Renewable Energies versus Nuclear Power

Comparison of Financial Support Exemplified at the Case of Hinkley Point C

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Abstract

The energy policy debate in Europe has set (industrial) competitiveness high on the agenda. Support for renewable energies (RE) was in debate and partly suspended. The recent discussion on supporting nuclear power in the UK has, however, demonstrated that renewables are not the only low-carbon option that requires financial incentives under the current framework conditions. The aim of this paper is to compare the costs of state aids necessary for constructing new nuclear power plants for the example of the planned plant at Hinkley Point C in the UK with support incentives for RE.

For doing so, a static and a dynamic approach are followed: The static approach compares today's support incentives for renewable energy with the state aid for Hinkley Point C, whereas for the dynamic approach a model-based assessment of future RE deployment up to 2050 in the EU is undertaken. This is done by use of the Green-X-model (www.green-x.at) and incorporates the impact of technological learning (future cost reductions) as well as aspects of market integration of variable renewables like solar and wind.

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The assessment is conducted at EU level and for selected EU countries where nuclear power plays a role at present or is considered as a viable future option. From an analytical point of view we undertake an evaluation of effectiveness (i.e. amount of electricity generation stipulated) and economic efficiency of RE and nuclear power support for today and for the future.

1 Introduction

The European Union is divided on the issue of electricity production. While there is consensus that generation technologies need to be low on greenhouse gas- emissions, the question of whether to use renewables or nuclear to meet this power demand is highly controversial. Both options still require financial support and this is not going to change in the near future. This raises the question of where our money should be invested in order to achieve greater economic efficiency: into support for renewable energies (RE) or support for nuclear power plants?

This paper sets out to answer this question. The recent state aid case for the construction of the nuclear power plant Hinkley Point in United Kingdom serves as the model for the nuclear option. After discussing the costs for the nuclear model, we undertake an overview on existing support schemes for renewables in the European Union. Next to that, we conduct the prospective comparative assessment. Here a detailed model-based scenario assessment serves as basis for estimating future cost developments concerning renewable energies. This is then again contrasted with the nuclear model derived from the Hinkley Point case. Finally, conclusions end up this paper.

2 Background – existing and planned support for nuclear power and renewable energies

This section is dedicated to shed light on support schemes for low-carbon energy technologies, specifically nuclear power and renewable energies in the electricity sector. Here the planned support scheme for the new nuclear power plant at Hinkley Point in United Kingdom serves as the model for the nuclear option. After a brief recap on the planned support scheme, classified as state aid, we lay down the resulting costs for the nuclear model case. Next to that we take a closer look at renewable energies, undertaking an overview on existing support schemes for renewables in the European Union.

2.1 New milestone in nuclear state aid: Hinkley Point

The launch of a state aid scheme for a new nuclear power plant at Hinkley Point C in the United Kingdom has been heavily debated across Europe since it has represented a change in paradigm concerning nuclear power. While in the early years of the nuclear built-up there have been arguments for very cheap nuclear electricity in future, new cost figures and specifically the requested support for Hinkley Point C have set an end to that myth. Below we recap some key figures and facts that could be extracted from official documents and public statements on that subject.

The NNB Generation Company Limited (NNBG), part of EDF Energy, plans to construct and operate a new NPP, consisting of two units with an electrical cumulative capacity of 3,260 MW, and an estimated electricity production of 26 TWh per year at the Hinkley Point NPP site (Hinkley Point C 1&2). If constructed, Hinkley Point C would be the UK's first new reactor since 1988.

The construction costs of Hinkley Point C were first estimated to be ca. € 19 billion (EDF, 2013), but were corrected by the EC to € 31.2 billion, and overall capital costs are assumed to be € 43 billion (EC, 2014a). To cover such enormous investments, EDF has undergone lengthy negotiations with the UK government. The start of the operation is supposed to be in 2023[2] with expected operational lifetime of 60 years. The key terms of the final agreement between EDF and the UK government contain the following provisions:

Financial support based on "contract for difference" model

The agreement took the form of a so-called "Contract for Difference" (CfD): if the wholesale prices for electricity fall below an agreed strike price, then the Secretary of State will pay the difference between the strike price and the wholesale price, ensuring that NNBG will ultimately receive a fixed level of revenues. When the wholesale price is higher than the strike price, NNBG will be obliged to pay the difference to the Secretary of State. The duration of the contract is 35 years for each of the two reactors.

