Chapter 2
Energy Conservation in Japan

Abstract A serious concern about the supply shortage of electricity after the nuclear disaster in Fukushima, together with a growing concern about global warming, has enhanced the need to promote energy conservation in Japan. The residential sector, which is the focus of this book, has increased its share of total energy consumption for the past two decades in Japan. Electricity represents approximately half of the residential energy consumption, and is a key factor in promoting energy conservation in the residential sector. Conventional policy measures such as energy taxes, subsidies, labeling, and technological standards for energy efficiency have contributed to the development and use of energy-efficient technologies, but additional policy interventions are necessary to further constrain electricity consumption. Innovative energy conservation instruments such as critical peak pricing, conservation requests, in-home displays, and home energy reports are expected to mitigate the increasing concern about electricity supply and CO_2 emissions by constraining the residential usage of electricity in the future.

Keywords Energy taxation · Subsidization · Labeling · Energy efficiency · Standards · CO_2 emissions

2.1 Energy Conservation Policies in Japan

The Japanese government has enforced the Energy Conservation Law (ECL), which was enacted in 1979 in the wake of the second oil crisis, to implement regulatory measures regarding energy conservation. The ECL obliges firms that consume large amounts of energy to disclose annual energy consumption and to submit long-term plans on energy conservation (JANRE 2011). These firms are found primarily in the manufacturing and transportation sectors. The ECL also requires manufacturers and importers of energy-using durable goods such as passenger cars, air-conditioners, and television sets, to meet so-called “Top Runner Standards,” which are energy efficiency standards that are based on the best available technologies. To heighten consumers’ awareness of energy efficient

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Table 2.1 Energy taxation by the Japanese government

Taxation	Fuel	Tax rate
Gasoline tax	Volatile oil (gasoline)	48.6 cents/L
Oil and gas tax	LPG for the car	17.5 cents/kg
Aviation fuel tax	Aviation fuel	18.0 cents/L
Petroleum and coal tax (inclusive of tax for climate change mitigation)	Crude oil and petroleum products	28.00 dollars/kL
	LPG and LNG	18.60 dollars/ton
	Coal	13.70 dollars/ton
Electric power development promotion tax	Electricity	3.75 dollars per 1,000 kWh

Note Tax rates are converted to U.S. currency (1 U.S. dollar = 100 yen)
Source Japan Ministry of the Environment. (http://www.env.go.jp/en/policy/tax/env-tax/20120814a_ertj.pdf, accessed January 2016)

products, the government encourages manufactures of energy-using durables to label energy consumption and energy efficiency on their products. Energy efficiency standards are also applied to commercial buildings and residential dwellings.

Together with a command-and-control approach, the government has adopted economic instruments for energy conservation (Arimura and Iwata 2015). Taxation and subsidization are the main economic instruments used in this regard. Table 2.1 summarizes energy taxation associated with the Japanese government. Tax rates are converted to U.S. currency (1 U.S. dollar = 100 yen). Gasoline tax, oil and gas tax, and aviation fuel tax are imposed on energy usage for transportation. The petroleum and coal tax is applied to the consumption of crude oil, petroleum products, gas (liquefied natural gas, LNG, and liquefied petroleum gas, LPG), and coal. This tax includes a charge for climate change mitigation. Finally, consumers pay the electric power development promotion tax for their electricity usage.

The government has also provided firms with subsidies for energy conservation measures. An example of this is the energy-efficient replacement of facilities at manufacturing plants. The subsidy provides for up to one-third of the costs for each facility replacement. Firms installing new energy-efficient facilities or purchasing equipment that meets efficiency standards can also receive a subsidy for interest payments. Additionally, subsidization is also available for the construction of highly efficient buildings and dwellings.

