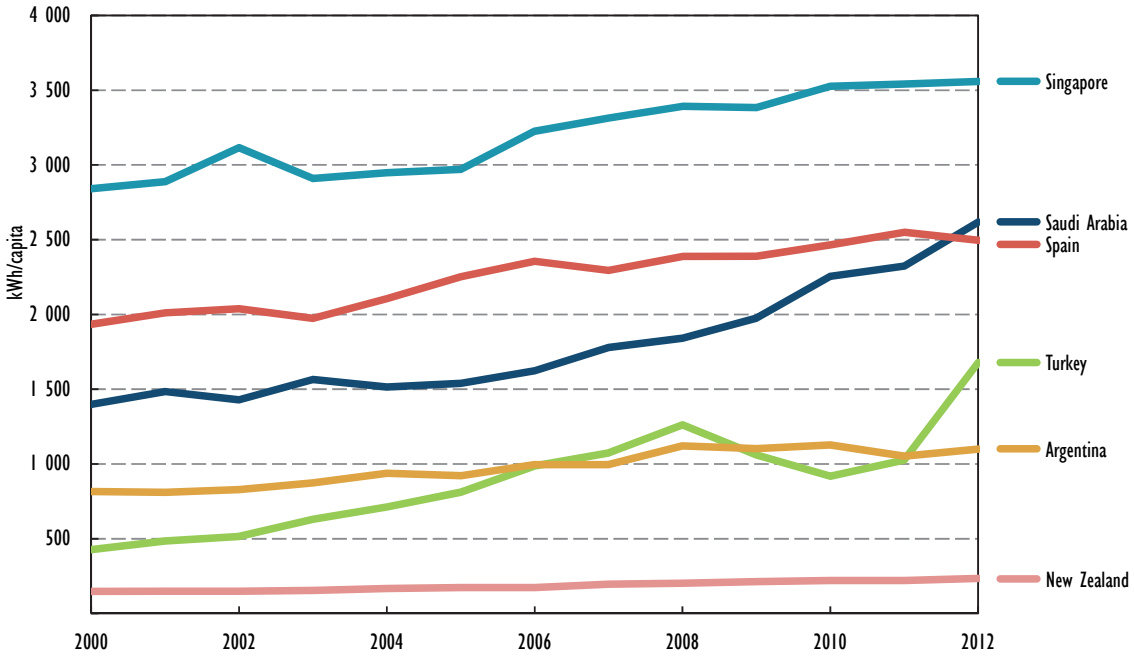


Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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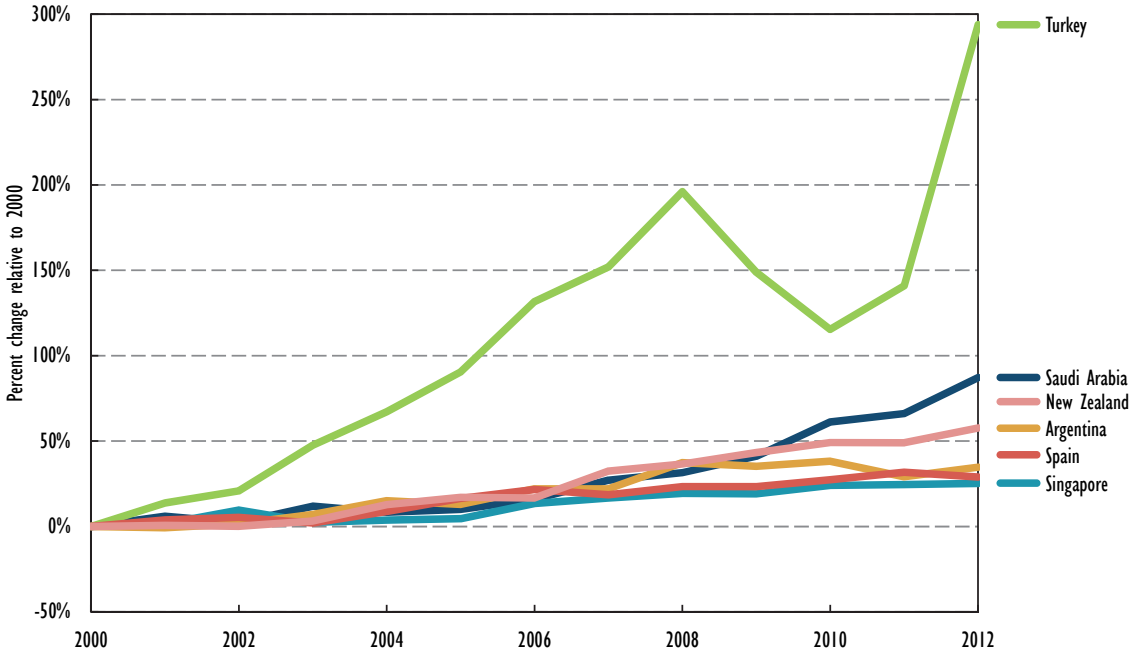
G20 members and guests

