European Union Research and Development Funding on Smart Cities and Their Importance on Climate and Energy Goals

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Abstract The scope of this paper is to examine the European Union support in terms of research and development funding on the topic of smart cities. A detailed literature review, based on a project-by-project investigation, and a data analysis process identified these expenditures since the research on this topic was first funded. The portion of the Sixth and Seventh Framework Programs funding dedicated to smart cities is only 3 % of the total funding for energy projects and an all-time low of 1 % is expected within Horizon 2020. The low funding for the investigated field fails to capitalize on the high savings potential represented by the urban primary energy use in Europe. Restructuring the funding distribution for research and development in energy could better fulfill the potential primary energy savings of the European urban sector and contribute to achieving the European Union's climate and energy goals for 2020, 2030, and 2050.

Keywords European Union · Cities · Primary energy · Research and development funding · Smart cities

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1 Introduction

After World War II, the reconstruction of Europe's economy and the establishment of lasting peace was necessary. The major challenge was neutralizing European countries' competition over natural resources. Thus, in 1951, the European Coal and Steel Community (ECSC) was founded. It was an international organization serving the unification of European nations, setting up a common coal and steel market among its member countries. The first member states were France, Federal Republic of Germany, Italy, Netherlands, Belgium, and Luxembourg, leading the way to the creation of the EU (Dinan 2014).

The EU is currently facing unprecedented climate and energy challenges and, to overcome these challenges, has established specific goals for the years 2020, 2030, and 2050. By 2020, the EU aims to decrease greenhouse gas (GHG) emissions by 20 % below 1990 levels. The energy use produced by renewable energy sources (RES) is expected to be 20 %. A 20 % drop in primary energy consumption is to be accomplished by upgrading energy efficiency as well (EC 2015a).

In order to provide a coordinated approach between EU member states and ensure regulatory certainty for investors, an integrated policy framework is necessary to achieve the 2030 goals. By that year, the EU aims to decrease domestic GHG emissions by 40 %, compared to 1990 levels. The energy produced by RES is expected to be 27 % of the total, and permanent improvements in energy efficiency are also foreseen through national policy measures (EC 2015b).

Further efforts are needed by the EU to achieve the 2020 targets, as well as the goals for 2030 and 2050. While the EU is on the right track to reach its RES and carbon emission targets by 2020, it is very likely that the energy efficiency targets will not be met (EC 2011a). The EU member states have affirmed the goal of decreasing Europe's GHG emissions by 80–95 % in comparison to 1990 levels by 2050 (EC 2015c).

In 2010, the primary energy utilization in Europe was almost 1,800 [Mtoe/a] (EUROSTAT 2013). The cities of the EU account for approximately 70 % of the primary energy consumption, and this portion is expected to rise to 75 % by 2030 (EIFER 2015). Three-quarters of Europe's population lives in urban areas and is responsible for roughly the same proportion of CO_2 emissions (Faure and Peeters 2008; EEA 2015). The entire primary energy consumption savings potential at the EU level corresponds to an estimated overall total of 390 [Mtoe/a] each year. Partially because of its large share of whole primary energy usage, the majority of these reductions are attributed to savings in the urban sector (EC 2008; Terluin and Post 2000; BPIE 2015).

Especially the smart city (SC) projects aim to create sustainable and efficient urban areas by addressing energy and climate challenges. The main intervention fields of SC projects concern the application of RES, improvements in energy efficiency, and emissions' offsetting (Pezzutto et al. 2015).

2 Methodology

With regard to the EU research and development (R&D) funding, the framework programs (FPs) have been the most substantial funding source since their inception (1984) (Di Valdalbero 2010; De Jagr 2011; Pezzutto 2014). Concerning the quantification of R&D spending for SC projects, the focus lies on the past two completed framework programs (Sixth and Seventh Framework Programs—FP6 and FP7) as these kinds of activities started in FP6 (Pezzutto et al. 2015). Hence, a period of about one decade (2002–13) is analyzed in detail. The European Commission (EC) provides detailed insights into the historical development of the R&D expenditures at EU level (EC 2012a, b, 2013a, b). These were counter-checked by a number of further scientific sources (WEC 2001; Raque 2005; Milias 2009). Moreover, a closer look at the follow-up program of the FP7, the recently begun Horizon 2020 (2014–20), is provided as well.