The important policy question is whether these conservation measures have contributed to an improvement in energy efficiency in Japan. Figure 2.1 illustrates energy intensity, which is defined as the ratio of total primary energy requirements (measured in ton of oil equivalent [toe]) to the gross domestic product (GDP) (measured in 100 million yen, 2005 price), for the period 1975–2012. Energy intensity indicates how efficiently energy is used in the economy. During the period of 1975–2012, energy intensity consistently decreased, dropping by approximately 38.9 % overall. This improvement of energy efficiency in Japan is

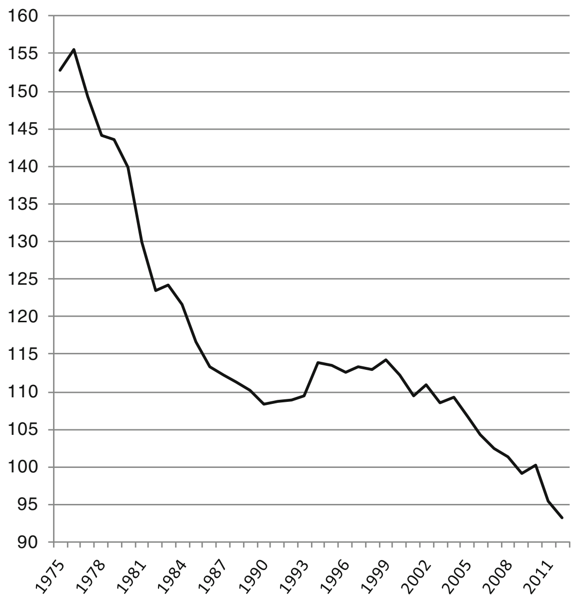

Fig. 2.1 Energy intensity in Japan, 1975–2012. *Note* Energy intensity is the ratio of total primary energy requirements (measured in ton of oil equivalent) to GDP (measured in 100 million yen, 2005 price). *Source* EDMC (2015)

remarkable among the developed countries. Table 2.2 compares energy consumption among selected OECD countries in 2012. Among six countries listed in the table, Japan is the second largest consumer of energy, and its share of electricity is the largest. The international comparison of energy intensity indicates that Japan is less energy-intensive than the OECD average. It uses energy more efficiently than France, Germany, and the United States. These findings indicate that energy conservation policies, amongst other factors, are key contributors to the improvement of energy efficiency in Japan.

Further conservation of energy is necessary for Japan, however, since its carbon dioxide (CO_2) intensity, which is measured by the ratio of CO_2 emissions to GDP,

Table 2.2 Energy consumption by selected OECD countries, 2012

	Japan	Italy	France	Germany	United Kingdom	United States	OECD total
Energy consumption (Mtoe) —Electricity share (%)	452 25.7	159 20.8	252 24.1	313 20.5	192 21.4	2,141 22.4	5,250 22.3
Energy intensity (toe/million US$, 2010 price)	82	79	96	91	83	137	116
CO_2 intensity (CO_2 ton/million US$, 2010 price)	220	176	124	211	201	328	267

Notes Mtoe stands for million ton of oil equivalent. Energy intensity is the ratio of total primary energy requirements (measured in ton of oil equivalent [toe]) to GDP (measured in million U.S. dollars, 2010 price). CO_2 intensity is the ratio of total CO_2 emissions to GDP
Source EDMC (2015)

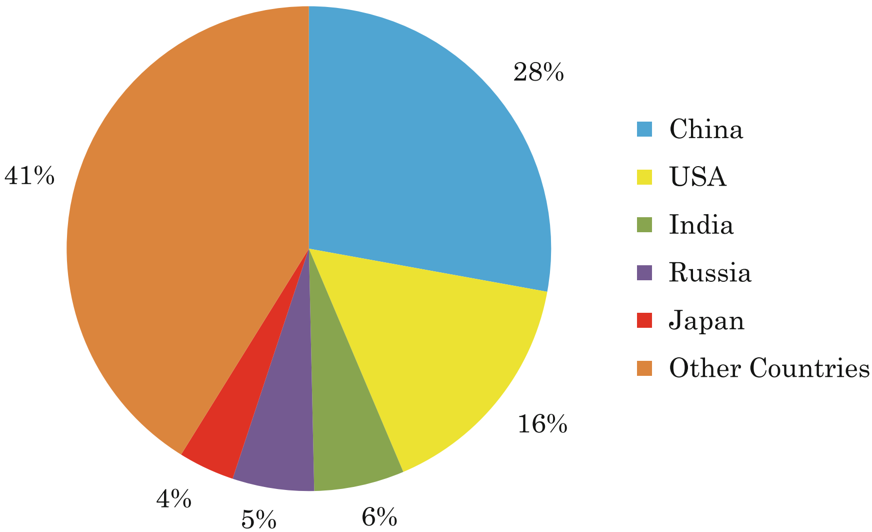

Fig. 2.2 Shares of CO_2 emissions by country, 2012. *Source* EDMC (2015)