2 Our analyses are based on the initial operation start time of 2023, and any update on this issue could not be taken into consideration. Nevertheless, the readers should keep in mind that as of September 2013, a delay of start date is expected (Gosden 2015).

The strike price is set at € 108 per MWh (expressed in real terms, as of 2012). If EDF constructs a second nuclear power plant at another site (i.e. Sizewell C) using the same design, the strike price would become €104 per MWh. The strike price will be fully indexed to the Consumer Price Index, meaning that based on current assumptions concerning inflation, this would translate into a nominal strike price of € 329 per MWh in 2058 (as the last year in which the CfD scheme applies).

After the modifications urged by the European Commission, a gain-share-mechanism for the overall profits will be in place for the entire project's lifetime, namely 60 years. If the construction costs are lower than expected, these gains will also be shared (EC, 2014a).

Credit guarantee

The NNBG will also benefit from a credit guarantee issued by the UK Treasury. This guarantee would significantly reduce EDF's risk exposure and therefore the cost of capital. After the modification in 2013, the guaranteed fee that the operator must pay the UK Treasury was significantly raised, resulting in an effective reduction of the subsidy by more than € 1.3 billion. (EC, 2014a). Table 1 summarises the main characteristics of the planned NPP at Hinkley Point C.

Tab. 1 Main characteristics of Hinkley Point C

Capacity per unit	MW_e	1,630
Number of units		2
Total capacity (two units)	MW_e	3,260
Electricity generation	TWh/a	26
Estimated start of operation	Year	2023
Financial support (Contract for Difference / Feed-in Tariff)	GBP_{2012}/MWh	92.5 (89.5)
Duration of support	Years	35

European regulations allow Member States to determine their energy mix within their national competence. However, when public money is spent to support companies, the European Commission must verify that this is done in accordance EU rules on state aid. Therefore the UK's support scheme was investigated in 2013. During this investigation, the UK was required to modify the terms of the project financing. In October 2014, the European Commission concluded that "the modified UK measures for Hinkley Point nuclear power plant are compatible with EU rules" (EC, 2014a).

The October 2014 decision of the European Commission has led to massive protests. The protesters include the Republic of Austria. Based on a legal study, Austria regards subsidies for nuclear power reactors as inacceptable according to EU legislation (BMWFW, 2014).

2.2 EU support for renewable energies

As outlined in detail in the RE-Shaping study (see Ragwitz et al., 2012), the first decade of the new millennium was characterized by the successful deployment of RE across EU Member States – total RE deployment increased by more than 40%. More precisely:

- Electricity generation from RE grew by approximately 40%, RE heating and cooling supply by 30% and biofuels in transport by a factor of 27 during the period 2001 to 2010,
- New renewables in the electricity sector (all technologies except hydropower) increased fivefold during the same period,
- Total investments in RE technologies increased to about € 40 billion annually in 2009 and more than 80% of all RES investments in 2009 were in wind and PV.
- With respect to PV an ongoing trend of achieving impressive cost reductions from year to year has started in the final period close to 2010. .

These impressive structural changes in Europe's energy supply are the result of a combination of strong national policies and the general focus on RES created by the EU Renewable Energy Directives in the electricity and transport sectors towards 2010 (2001/77/EC and 2003/30/EC).

Despite the challenges posed by the financial and economic crisis, RE investments were generally less affected than other energy technologies and partly increased even further over the last couple of years. The European Energy and Climate Package is one of the key factors that contributed to this development. The EU ETS (Emissions Trading System) Directive has introduced full auctioning post 2012, thus exposing fossil power generation to the full cost of carbon allowances, at least in theory. In practice, an oversupply of allowances has however led to a deterioration of prices on the carbon market.

The pathway for renewables towards 2020 was set and accepted by the European Council, the European Commission and the European Parliament in April 2009. The related policy package, in particular the EU Directive on the support of energy from renewable sources (2009/28/EC), subsequently named RE Directive, comprises the establishment of binding 2020 RE targets for each Member State – in line with overall EU target of increasing the RE share to 20% by 2030.

Later on, the EU Energy Roadmap 2050 gave first signals of renewable energy development pathways beyond the year 2020 and identified renewables as a "no-regrets" option. In a next step, Europe's way forward towards 2030 has been discussed intensively. Thus, at the Council meeting of this October (2014) the next step was taken: A binding EU-wide RES target of achieving at least 27% as RES share in gross final energy demand was adopted. This has to be seen as an important first step in defining the framework for RES post 2020. Other steps, like a clear concept for, and an agreement on the effort sharing across Member States have to follow.