Figure E13 • Services energy use per capita in G20 and guest economies, 2000-12



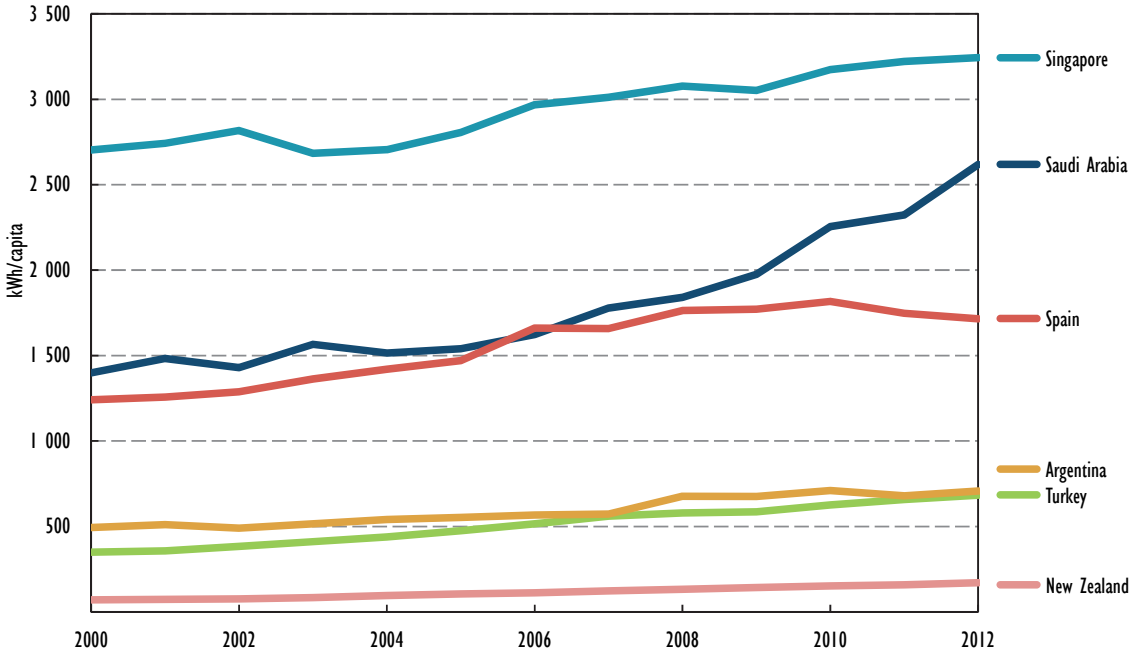
Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure E14 • Change in services energy use per capita in G20 and guest economies, 2000-12



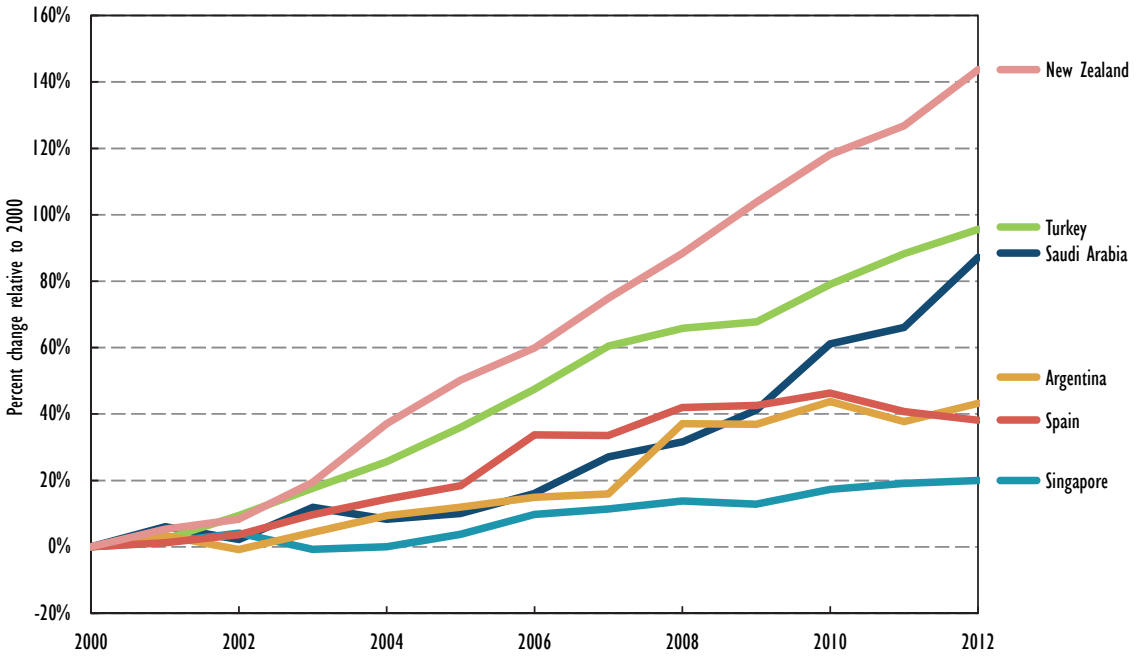
Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure E15 • Services electricity use per capita in G20 and guest economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure E16 • Change in services electricity use per capita in G20 and guest economies, 2000-12