With regard to EU R&D funding for the energy sector, non-nuclear and nuclear energy (NNE and NE) funding have been separated (Raque 2005; Milias 2009). The energy funding category includes both.

In order to obtain a clear understanding of the EU NE and NNE R&D in all combined framework programs (FP1–7, 1984–2013), the EU R&D spending on NE was retrieved from EC indications and directly compared with metrics for NNE.

An extensive database was created to quantify the EU funding for NNE related R&D. It contains all FP6 and FP7 energy projects declared by the EC. The mentioned database includes the absolute majority ($\sim$94 %) of the programs' funding declared by the EC dedicated to the energy sector (Di Valdalbero 2010; EC 2013a, b). In order to avoid combining R&D spending provided by the EU and other expenditures, solely the EC contribution per project has been taken into account and not the total budget.

Table 1 summarizes the EC classification method with regard to the NNE section and respective subsections.

There is not a category specifically dedicated to smart cities (SCs). This has been quantified through adding the FP6 and FP7 CONCERTO (demonstrating large-scale reductions in fossil fuel consumption using renewable energy sources and demand management) spending to those of the FP7 smart cities and communities initiative (SCIS 2015; EC 2015c, d, e).

In order to provide a real basis of comparison between NE and NNE spending in the FPs, several sources were combined in Figs. 3 and 4. Thus, the NNE FP7 section also includes funding from the IEE (Intelligent Energy Europe), CIP (Competitiveness and Innovation Framework Program), and EIT (European Institute of Innovation and Technology) programs. In contrast, the NE expenditures include Euratom (European Atomic Energy Community), JRC (Joint Research Centre) activities on NE and Iter (International Thermonuclear Experimental Reactor) spending from FP1 to FP7.

A fundamental and technical analysis has been applied to provide a future scenario of the R&D funding distribution within the energy sector for the Horizon

Table 1 EC classification method of the non-nuclear energy sector and respective subsections (EC 2013a; EUROSTAT 2014a)

Non-nuclear energy section	Non-nuclear energy subsections
Renewable energy sources	Photovoltaics, concentrated solar power, bioenergy, wind energy, ocean energy, geothermal energy, hydro energy, renewable heating and cooling
Coal	Carbon capture storage CO_2 capture, carbon capture storage CO_2 storage, other
Energy networks	
Energy efficiency	Building, CONCERTO, other
Socio economics	
Fuel cells and hydrogen/joint technology initiative fuel cells and hydrogen[a]	Fuel Cells, hydrogen
Energy materials/future emerging technologies	
Energy storage	
Basic research	
All other activities	

[a]In the fuel cells and hydrogen category, the joint technology initiative/fuel cells and hydrogen funding were added to the fuel cells and hydrogen topic, just as the EC calculates

2020 program, and in particular for SCs. The technical analysis consists of a regression calculation for FP6 and FP7 funding values through Horizon 2020. The fundamental investigation is based on anticipated expenditures as retrieved from scientific literature. More weight has been attributed to the indications retrieved by the fundamental analysis, which have been used to adjust the outcome of the technical analysis (Schlichting 2013).

In order to generate an equal basis for comparison among R&D expenditures in time and to calculate reasonable data for future development indications, all monetary amounts are given in real values (2013 prices). The real monetary amounts were calculated using EUROSTAT data on annual inflation rates (EUROSTAT 2015). The year 2013 is selected as the time reference because it is the most recent point in time for EU R&D expenditures within the last completed framework program (FP7).

3 Results

Even if the EU's R&D budget increased by a factor of more than ten from the first to the last completed framework program (FP1–7), in absolute amount of funding (from 6.0 to 63.8 bn.€), R&D spending remained relatively low compared to total EU expenditures, oscillating between approximately 2 and 6 %. Figure 1 indicates the trend of R&D spending within the FPs as a percentage of the respective total EU