is larger than that in Italy, France, Germany, and the United Kingdom, as shown in Table 2.2. In fact, as Fig. 2.2 shows, Japan was the fifth largest emitter of CO_2 in the world as of 2012, following China, the United States, India, and Russia. Further conservation of energy would contribute to constraining CO_2 emissions, because more than 90 % of CO_2 emissions originate from energy consumption in Japan (EDMC 2015).

The Japanese government has attempted to constrain CO_2 emissions, which represent more than 90 % of total emissions of greenhouse gases in the country. Despite its efforts, CO_2 emissions have steadily increased in Japan, with an annual average growth rate of approximately 0.6 % during the period of 1990–2013 (EDMC 2015). By using the carbon sink in domestic forests and the Kyoto Mechanisms, the government has achieved its targeted reduction of greenhouse gases from the Kyoto Protocol: a 6 % reduction in annual average emissions below the 1990 level during a five-year commitment period (2008–2012). Recently, the government submitted a plan to the United Nations prior to the Paris climate conference in 2015 to reduce greenhouse gas emissions by 26 % from 2013 levels by the year 2030.

2.2 Energy Conservation in the Residential Sector

The residential sector, which is the focus of this book, has increased its share of total energy consumption for the past two decades. Along with this increase in energy consumption, the residential sector raised its share of CO_2 emissions from

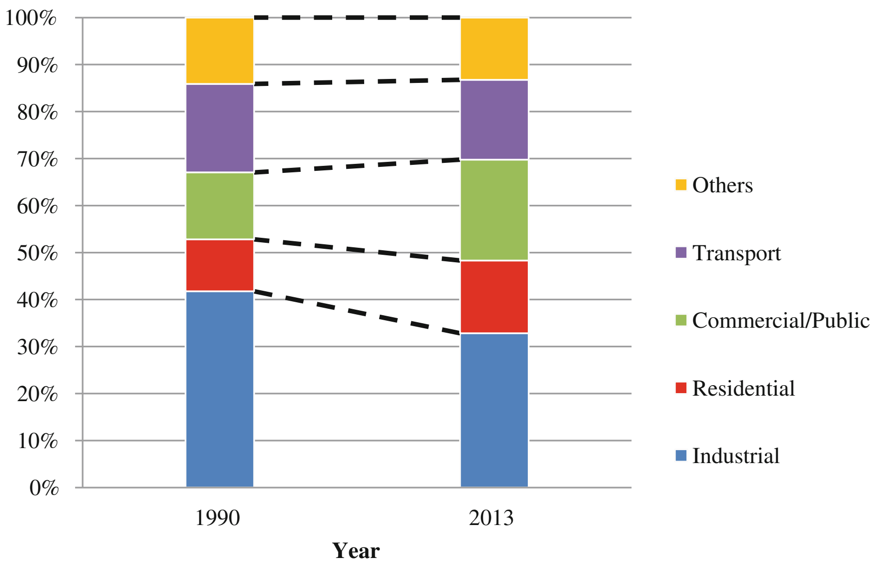

Fig. 2.3 Shares of CO_2 emissions by sector in Japan. *Source* EDMC (2015)

11 % in 1990 to 16 % in 2013, as shown by Fig. 2.3. This is in sharp contrast with the industrial sector that dropped its share of CO_2 emissions from 42 % in 1990 to 33 % in 2013. Constraining CO_2 emissions from residential energy usage is crucial for the achievement of the plan submitted to the United Nations to reduce CO_2 emissions in Japan.