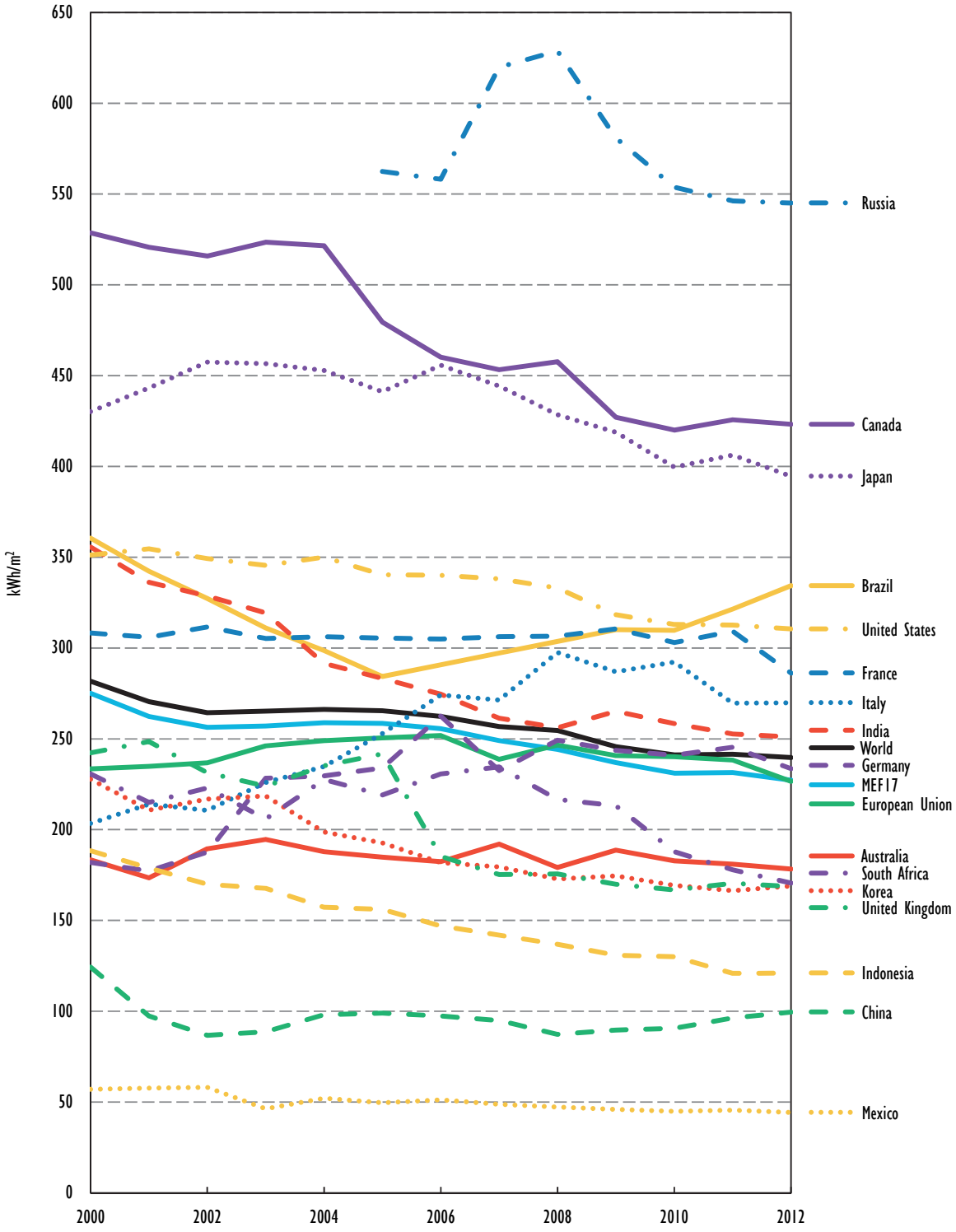


Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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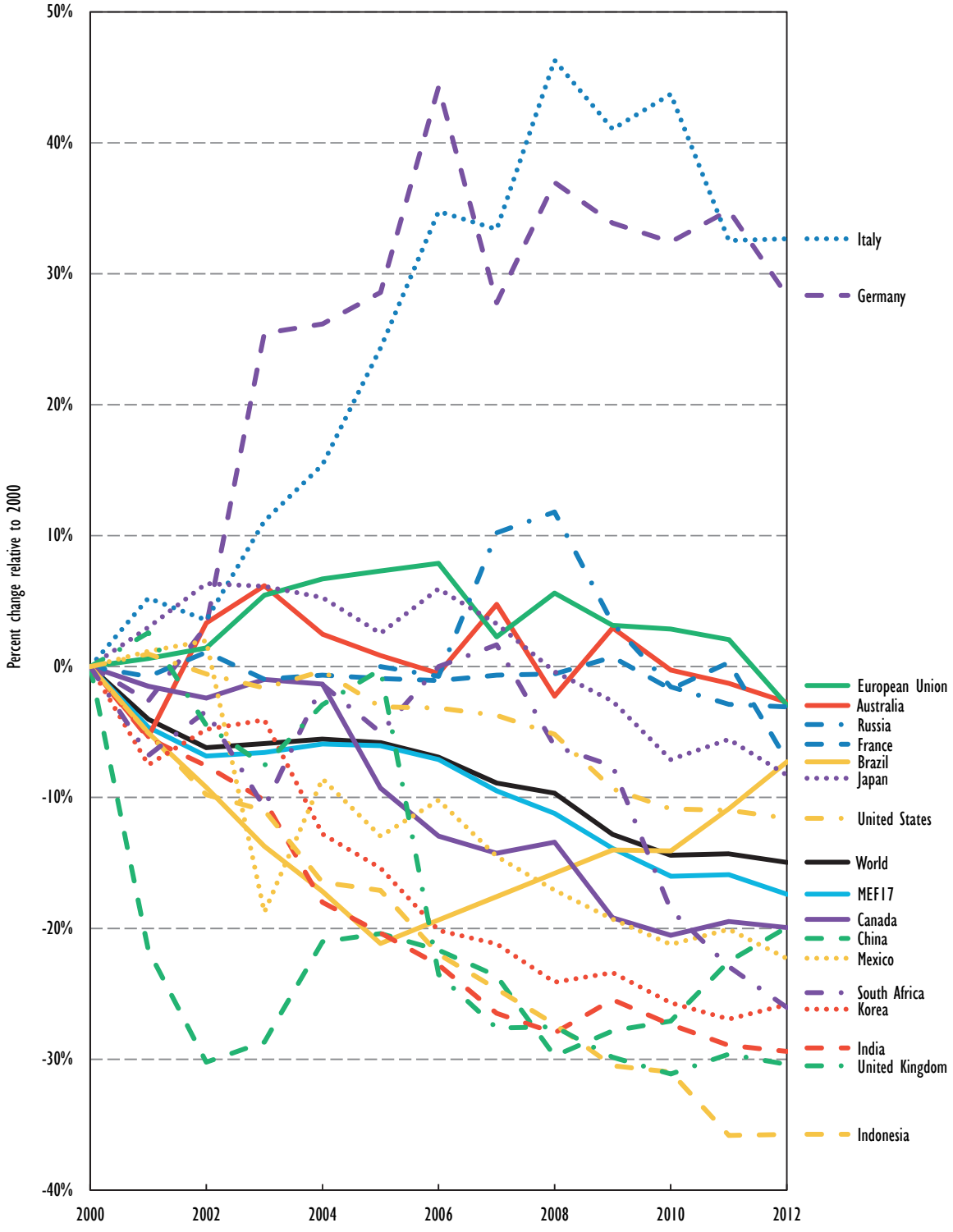
Floor area intensity