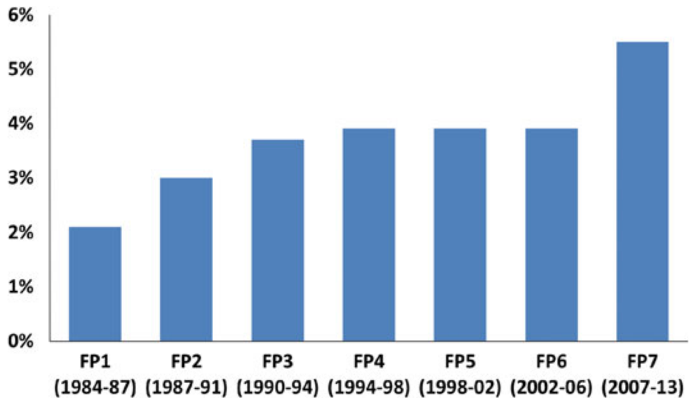

Fig. 1 R&D spending within the framework programs as a percentage of the respective total European Union budgets (%) (WEC 2002; De Jagr 2011; Paris School of Economics 2011; EWEA 2012; EC 2010, 2013c, 2015d) (Almost all indicated FPs have a time overlap. In particular, FP3 began one year before the end of the FP2. The indicated time overlap of the FPs does not correspond with a budget overlap, e.g. FP2 ended in 1991, while FP3 started already in 1990.)

budgets (WEC 2002; De Jagr 2011; Paris School of Economics 2011; EWEA 2012; EC 2010, 2013c, 2015d):

However, taking the population growth caused by the EU enlargement into account, the R&D expenditures per EU inhabitant have declined from around three Euros in the 1980s to two Euros in the 1990s, and one Euro in the mid-2000s (Di Valdalbero 2010).

Moreover, from FP1 to FP7, energy R&D suffered a significant reduction. As Fig. 2 illustrates, the percentage of energy R&D was significantly reduced from FP1 to FP2. From FP3 to FP4 the energy budget increased slightly. Afterwards, a constant reduction until FP7 is evident. As of FP7, the percentage of funding dedicated to energy is roughly one-third of what it was in FP1.

In FP1, energy received the highest single budget of all R&D topics and in FP7 it was in the second to last position. The other fields receiving R&D funding from

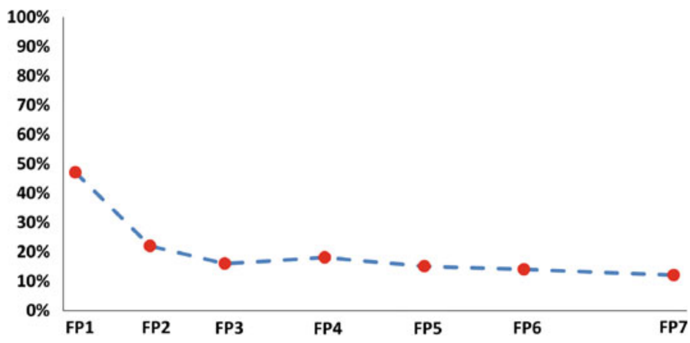

Fig. 2 Energy-theme focus within the seven framework rograms (FP1–7) (%) (Milias 2009)

the EC, such as environment, industrial and material sciences, and information–and-communication technologies gained more and more importance since FP1. The increases in these fields caused the reduction in R&D funding for energy as a percentage of total funding. Only the life sciences received less financing than energy within the last completed FP (FP7) (EKT/NHRF 2013).

In contrast to the decreasing values in terms of percentages, an increase in the total available amount of money occurred for energy from FP1–7. The largest increases occurred between FP3–4 and FP6–7, while there were substantial reductions from FP1 to FP3 and FP4–6. See Fig. 3.

From the first to the last completed FP (FP1–7), the funding for energy research more than tripled, with 3.2 bn.€ allocated in FP1 and 11.5 bn.€ in FP7.

Figure 4 shows a comparison between NE and NNE EU R&D funding during FP1–7. In each of the FPs, NE received more R&D funding than RES and all other

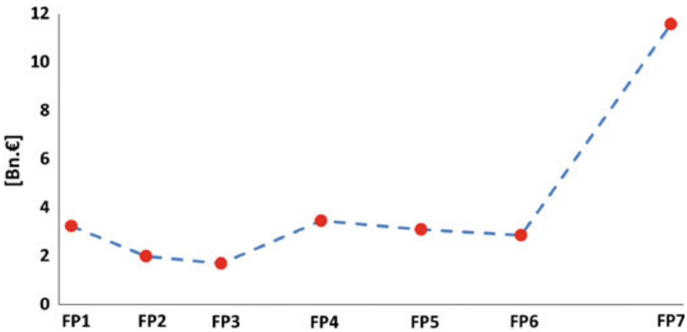

Fig. 3 Energy R&D spending by the European Union (1984–2013) (WEC 2002; Raque 2005; Milias 2009; Di Valdalbero 2010; EUROSTAT 2014b; EC 2013a, 2015d)