Table 2.3 provides a breakdown of 2013 residential energy use in Japan. The end-use category "other uses" includes lighting equipment, refrigerators, television sets, clothes washers, dryers, dishwashers, electronic equipment, and numerous small electric appliances. Except for these "other uses" whose energy source is electricity, water heating is the largest among the major end-use categories. Electricity represents approximately half of the residential energy consumption.

Table 2.3 Residential energy consumption by fuel and end-use categories, 2013 (1,000 kilocalories per household)

	Space heating	Air conditioning	Water heating	Cooking	Other uses	Total (%)
Electricity	377	223	347	206	3,281	4,434 (49.1)
Gas	494	0	1,688	566	0	2,748 (30.5)
Kerosene	1,432	0	405	0	0	1,837 (20.4)
Total (%)	2,303 (25.5)	223 (2.5)	2,440 (27.1)	772 (8.6)	3,281 (36.3)	9,019 (100.0)

Source EDMC (2015)

Thus, saving electricity is the main target for residential energy conservation in Japan. Gas is the primary energy source for water heating as well as for cooking. Space heating occupies roughly one-fourth of total residential energy demand, and kerosene is the primary energy source for this end-use category. Electricity is the only energy source for air conditioning, which has a small consumption share of 2.5 % among all end-use categories, though the number of room air conditioners was 2.8 per household in 2013.

Residential energy conservation depends on technical, demographic, climatic, economic, and psychological factors. These factors include end-use technologies, dwelling and household characteristics, climate conditions, income, energy prices, and environmental consciousness. Given these factors, energy conservation policies of the Japanese government have focused on the development and use of energy-efficient technologies by regulatory and economic measures.

Table 2.4 summarizes the main conservation measures for the residential sector in Japan. Gasoline-fueled cars, energy appliances, and dwellings are subject to regulation on energy efficiency standards. These standards reflect the best available technologies. The fuel economy of gasoline-fueled cars under the current standard is higher than that in 1995 by 22.8 %. Energy efficiency improvements under the current standards substantially differ across energy appliances: from the 1.9 % improvement relative to the 2000 level in the thermal efficiency of gas heaters, to the 67.8 % improvement relative to the 1997 level in the coefficient of performance of air conditioners. Because of standards on heat loss coefficients and thermal insulation materials, annual energy consumption of the typical house that is subject to the current standard is less than the annual energy consumption of non-insulated houses by 60.7 %.

Labeling enables consumers to be aware of the energy efficiency of each electrical appliance. Labeling on such appliances as air conditioners, television sets, refrigerators, and fluorescent lights indicates annual electricity use relative to the efficiency standards. Subsidies for energy-efficient appliances take a form of

Table 2.4 Energy conservation measures for the residential sector in Japan

Measures	Items	Details
Efficiency standards	Gasoline-fueled cars	Fuel economy of 15.1 km per liter (22.8 % improvements in energy efficiency)
	Energy appliances	Energy efficiency improvement ranging from 1.9 to 67.8 %
	Dwellings	Heat loss coefficients and thermal insulation materials
Labeling	Electrical appliances	Annual electricity use relative to the efficiency standards
Tax deductions and subsidies	Electrical appliances	Subsidies for energy-efficient appliances
	Dwellings	Tax deductions, low-interest mortgages, and subsidies for newly built or renovated energy-efficient houses

Source JANRE (2011)