Concerning financial support for RE, various policy instruments have been implemented across EU Member States to promote the use of RE (cf. Box 1). Although there are already substantial experiences with the use of support schemes, the dynamic framework conditions have led to a continuous need for reforming the applied policies. Also policy priorities have changed in most Member States. Whilst the policy effectiveness or the ability of support instruments to trigger new investments was a main policy target while the RE-share was still negligible, economic efficiency has become increasingly important in the light of higher shares of RE, rising support costs and the financial crisis. In particular the strong growth of photovoltaics in some Member States has enhanced this change of policy priorities. The stronger focus on cost control mechanisms has led to a revival of tender or auction mechanisms to control the additional RE-capacity eligible for support and to determine support levels in a competitive bidding procedure. Another highly relevant issue regarding renewables support is related to the increasing share of intermittent RE leading to evolving requirements for effective electricity market design. While initially fair remuneration of RE power in the market should be a priority for market design, a more systemic focus on system flexibility should be adopted with a rising share of RE. This is reflected in several market design parameters, e.g. how the system matches temporal profiles of different generation and load types and how it accommodates the spatial profile of intermittent RE generation.

Box 1 Support schemes for electricity from renewable sources

Globally as well as within the European Union, a feed-in tariff (FIT) system is the most common policy instrument for promoting electricity generation from renewable energy sources (RES-E).A quota obligation with tradable green certificates (TGCs) is another widely implemented support scheme. These main instruments for RES-E are often accompanied by complementary instruments like grants offering investment support, fiscal incentives (e.g. tax reductions) or (cheap) loans. The two main support instruments can be characterised as follows:

1. **Feed-in tariffs** offer financial support per kWh generated, paid in the form of guaranteed (premium) prices and combined with a purchase obligation by the utilities. The most relevant distinction is between fixed FIT and feed-in premium systems. The former provides total payments per kWh of electricity of renewable origin while the latter provides a payment per kWh on top of the electricity wholesale-market price (Sijm 2002). In recent years, feed-in tariff systems are also combined with auctions for price determination as well as for having a cost/quantity control on the market. Note that the planned CfD scheme in the UK falls also under the category of a FIT scheme.
2. In a **quota obligation with Tradable Green Certificates** the government defines targets for RES-E deployment and obliges a particular party of the electricity supply-chain (e. g. generator, wholesaler or consumer) with their fulfilment. Once defined, a parallel market for renewable energy certificates is established and their price is set following demand and supply conditions (forced by the obligation). Hence, for RES-E producers, financial support may arise from selling certificates in addition to the revenues from selling electricity on the power market.

3 Method of approach

Renewable energies were compared with the nuclear option by looking at the quantities of power they can both generate and the level of financial support this requires. This mirrors the extra costs which must be borne by the end consumer or society. Five different renewable technologies were analysed: biomass, onshore and offshore wind, small-scale hydropower plants and photovoltaics.

In brief, the static approach compares the current (as of 2013) level of incentives for renewables with the state support mechanism for Hinkley Point. The dynamic approach, in contrast, also considers additional factors including future cost reductions achieved through increasing technological experience and aspects of market integration of variable renewables like solar and wind power. The dynamic approach has been calculated up to 2050; the nuclear option is added from 2023 onwards (planned start-up for Hinkley Point C). The dynamic calculation applies a detailed model-based analysis using the Green-X-model (www.green-x.at). This model takes into account a multitude of factors including costs, potentials, regulatory frameworks, diffusion constraints like non-cost barriers, electricity prices and energy demand, all of which have a strong impact on the economics of power generation. Below we provide for the interested reader further insights on both approaches taken.

3.1 Static approach: comparison of planned support for nuclear with existing RE support

The level of financial support paid to the supplier of nuclear as well as of electricity from the renewable energy sources (RES-E) is a core characteristic of a support policy. Actual support levels are, however, often not directly comparable, and details of the support policy applied, including main instrument like Feed-in-Tarifs (FIT) or quotas as well as complementary incentives, need to be taken into account.