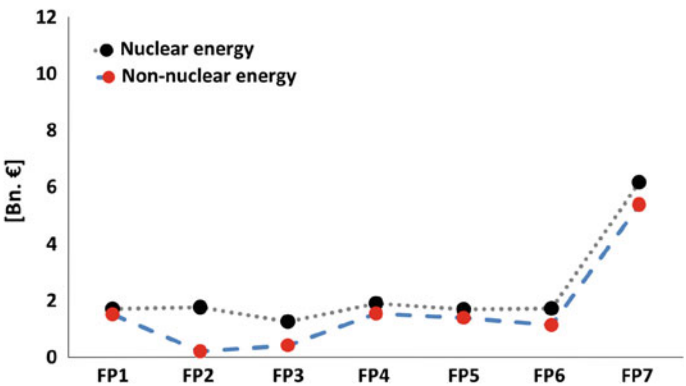

Fig. 4 R&D spending for energy in the framework programs (FP1–7) (%) (EUR-Lex 1983, 1996; Milias 2009; Di Valdalbero 2010, EC 1987, 1993, 1997, 1999, 2013d, e, f, g, h, i) (Without the funding portions of the IEE, CIP and EIT, the NNE R&D spending within FP7 would reach a value of 2.7 bn.€.)

energy sectors combined (EC 2013d, e, 2015d). It has to be stressed that safety, protection from excessive exposure to radiation, maintenance of nuclear security, and radioactive-waste disposal are the key points of the EU NE R&D (EC 2011b).

3.1 The Sixth Framework Program

The Sixth Framework Program had a 24.0 bn.€ budget. From this, approximately 2.8 bn.€ were dedicated to R&D activities in the energy sector. Those 2.8 bn.€ were split into 1.7 bn.€ for NE and 1.1 bn.€ for NNE (Di Valdalbero 2010; EC 2006, 2013a).

Nuclear energy received the absolute majority of energy R&D funding, representing approximately 60 % of the total.

The RES section follows with about 15 % of the energy funding. However, considering the contents of all funded projects, in sum around 20 % of the spending for the energy sector went to RES, as several projects in other categories (within energy efficiency, basic research and all other activities) dealt with renewable energy too. Bioenergy, photovoltaics and wind energy got the largest amount of funding regarding the RES part with around 7, 4 and 2 % respectively. Geothermal and ocean energy follow with about 1 %. Renewable heating and cooling (RHC) and concentrated solar power (CSP) rank in the second to last position with less than 0.5 %, and hydro energy is to found in the last place with around 0.1 %.

The category of fuel-cells and hydrogen/joint technology initiative on fuel cells and hydrogen (FCH/JTI FCH) comes next with approximately 10 % of the total. Within the last mentioned field, fuel cells received approximately 2 % more funding than R&D on the hydrogen theme. Smart cities (CONCERTO) follows with 6 %. In the present case, R&D spending on SCs derive exclusively from CONCERTO projects. Coal shows a value of around 4 %, equally divided between carbon–capture-storage–CO_2-Ccpture (CCS-CO_2 Capture) and carbon–capture-storage–CO_2-storage (CCS-CO_2 Storage). Next, the topic of energy networks is reported as about 2 %. Energy efficiency (other), socio-economics, and all other activities follow with approximately 1 % each. The last positions are held by coal (other), energy storage and basic research (<0.5 %) (EC 2013a). See Fig. 5.

3.2 The Seventh Framework Program

The Seventh Framework Program budget was 63.8 bn.€. From this, about 8.8 bn.€ were dedicated to R&D activities in the energy sector. Those 8.8 bn.€ are split into 6.1 bn.€ for NE and 2.7 bn.€ for NNE (Di Valdalbero 2010; EC 2007, 2013a).

As was the case in the previous FP program (FP6), also within FP7, NE R&D holds the absolute majority of funding, with approximately 68 %.