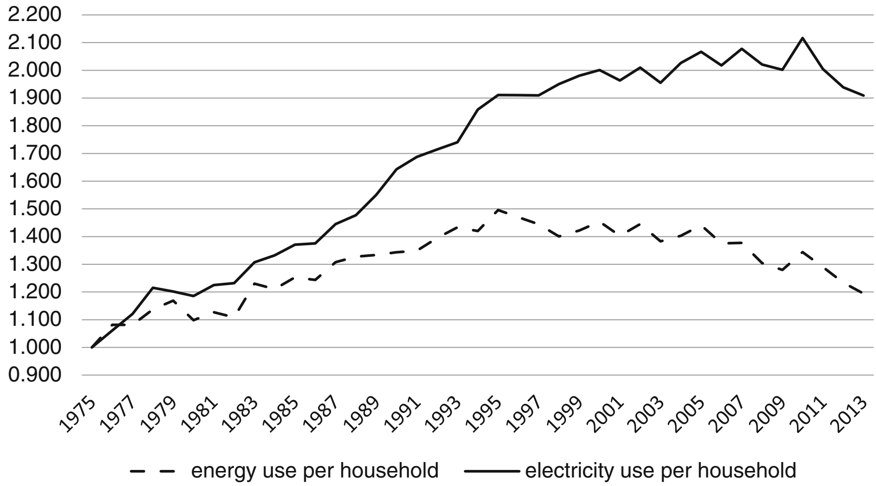

Fig. 2.4 Energy use per household in Japan, 1975–2013 (1975 = 1). *Source* EDMC (2015)

electronic points that can be used to purchase designated goods or can be exchanged for merchandise vouchers. Tax deductions, low-interest mortgages, and subsidies are also available to consumers who invest in newly built or renovated energy-efficient houses.

These conservation measures have contributed to constraining energy use in the residential sector for the last two decades. Indeed, since the late 1990s, energy consumption per Japanese household has gradually declined, as shown by Fig. 2.4. This decrease in energy use per household reflects the impact of the energy conservation measures implemented by the Japanese government. Before the nuclear disaster in Fukushima that occurred in 2011, however, electricity use per household continued to increase. Although electricity consumption per household declined in the wake of the nuclear disaster in Fukushima, it is not clear whether this downturn trend will be temporary or persistent. An additional policy intervention is necessary to further constrain electricity use in the residential sector because of a rising concern about the security of the electricity supply in Japan.

2.3 Security of the Electricity Supply After Fukushima

Along with increased CO_2 emissions, a rising concern about the secure supply of electricity has raised residential energy conservation to an urgent need in the wake of the nuclear disaster that occurred in March 2011 in Fukushima. The concern about a secure supply of electricity after Fukushima emerged as the demand for electricity came precariously close to the available electricity supply capacity in several regions.

Table 2.5 Regional electricity supply and demand in Japan on the day of the highest daily demand in the summer of 2013

Utility	Supply (million kilowatts)	Demand (million kilowatts)	Reserve margin (%)	Maximum temperature (°C)
Hokkaido	5.4	4.5	21.1	31.0
Tohoku	15.0	13.2	13.6	32.6
Tokyo	54.9	50.9	7.9	35.1
Chubu	27.3	26.2	4.0	38.4
Kansai	29.4	28.2	4.3	37.0
Hokuriku	5.5	5.3	5.1	36.3
Chugoku	11.7	11.1	5.0	35.4
Shikoku	5.8	5.5	5.0	35.5
Kyushu	17.0	16.3	4.3	36.5
Okinawa	2.1	1.5	36.2	33.6

Note The reserve margin is the ratio of excess supply to the maximum demand for electricity
Source JMETI (2013)

Table 2.5 presents regional electricity supply and demand on the day when the demand was the highest in the summer of 2013. On that day, the maximum ambient temperature ranged from 31.0–38.4 °C, and it exceeded 35.0 °C in seven regional utilities out of ten. As of 2013, ten vertically integrated, privately owned electric utilities were to supply electricity to their regions. As shown by Table 2.5, in six regional utilities, the reserve margin, the ratio of excess supply to the maximum demand for electricity, was much lower than 8 %, which is considered the minimum level to ensure a secure regional supply of electricity in Japan.

The insecure supply of electricity was primarily due to the ceased operation of nuclear power plants after the nuclear disaster in Fukushima. Figure 2.5 compares the electricity supply share of each fuel type in Japan between two periods: before and after the nuclear disaster. Fossil fuels include oil, gas (LNG), and coal. Renewables include wind, solar, and geothermal power. Figure 2.5 indicates that nuclear power plants, which generated approximately one-fourth of total electricity supply in Japan before the disaster, represented only 1.0 % of electricity supply in 2013. Power plants using fossil fuels substituted for nuclear power plants after the disaster. In fact, almost all nuclear power plants ceased operations in 2013, and no nuclear power plants remained operational by 2014. Safety regulations of nuclear power plants require nuclear power stations to stop operating until they have met new safety standards, which are more stringent than before the disaster.