Figure E17 • Services energy use per floor area in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

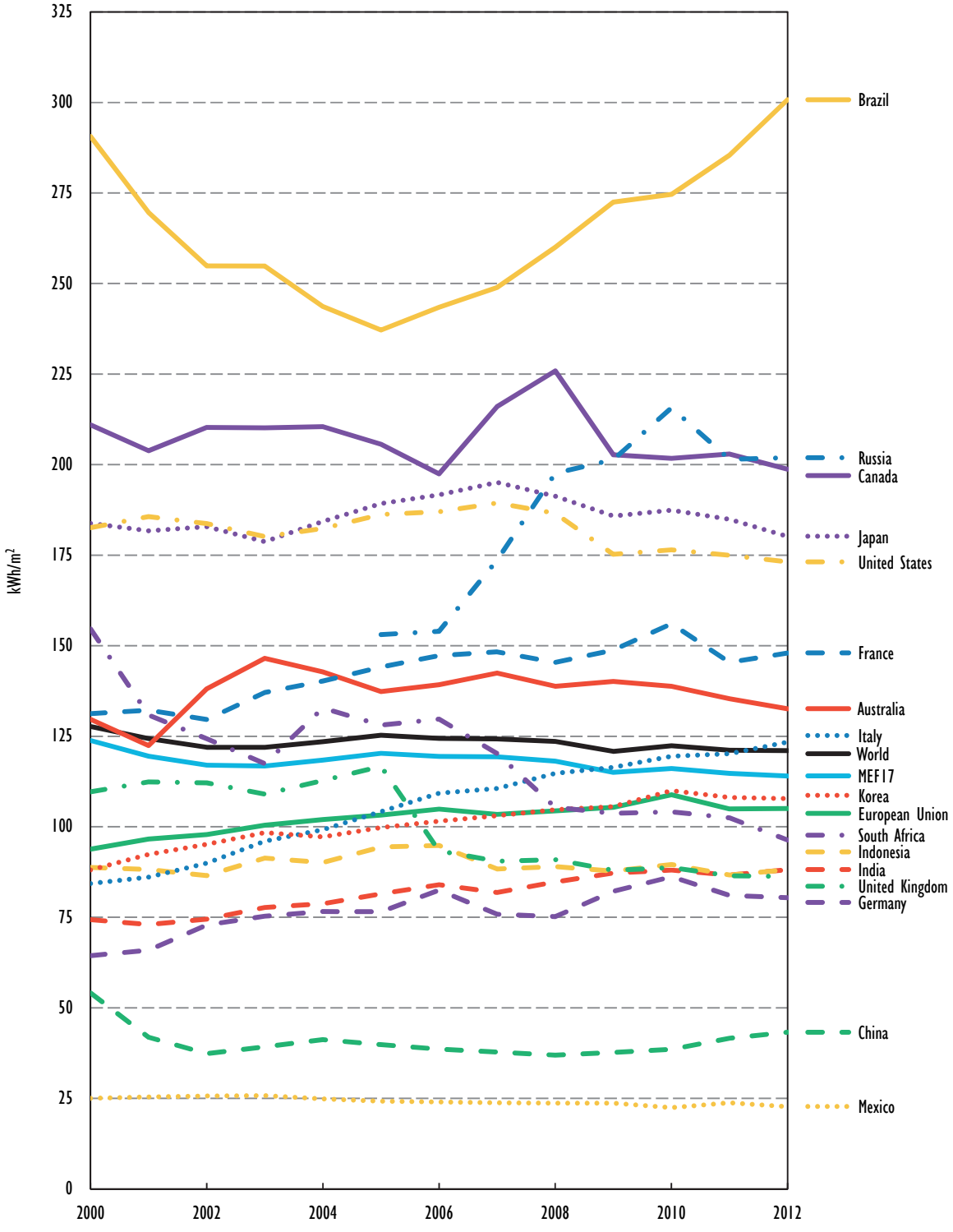
Figure E18 • Change in services energy use per floor area in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