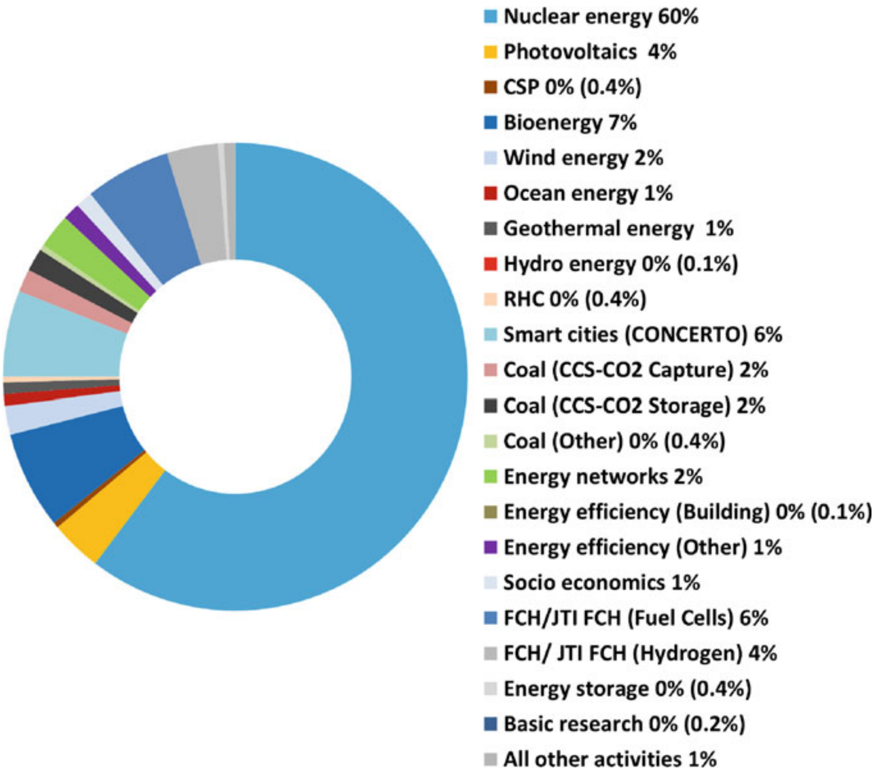

Fig. 5 Sixth Framework Program funding distribution for various energy sectors (2002–06) (EC 2013a) (The section energy efficiency (CONCERTO) is fully taken by smart cities (CONCERTO) and thus do not appear in Fig. 5. The same applies to following Figs. 6 and 7.)

Next, about 12 % of the whole funding for energy in FP7 has been dedicated to RES. Once more bioenergy, photovoltaics, and wind energy received the largest shares of funding within the RES part with around 4, 3 and 2 % respectively. Concentrated solar power, ocean energy, and RHC follow with about 1 % each. Geothermal energy is located in the penultimate position with approximately 0.3 %, and hydro energy is last again, with about 0.2 %.

The FCH/JTI FCH section follows with around 6 %, equally distributed between the fuel cells and hydrogen themes. Energy networks are next with 5 %. Coal shows a value of 3 %, equally divided between CCS-CO_2 Capture, CCS-CO_2 Storage and Other. The topic of smart cities (CONCERTO) and energy efficiency (buildings and other) received about 2 % each. In this case, R&D spending on SCs only partly comes from CONCERTO projects: two-thirds of the 2 % given for smart cities (CONCERTO) R&D funding derive from the FP7 smart cities and communities projects. Energy storage and all other activities follow with approximately 1 % respectively. The last positions are covered by socio economics,