To secure electricity supply, the Japanese government imposed mandatory restrictions of electricity use on industrial and commercial customers, contracting 500 kW or more in the Tohoku and Kanto regions (JCS 2011). The Tohoku region includes Fukushima where the nuclear disaster occurred. The Kanto region, which includes the Tokyo metropolitan area, is adjacent to the Tohoku region. The industrial and commercial customers who contracted 500 kW or more in these regions were obliged to reduce electricity use for peak hours in the summer of 2011

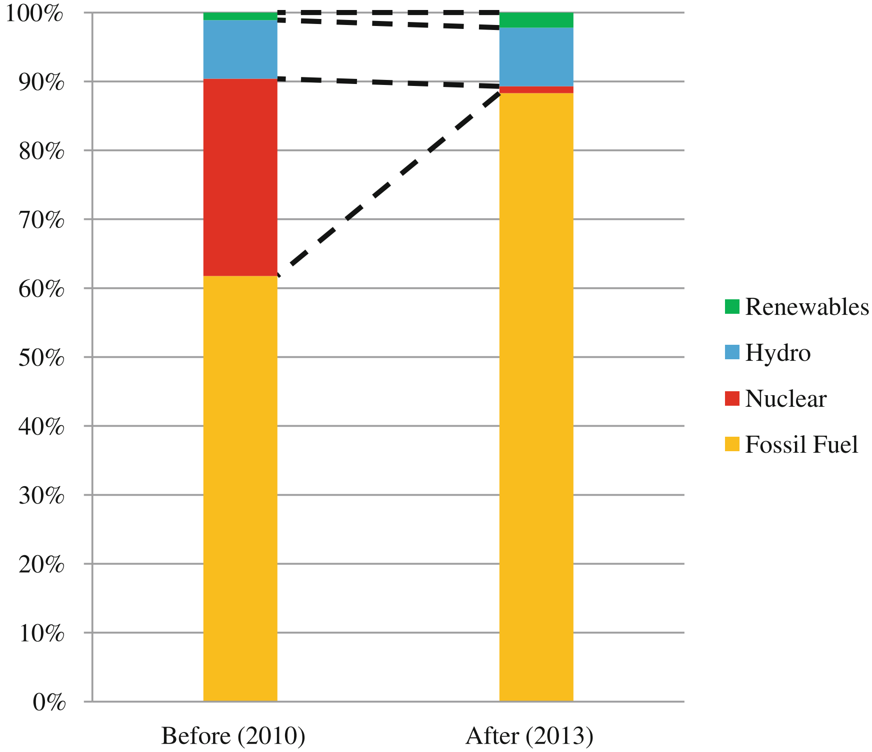

Fig. 2.5 Kilowatt-hour shares of electricity generation by fuel in Japan, before and after the nuclear disaster in Fukushima. *Notes* Fossil fuels include oil, gas (LNG), and coal. Renewables include wind, solar, and geothermal power. *Source* Federation of Electric Power Companies of Japan (http://www.fepc.or.jp/, accessed January 2016)

by 15 % from usage levels in the summer of 2010. The government also called for a voluntary reduction in the electricity use of other customers in the Tohoku and Kanto regions. Voluntary electricity saving was also called for in the Kansai region, which includes one of the three metropolitan areas in Japan.

These mandatory and voluntary restrictions on electricity use achieved a substantial reduction in electricity demand during peak hours in the summer of 2011 (JCS 2011). The maximum demand for electricity was reduced by 18 % relative to the previous year in the Tohoku region. The reductions in maximum demand for electricity were 19 and 8 % in the Kanto and Kansai regions, respectively. These reductions in the peak electricity demand together with the increased trade of electricity across regions prevented electricity supply from being interrupted.