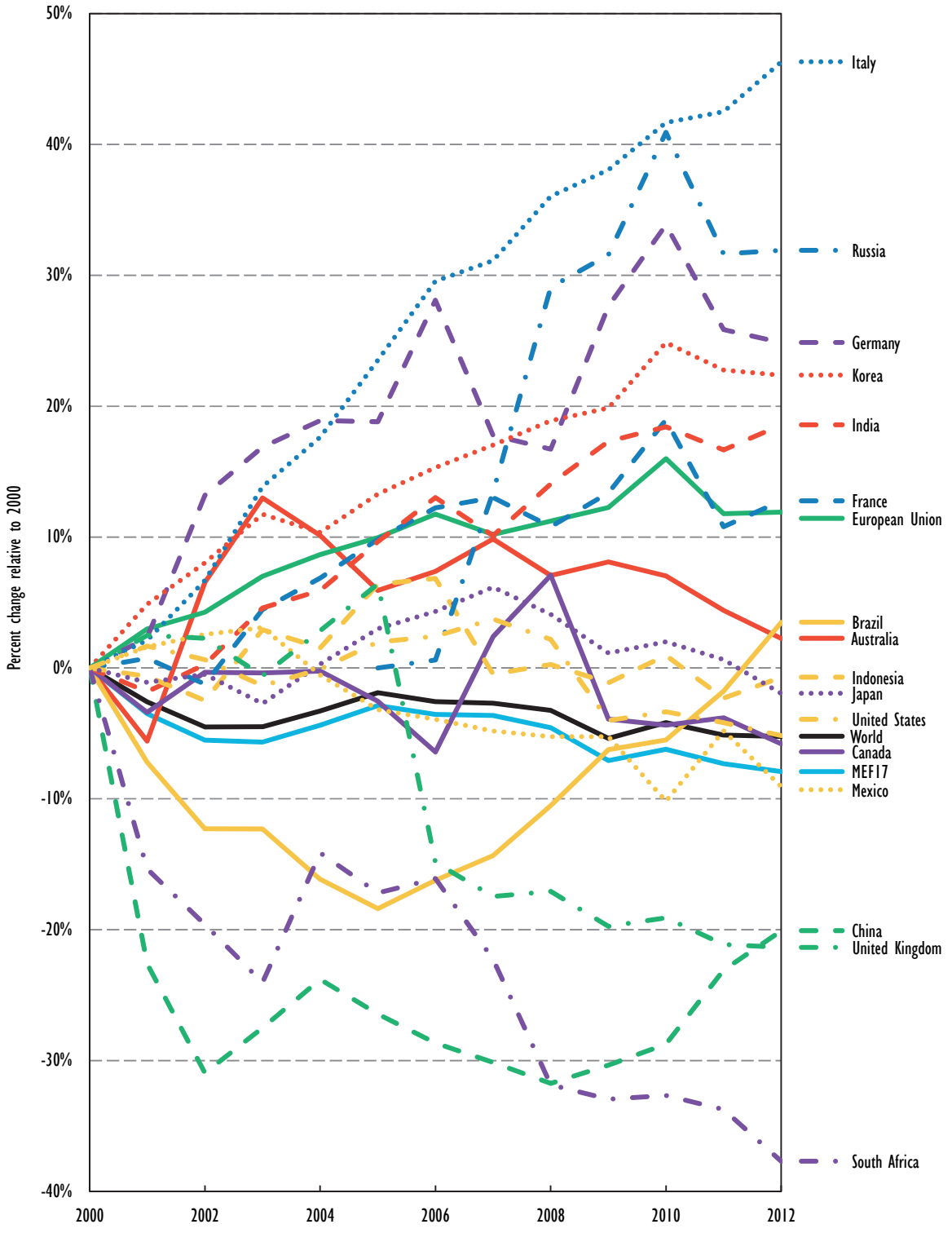
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Figure E19 • Services electricity use per floor area in MEF economies, 2000-12



Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure E20 • Change in services electricity use per floor area in MEF economies, 2000-12