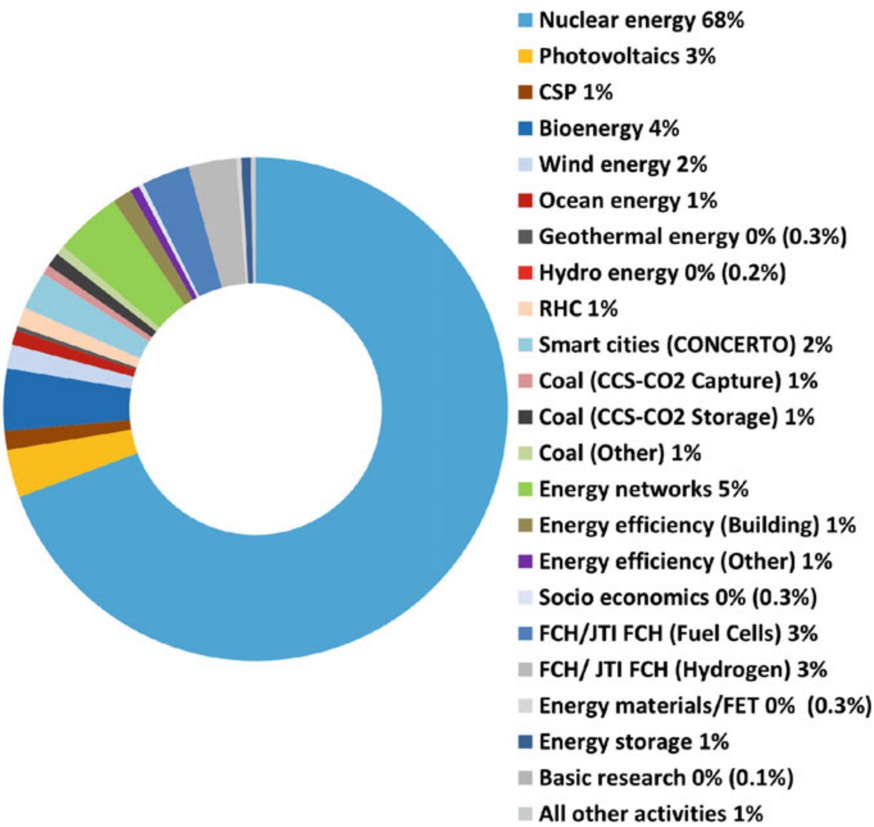

Fig. 6 FP7 R&D funding distribution for various energy sectors (2007–13) (EC 2013a)

Energy materials/FET (future emerging technologies) and basic research (<0.5 %) (EC 2013a). See Fig. 6.

Energy materials/FET is a new topic in FP7. It received less than 0.5 % of R&D energy funds (EC 2013a).

3.3 Comparison of the Sixth and Seventh Framework Programs

Comparing FP6 and FP7, it has to be stressed that there was a significant increase in the total available amount of money for energy research. Hence, the funding for energy R&D in FP6 was around 2.8 bn.€ and at FP7 about 8.8 bn.€ (Milias 2009; Raque 2005). Thus, the total energy budget for the EU FPs has almost tripled from FP6 to FP7. It has to be remembered that the duration of FP7 was almost double that of FP6; FP6 lasted 4 years, while FP7 lasted seven (EC 2006, 2007).

Nuclear energy increased by about nine percentage points in FP7. Contrarily, the smart cities (CONCERTO) field suffered from a significant decrease. In fact, it shows one-third of the value given in the previous FP, which correlates to a loss of 4 % points. Despite this reduction in percentage, a slight increase in total amount of money occurred. The smart cities (CONCERTO) topic was supported by about 169 and 176 mil.€ in FP6 and FP7 respectively. However, the latter cited increase is minor, leading to a measure of approximately the same R&D spending for the smart cities (CONCERTO) theme in FP6 and FP7, with 0.2 bn.€ each.

Also, the FCH/JTI FCH section received significantly less funding, with a reduction of approximately four percentage points. The percentage of funding going to RES decreased for all sources between FP6 and FP7. This is especially apparent for bioenergy, which received approximately only half the share in FP6. Only CSP and RHC show a percentage increase in FP7 compared to the previous program. However, the last two indicated energy categories represent only around 1 % of the total. In contrast to the latter mentioned percentage decrease, a significant increase in the total available amount of money is registered for the entire RES portion in FP7. The latter mentioned topic was supported by around 0.4 and 0.9 bn.€ in FP6 and FP7 respectively. The energy-networks theme increased by about 3 percentage points. Also the energy-efficiency sector (buildings and other) as well as the energy-storage part show an increment of about 1 percentage points. The whole coal theme (CCS-CO_2 capture, CCS-CO_2 storage and other) as well as socio-economics each lost a percentage point. The remaining topics (basic research and all other activities) stayed within the same range (EC 2013a).