For a comparative assessment of support incentives, the available remuneration level during the whole lifetime of a (RE) power plant has to be taken into account. This is also stated in a detailed assessment report of the performance of RE support policies in EU Member States (Steinhilber et al. 2011). To make the remuneration levels comparable, following the methodology applied in (Steinhilber et al. 2011), time series of the expected support payments per unit of electricity generated are created for each of the assessed options (i.e. biomass, small hydro, photovoltaic (PV) and wind (on- and offshore) as well as nuclear power by country) and the net present value (NPV), representing the current value of overall support payments, is calculated. After that the annualised remuneration level is calculated from the NPV using a discount rate of 6.5% and following under each type of instrument a normalisation to a common duration of 20 years. Below Formula (1) and (2) show further details on the underlying calculation approach.

$$NPV = \sum_{n}^{N} \frac{SL_t}{(1+z)^n} \tag{1}$$

$$A = \frac{z}{(1-(1+z)^{-N})} * NPV \tag{2}$$

where:

NPV: Net present value;
SLt: Support level available in year t;
A: Annualised remuneration level;
Z: Interest rate;
n: Reference year;
N: Payback time

In addition, expected future wholesale electricity prices are normalised over the same time period. In the case of a quota scheme with tradable green certificates (TGCs), it is assumed that the total remuneration level is composed of the conventional electricity price (wholesale electricity prices) and the average value of TGCs. The results on remuneration levels, wholesale electricity prices or net support expenditures are expressed subsequently in real terms, using $€_{2013}$.

3.2 Dynamic approach: a prospective model-based assessment of planned support for nuclear with expected future RE support

The dynamic assessment follows the principles sketched above, assessing effectiveness and economic efficiency (i.e. cost effectiveness) of RE and nuclear power support from a future perspective. The approach taken builds on a model-based assessment of future RE deployment in the European Union and at country level for the UK up to 2050.

A scenario of dedicated RE support is assessed that follows the policy decisions taken, i.e. the binding 2020 RE target (of reaching a share of 20% RE in gross final energy demand), and that reflects the European policy agenda for tomorrow where mitigation of climate change and the built-up of a sustainable energy system are expected to remain as top priorities in the period post 2020. The scenario proclaims the prolongation of establishing enhancing framework conditions at EU level while national (or in future European) RE support instruments aim for setting the corresponding incentives to assure the achievement of European RE targets by 2030 and beyond. Complementary to fine-tuned financial incentives for RE this requires enabling framework conditions and a mitigation of currently prevailing non-economic barriers (i.e. administrative barriers and grid constraints that hinder the upscaling of RE deployment across Europe at present).

To derive the scenario, the Green-X model is used. Green-X is a dynamic simulation model for assessing the impact of energy policy instruments on future RE deployment and related costs, expenditures and benefits at technology-, sector- and country-level, that has been widely used in various studies at a national and European level, e.g. for the European Commission to assess the feasibility and impacts of "20% RE by 2020", and to explore policy options post 2020 – for a detailed description of this model we refer to (Green-X, 2015).

Future requirements concerning support schemes for RE

Generally, the need to incentivise the deployment decreases for RE technologies thanks to technological learning. Technological progress and related cost reductions go hand in hand with the ongoing market deployment of a certain technology. This has been impressively demonstrated for example by the uptake of PV in Germany and other countries and the achieved significant decline of capital cost. But what has been observed for PV is by far not an exceptional case, it is rather an affirmation of a general empirical observation – i.e. the technological learning theory.

On the contrary, with ongoing market deployment of variable renewables like solar and wind we see however also an opposing tendency that ultimately may cause an increase in the need for financial support. This concerns the market value of the produced electricity that is fed into the grid. For these technologies it is becoming apparent that in future years (with ongoing deployment) a unit of electricity produced is less valuable than of a dispatchable RE technology like biomass where the plant may interrupt operation during periods of oversupply (because of massive wind and solar power inflow) and correspondingly may low the wholesale power prices. Accordingly this may increase the required net support, determined by difference between total remuneration and market value.

Whether the cost decrease due to technological learning or the increase in support requirements due to a decreasing market value will be of dominance depends on the country- and technology-specific circumstances. This will be analysed in further detail for all assessed energy technologies for the UK and EU 28 within the dynamic assessment.

Overview on key parameters

In order to ensure maximum consistency with existing EU scenarios and projections the key input parameters of the scenarios presented in this work are derived from PRIMES modelling (EC, 2013) and from the Green-X database with respect to the potentials and cost of RE technologies. Table 2 shows which parameters are based on PRIMES, on the Green-X database and which have been defined for this assessment.