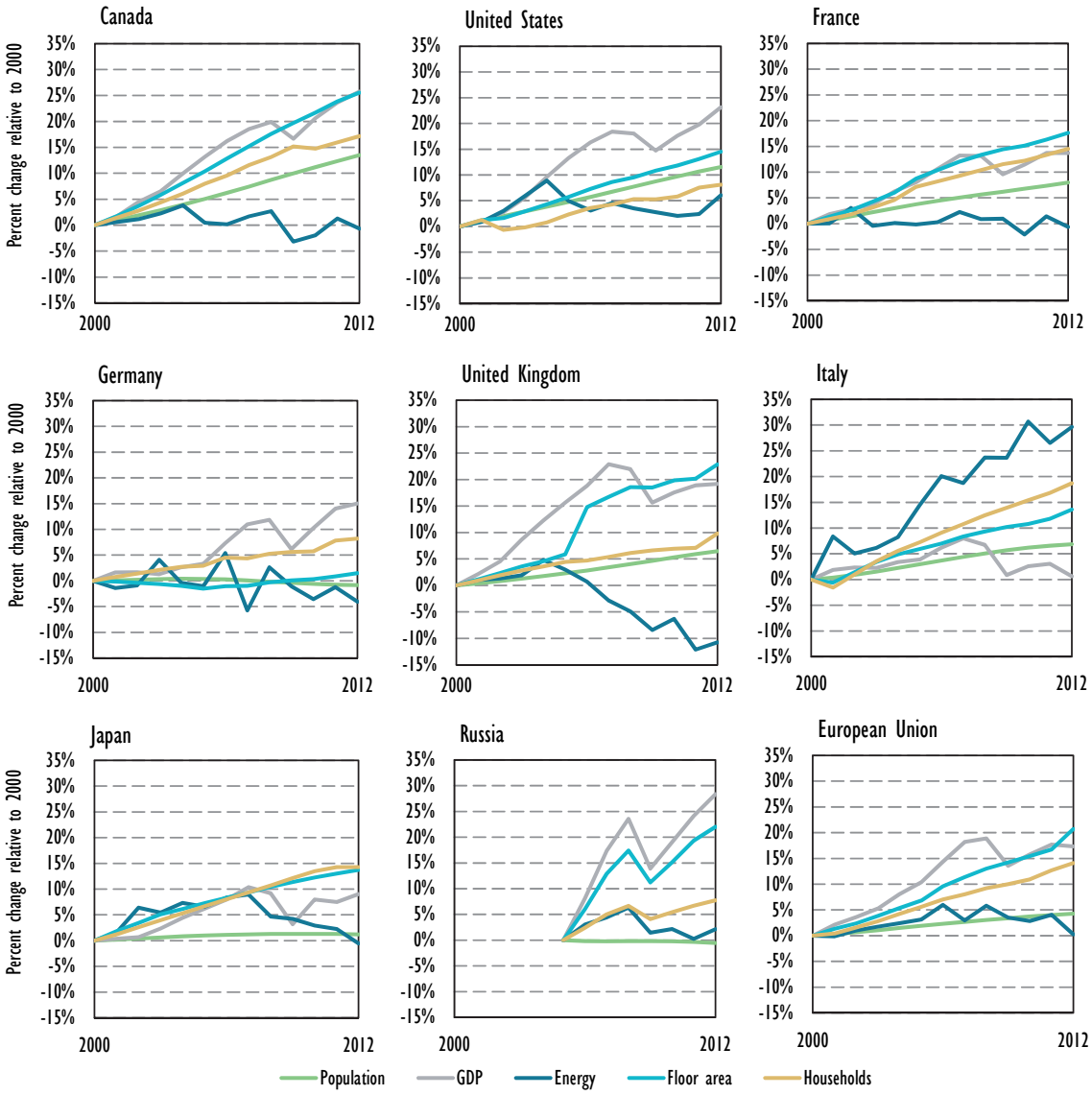


Source: Calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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Annex F. Building energy trends and drivers by economy

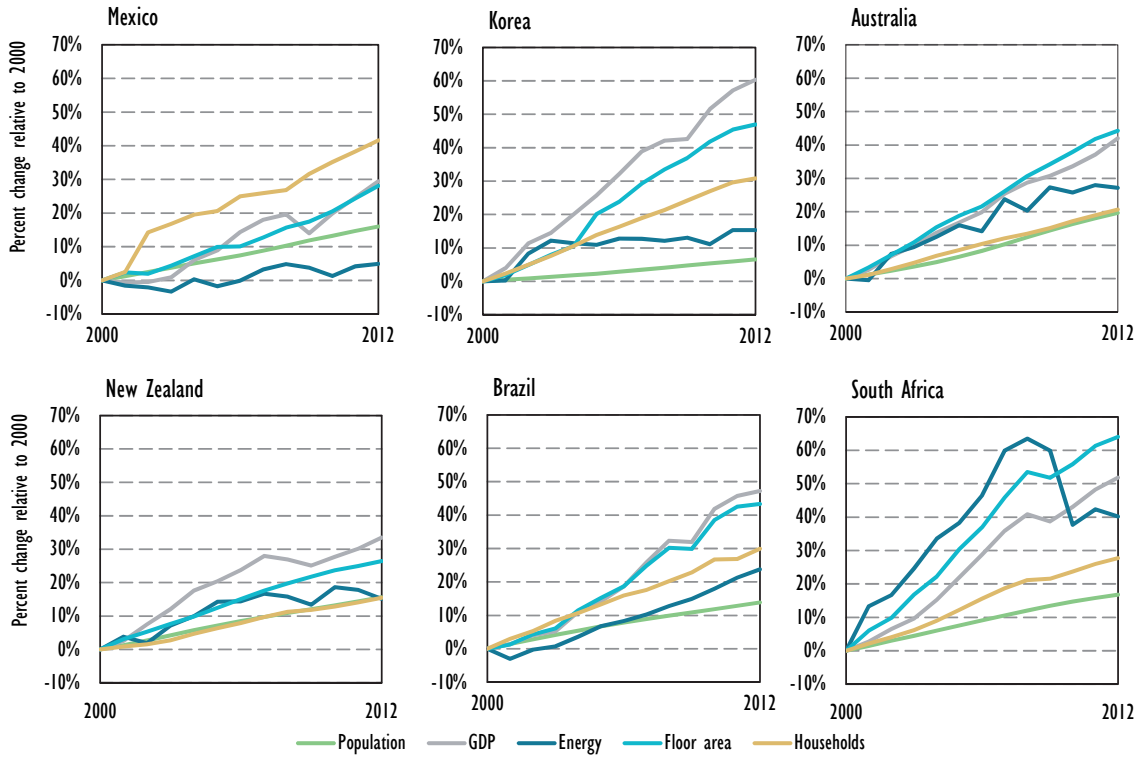
Figure F1 • Change in total building energy use and major drivers in MEF economies, 2000-12



Note: Scale -15% to 35%.

Sources: Population: IEA (2015b), *Statistics Database*, www.iea.org/statistics/statisticssearch; GDP: IMF (2014), *World Economic Outlook Database*, April, www.imf.org/external/pubs/ft/weo/2014/01/weodata; calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

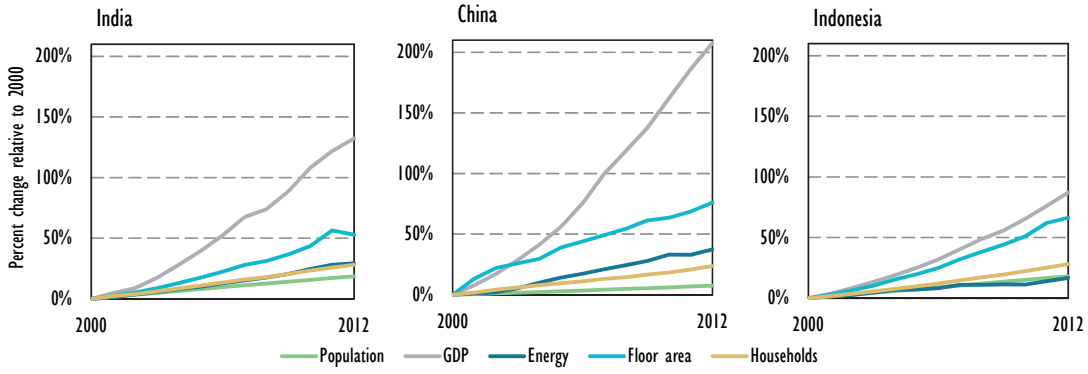
Figure F2 • Change in total building energy use and major drivers in MEF economies, 2000-12



Notes: South Africa data has data quality issue; see Figure D2 note for more information. Scale -10% to 70%.