3.4 The Sixth and Seventh Framework Programs

In order to quantify the total R&D expenditures on the SCs topic since their existence, Fig. 7 merges the funding portions of the various energy sectors of the Sixth and Seventh Framework programs:

Due to the significantly higher amount of R&D funding provided in FP7 compared to FP6, the rankings given in Fig. 7 do not vary considerably from the previous FP7 ranking. Only the SCs topic rose by one rank, exceeding the energy efficiency (buildings and other) theme with 3 and 2 % respectively. The FCH/JTI FCH and energy networks topic gain and lose 1 % respectively, holding the same position as in FP7.

It has to be stated that the majority of the above mentioned $\sim$3 % funding for SCs R&D belongs to CONCERTO projects. The CONCERTO initiative provided almost two-thirds of the funding for SCs (EC 2013a).

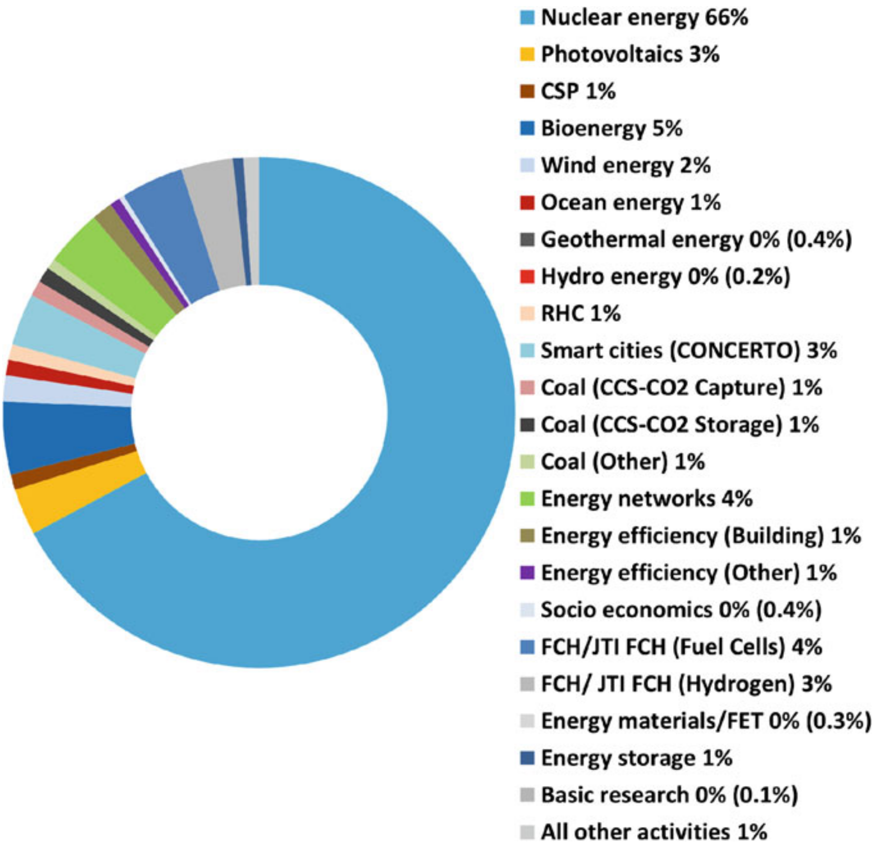

Fig. 7 FP6 and FP7 R&D funding distribution for various energy sectors (2002–13) (EC 2013a)

3.5 Outlook

In order to evaluate a possible future scenario of EU R&D funding assigned to energy related issues and in particular to SCs, the future Horizon 2020 (2014–20) funding program is now considered.

Summing up future expenditures indicated for the NE and NNE sectors separately, both are expected to have an equal amount of funding with approximately 5.9 bn.€ each. Thus, as shown in Fig. 8, NE would remain the sector with the majority of EU R&D expenditures, consuming around half of the total (Milias 2009; EC 2013a, 2015f; ITER 2015).