More precisely, the PRIMES scenario used is the reference scenario as of 2013 (EC, 2013). However for this assessment, demand projections have been contrasted with recent statistics (from Eurostat) and corrected where adequate (in order to assure an appropriate incorporation of impacts related to the recent financial and economic crisis). Moreover, mid- to long-term trends have been further modified to reflect an adequate representation of energy efficiency, assuming a proactive implementation of energy efficiency measures in order to reduce overall demand growth. Here we base our demand trends on a detailed study led by Fraunhofer ISI, done on behalf of the European Commission (Braungardt et al. 2014).

Tab. 2 Main input sources for scenario parameters

Based on PRIMES	Based on Green-X database	Defined for this assessment
• Primary energy prices • Conventional supply portfolio and • conversion efficiencies • CO2 intensity of sectors	• RE cost (investment, fuel, O&M) • RE potential • Biomass trade specification • Technology diffusion / Non-economic barriers • Learning rates • Market values for variable RES-E	• RE policy framework • Reference electricity prices • Energy demand by sector*

4 Results

The **static approach** undertaken at country level provides a comparison of planned support for nuclear power at Hinkley Point C in the UK with existing RE support, that is, as implemented in 2013. Key outcomes of that are summarised in Fig. 1, indicating by RE technology the possible annual electricity generation that could be supported with currently implemented RE policies in analysed countries. For doing so, average remuneration and net support levels are taken as given. Note that generally a range of feasible generation volumes is depicted for the assessed RE technologies by country:

- The lower boundary of possible volumes answers the question how much renewable electricity (from different technologies) could be supported in the assessed country, if annual net support expenditures as expected for Hinkley Point C under UK circumstances are taken as given.
- If a new nuclear power plant like the one planned for Hinkley Point C is constructed in another country under similar support conditions as planned for the UK (i.e. same FIT level as set in the UK), the net support level would differ because of different electricity wholesale prices. Thus, the upper range in Fig. 1 is consequently taking into account this difference, using country-specific wholesale prices and corresponding annual net support expenditures, and showing how much electricity generation could be achieved with that for the assessed RE technologies.

In accordance with Fig. 1, key results of the static assessment can be summarised as follows:

Under similar budgetary constraints, a higher amount of electricity generation appears feasible with wind onshore and small-scale hydropower plants compared to nuclear in all analysed

- countries (with the exception of hydro in the Czech Republic). This means, in turn, that small hydro and wind onshore represent "least cost" options from today's perspective across all assessed countries. In those countries where support is offered to that option, i.e. the UK and Poland, co-firing of biomass in fossil-fuel based power plants represents another cost-effective generation option.
- A cross-country comparison indicates a comparatively small benefit for wind onshore in the UK. While in all other countries remuneration levels and net support are significantly lower and, in turn, feasible generation volumes are higher for wind onshore compared to nuclear power. This is the result of an unequal risk perception of two distinct policy instruments that come into play for the UK: Today's support for wind onshore in the UK via a certificate trading regime can be classified as significantly more risky than safe revenues stemming from a "Contract for Difference" scheme as planned for Hinkley Point C.
- Both PV and wind offshore represent the most costly options from today's perspective in the majority of countries.

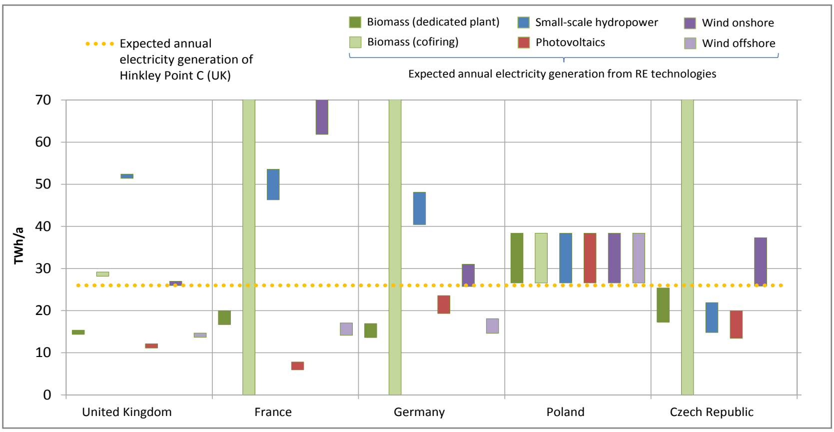

Fig. 1 Comparison of expected annual electricity generation of Hinkley Point C with feasible volumes from assessed RE technologies by assessed country (Source: Own calculations)