Sources: Population: IEA (2015b), *Statistics Database*, www.iea.org/statistics/statisticssearch; GDP: IMF (2014), *World Economic Outlook Database*, April, www.imf.org/external/pubs/ft/weo/2014/01/weodata; calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

Figure F3 • Change in total building energy use and major drivers in MEF economies, 2000-12



Note: Scale 0% to 210%.

Sources: Population: IEA (2015b), *Statistics Database*, www.iea.org/statistics/statisticssearch; GDP: IMF (2014), *World Economic Outlook Database*, April, www.imf.org/external/pubs/ft/weo/2014/01/weodata; calculations derived with IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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Table F1 • Historic and forecasted GDP in MEF and G20 economies, 2000 and 2012-50

Economy	GDP (2012 USD billion) in 2000	GDP (2012 USD billion) in 2012	Change in GDP (%)	GDP (2012 USD billion) in 2050	Change in GDP from 2012 (%)
World	55 056	83 302	51%	272 736	227%
MEF 17	45 449	66 636	47%	214 974	223%
Australia	677	961	42%	2 316	141%
Brazil	1 585	2 334	47%	8 021	244%
Canada	1 172	1 474	26%	2 986	103%
China	4 102	12 621	208%	67 400	434%
European Union	13 632	15 995	17%	29 272	83%
France	1 968	2 238	14%	3 712	66%
Germany	2 754	3 167	15%	5 272	66%
India	2 060	4 786	132%	39 515	726%
Indonesia	643	1 204	87%	5 973	396%
Italy	1 803	1 815	1%	2 935	62%
Japan	4 181	4 559	9%	6 878	51%
Korea	996	1 598	60%	3 731	134%
Mexico	1 387	1 796	29%	4 877	172%
Russia	1 439	2 486	73%	6 417	158%
South Africa	380	577	52%	1 484	157%
United Kingdom	1 942	2 315	19%	3 933	70%
United States	13 194	16 246	23%	36 106	122%
Remaining G20	1 562	2 734	75%	7 933	163%

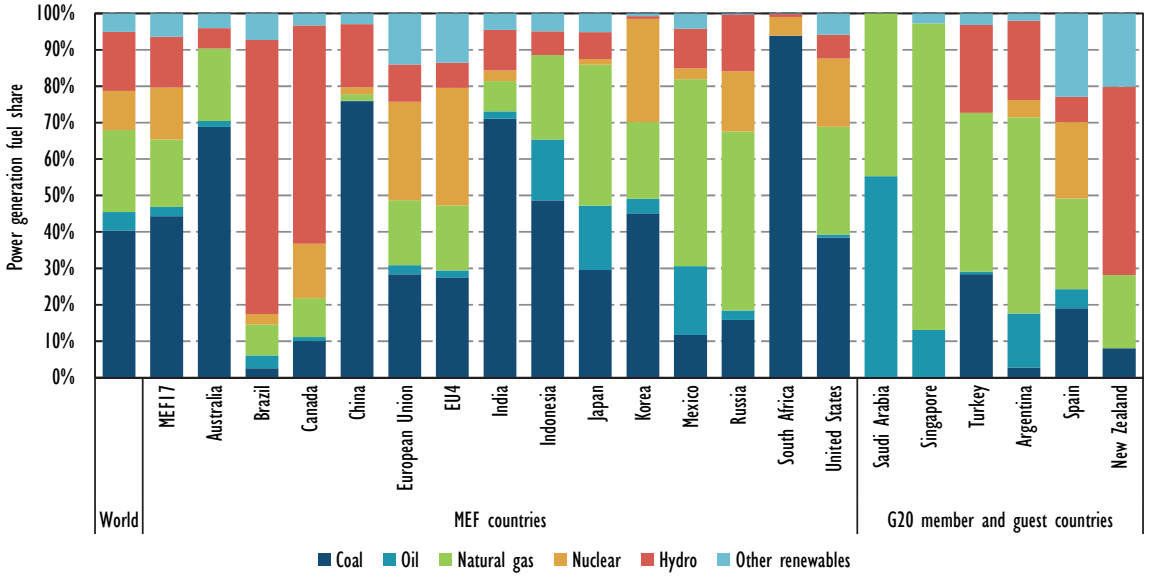
Source: GDP: IMF (2014), *World Economic Outlook Database*, April, www.imf.org/external/pubs/ft/weo/2014/01/weodata and IEA projections to 2050.

Annex G. Electricity generation fuel shares

While this report focuses on final energy, governmental and non-governmental participants in BEET 4 highlighted the importance of also understanding the total primary energy use associated with the buildings sector, including the fuel used in generating electricity. Power sector fuel shares do vary considerably among MEF and G20 economies (Figure G1).

As of 2012, fuel shares in the electricity sector varied considerably among MEF and G20 economies. The portion of electricity derived from fossil fuels also varied, with Brazil and New Zealand having the lowest fossil fuel shares.

Figure G1 • Power sector fuel shares in MEF and G20 economies, 2012



Note: EU4 refers to France, Germany, Italy and the United Kingdom, which share an interconnected electric grid.