Next, based on a linear regression until Horizon 2020, a prediction concerning the R&D spending distribution for the various NNE sections has been created. Contrary to the anticipated future expenditures, the linear regression predicted that NE would receive 76 % of the funding. This discrepancy was handled by reducing

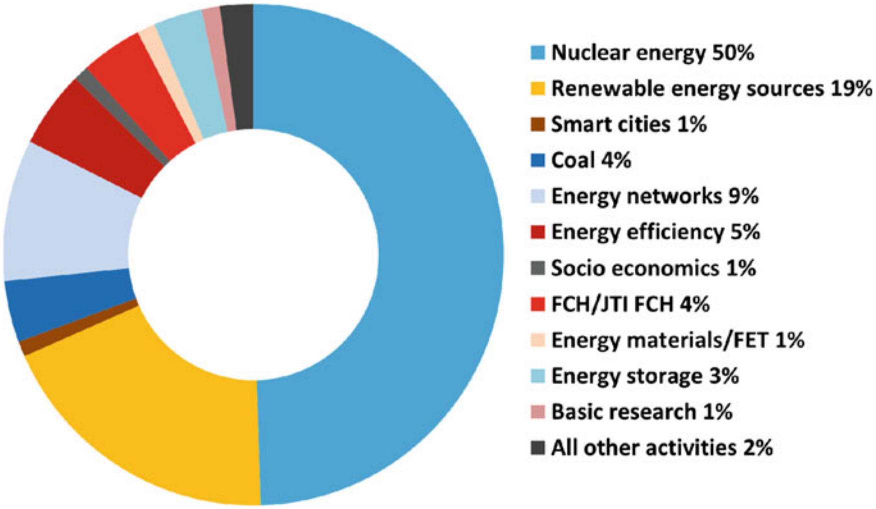

Fig. 8 Expected funding distribution for the Horizon 2020 energy theme (WEC 2002; Milias 2009; Di Valdalbero 2010; EC 2006, 2007, 2013a, 2015f; ITER 2015) (As CONCERTO activities are not planned within Horizon 2020, the smart-cities section stands alone within this chart.)

the NE funding to 50 %, and evenly distributing the difference among the other sectors. Renewable energy sources follow with almost 20 %. Energy networks come next with nearly 10 %. The remaining sectors all represent 5 % or less in the following order: coal, energy efficiency, FCH/JTI FCH, energy storage, all other areas, energy materials/FET, smart cities, socio economics and basic research (Milias 2009; Di Valdalbero 2010; EC 2006, 2007, 2013a, 2015f; ITER 2015).

Figure 8 combines the predictions for the entire energy sector within Horizon 2020.

Regarding the monetary quantification, it has to be stated that the total EU budget increased by around 10 % from FP7 to Horizon 2020, with the total FP7 budget at 63.8 bn.€ and Horizon 2020 at 70.9 bn.€ (EC 2007; EU 2012). Horizon 2020 is expected to last as long as the FP7: 7 years.

4 Discussion and Conclusions

Energy has been central to the European Union ever since its inception, originally as the European Coal and Steel Community in 1951 (El-Agraa 2011: 257). The European Union is taking drastic action to address the current climate and energy challenges. Specific goals for the years 2020, 2030, and 2050 have been established.

However, the European Union funding available for research and development in the energy field has significantly decreased as a percentage since the start of the framework programs. Moreover, because of European Union enlargements and the associated population growth, the expenditures on research and development for each inhabitant has declined from three Euros per person in the 1980s to one Euro per person in the mid-2000s.

The European Union utilized approximately 1,800 [Mtoe/a] of primary energy in 2010. Cities are currently responsible for around 70 % of this consumption and are expected to be responsible for up to 75 % by 2030. Approximately three-quarters of Europeans live in urban areas, and they are responsible for roughly the same percentage of CO_2 emissions.

It is estimated that the European Union can reduce the annual primary-energy consumption by 390 [Mtoe/a]. Because the urban sector uses a large share of the primary energy, it is believed that the majority of these savings could come from improvements in cities.

In particular, smart city projects aim to create sustainable and efficient urban areas by addressing energy challenges. The main intervention fields of smart-city projects concern the application of renewable energy sources, an increase in energy efficiency, and carbon-dioxide-emission reduction.

However, only 3 % of the total energy funding in the Sixth and Seventh Framework Programs was used for smart cities research and development. This value is expected to see an even further reduction within Horizon 2020, reaching a value of 1 %. Moreover, nuclear energy was a major recipient of European Commission research and development financing. From 2002 to 2013, the nuclear sector received significantly more funding than all of the other energy fields combined.

Shifting the focus of European Commission funding to favor smart cities would assist in achieving the 2020, 2030, and 2050 goals. They would then target the sector with the highest energy consumption, and, like the latter mentioned goals, they aim to utilize renewable energy sources and energy efficiency and to reduce greenhouse gas emissions.

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