In November 2011, the Japanese government decided that additional measures were required in its "action plan" for the secure supply of electricity (JCS 2011). These measures for the residential sector aimed to promote home energy management systems (HEMS), smart meters, storage batteries, energy-efficient appliances and dwellings, photovoltaics, and fuel cells. The government also suggests that electricity pricing, which contributed to the reduction in the peak electricity demand of industrial sectors in the summer of 2012 and 2013 (Isogawa and Ohashi 2015), should be applied to the residential sector.

2.4 Conclusion

Residential energy conservation, particularly the reduction in the peak demand for electricity, is expected to mitigate the concern about the secure supply of electricity amid the lack of available nuclear power plants in Japan. The innovative instruments for energy conservation (i.e., critical peak pricing [CPP], conservation requests [CRs], in-home displays [IHDs], and home energy reports [HERs]) are expected to play an important role in the government's action plan for the secure supply of electricity. CPP attempts to reduce the peak demand for electricity by pricing, while CRs rely on consumers' voluntary reduction of electricity usage during peak hours. IHDs and HERs could complement smart meters and HEMS by providing consumers with accurate and timely information about electricity use and energy conservation. These instruments are expected to mitigate the increasing concern about electricity supply and CO_2 emissions by constraining the electricity use of households.

Focusing on conventional instruments such as time-of-use pricing, the previous studies (Matsukawa et al. 2000; Matsukawa 2001, 2004, 2011) provide evidence that the use of innovative instruments could be potentially effective for Japanese consumers. The residential sector was found to modestly adjust demand for electricity in response to a temporal variation in electricity prices, which could suggest the effectiveness of CPP (Matsukawa et al. 2000; Matsukawa 2001). Additionally, the residential sector was found to slightly reduce electricity consumption in response to the provision of information about electricity usage at home and energy-conservation tips (Matsukawa 2004, 2011), which could suggest the effectiveness of IHDs and HERs.

The following chapters in this book focus on the effects of innovative instruments for residential energy conservation that have not been investigated by the previous studies on Japanese consumers. These effects are investigated during a series of randomized field experiments. The experiments were conducted as part of the Keihanna Eco-City Next-Generation Energy and Social Systems Demonstration Project, which was subsidized by the Japanese government and aimed to evaluate alternative systems for energy management concentrating on energy conservation, reduction in the peak demand for energy, and balancing energy supply and demand (NEPC 2016). These energy management systems targeted residential communities and commercial buildings where HEMS, electric vehicles, photovoltaics, and storage batteries were installed. In addition to these systems, the project also conducted a series of experiments to determine how CPP, CRs, IHDs, and HERs affected the electricity consumption of households.

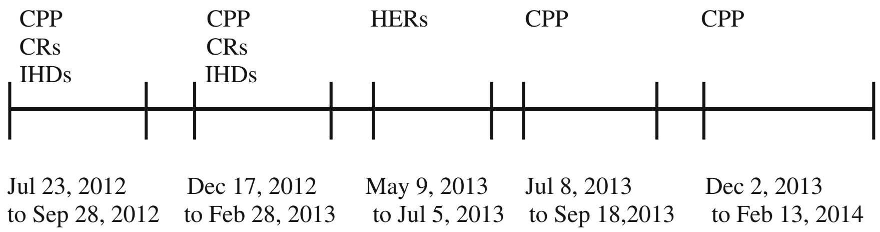

Fig. 2.6 Timeline of the field experiments on which Chaps. 3–5 focus

Using the data from the field experiments, Chaps. 3–5 examine the effects of CPP, CRs, IHDs, and HERs on residential usage of electricity. Figure 2.6 illustrates the timeline of the field experiments on which these chapters focus. Chapter 3 focuses on CPP and CRs whose experiments were conducted in summer 2012 (from July 23 to September 28) and in winter 2012/2013 (from December 17 to February 28). It also focuses on CPP experiments in summer 2013 (from July 8 to September 18) and in winter 2013/2014 (from December 2 to February 13). Chapter 4 focuses on IHDs from which participating households could obtain electricity information at any time during the first and second experiments on CPP and CRs. Chapter 5 focuses on HERs participating households received during May 9 through July 5 in 2013.

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