Source: IEA (2014a), "World energy balances", *IEA World Energy Statistics and Balances* (database).

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Acronyms, abbreviations and units of measure

Acronyms and abbreviations

2DS	IEA 2°C Scenario
6DS	IEA 6°C Scenario
APEC	Asia-Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
BEET	Building Energy Efficiency Task Group
CDD	cooling degree days
DR	deep renovation
DER	deep energy renovation
EEI	energy efficiency indicator
EPBD	Energy Performance of Buildings Directive
ETP 2015	*Energy Technology Perspectives 2015*
GDP	gross domestic product
GHG	greenhouse gases
HDD	heating degree days
IEA	International Energy Agency
IPEEC	International Partnership for Energy Efficiency Cooperation
IPEEI	IPEEC Improving Policies through Energy Efficiency Indicators
MEF	Major Economies Forum
nZEB	nearly zero-energy building
PPP	purchasing power parity
SPT	Sustainable Energy Policy and Technology Division (IEA)
VLEB	very low-energy building
WEC	World Energy Council
ZEB	zero-energy building

Units of measure

EJ	exajoule (10^18 joules)
kWh	kilowatt (10^3 watts) hour
m^2	square metre
PJ	petajoule (10^15 joules)

Definitions

G20 economies: Argentina, Australia, Brazil, Canada, China, European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, United Kingdom and United States.

MEF economies: Australia, Brazil, Canada, China, European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, South Africa, United Kingdom and United States.

Residential sub-sector: The residential sub-sector includes those activities related to dwellings, whether single-family homes or multi-family buildings. It covers all energy-using activities in apartments and houses, including space and water heating, cooling, lighting and the use of appliances. It does not include energy used for personal transport, which is covered in the transportation sector.

Services sub-sector: The services sub-sector includes activities related to trade, finance, real estate, public administration, health, food and lodging, education and commercial services (International Standard Industrial Codes 50 to 55 and 65 to 93). It is also referred to as the commercial and public services sub-sector. It covers energy used for space heating, cooling and ventilation, water heating, lighting, and for other miscellaneous equipment such as commercial appliances and cooking devices, x-ray machines, office equipment and generators. Energy used for transportation, or for commercial transport fleets, is excluded from the services sub-sector.

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA.

International Energy Agency

Secure • Sustainable • Together

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International Partnership for Energy Efficiency Cooperation

The International Partnership for Energy Efficiency Cooperation (IPEEC) is an autonomous partnership of 16 members established in May 2009. IPEEC's establishment arose from successive meetings of the G8+5 economies, with the aim to accelerate energy efficiency advancements across the world's major economies.

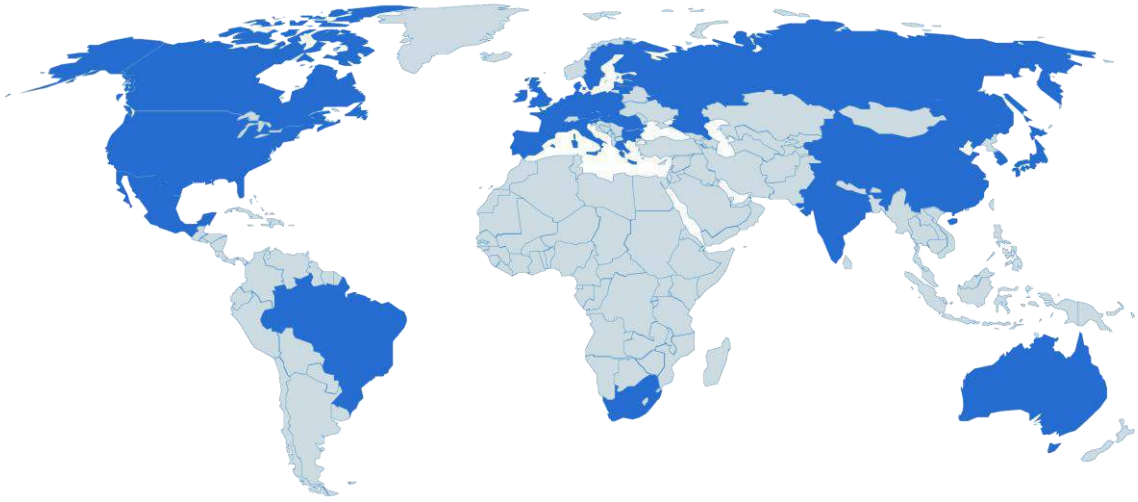
Since its inception, IPEEC members have been working together through dedicated member-led Task Groups, to identify and implement policies and programs to hasten the deployment of energy efficiency technologies, measures and best practices. IPEEC Task Groups implement their work across a spectrum of high-impact energy efficiency areas, supported by the coordination, communication and high-level analyses of the IPEEC Secretariat.

The IPEEC mandate includes the following objectives:

- Provide an international forum that helps participating countries identify and share proven, innovative practices and data on energy efficiency.
- Undertake joint projects for the development and implementation of energy efficiency policies and measures at a global scale.
- Improve decision-making through information and outputs provided by Task Groups.
- Foster coordination of countries engagement in related bilateral and multilateral initiatives.

IPEEC's members include:

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- France
- Germany
- India
- Italy
- Japan
- Mexico
- People's Republic of China
- Republic of Korea
- Russian Federation
- South Africa
- United Kingdom
- United States of America



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This is a joint publication of the International Energy Agency (IEA) and the International Partnership for Energy Efficiency Cooperation (IPEEC), produced with inputs from participating governments.

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IEA Publications
9, rue de la Fédération, 75739 Paris cedex 15

Printed in France by IEA, April 2015

Cover design: IEA. Photo credits: GraphicObsession.