The static assessment as discussed above compares today's incentives for RE with a planned aid scheme for nuclear power that may become effective ten years ahead. Since partly significant cost reductions have been achieved throughout the last decade for several RE technologies it can be expected that ongoing technological learning will trigger additional cost decreases and, consequently, reduce the need for RES-E support in forthcoming years. Thus, complementary to the above, a **dynamic approach** is followed within this study: Building on the Green-X scenario of dedicated RE support and the therein sketched deployment of renewables in the EU28, a comparative assessment of future RE support with the planned subsidy for Hinkley Point C is undertaken for all assessed countries. More precisely, the years from 2023 to 2050 form the assessment period whereby 2023 is chosen since this is the year when Hinkley Point C is expected to start full operation. Within that assessment support expenditures for RES-E and nuclear power are contrasted and, finally, the cost-effectiveness of the two distinct pathways is derived.

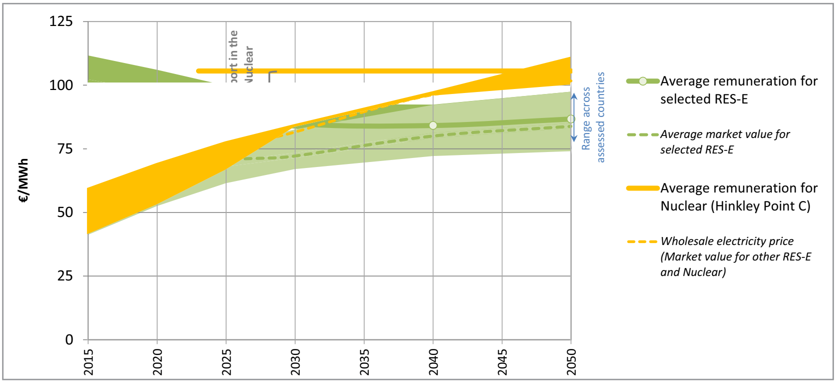

Fig. 2 Future development of remuneration levels and corresponding market values of the assessed RE technologies (as aggregate) and of nuclear power across assessed countries and at EU28 level according to the Green-X scenario of dedicated RE support (Source: Own assessment (Green-X))

Fig. 2 shows the development over time of remuneration levels and the corresponding reference price for the assessed technology options, using weighted average figures to determine market value and the remuneration level for the aggregated RE technology cluster that comprises the basket of assessed individual RE technologies. This graph shows these developments at EU 28 level (i.e. via dotted or solid lines) while shaded areas indicate the ranges of expressed items occurring across assessed countries. Generally, the need for net support for a new installation in a given year can then be derived by subtracting the market value from overall remuneration. Thus, this allows for a first interpretation of cost efficiency:

- For nuclear power it can be observed that during early years of operation a significant gap between remuneration and market value, in this case determined by the yearly average wholesale electricity price, occurs. This is however getting smaller in later years thanks to the expected increase in wholesale electricity prices (that goes hand in hand with an increase of fossil fuel and carbon prices over time).
- For renewables an interpretation appears more difficult since outcomes reflect the over shading impacts of a basket of technologies that come into play: In early years a strong decline of remuneration levels is apparent, reflecting expected technological progress across all considered RE technologies but, thanks to their dominance driven by cost trends for on- and offshore wind as well as photovoltaics. In later years, with increasing deployment the merit-order-effect and the related decrease in market values of variable renewables is applicable. Offshore wind is then mainly responsible for the small gap remaining, where average RE remuneration is higher than the market value at EU28 level as well as in some of the assessed countries. In general, similar to nuclear the need for net support shows a decreasing tendency in the final years up to 2050.

Comparing cumulative electricity generation and corresponding support expenditures that would arise throughout the assessment period (2023 to 2050) an overall conclusion related to the cost effectiveness of the two distinct pathways (i.e. nuclear versus RE) can be drawn next. Results on specific net support as derived by dividing cumulative support expenditures by cumulative electricity generation are shown in Fig. 3. Complementary to that, resulting cost savings at country as well as at EU28 level that would arise if the preferred option is followed are shown in Fig. 4.

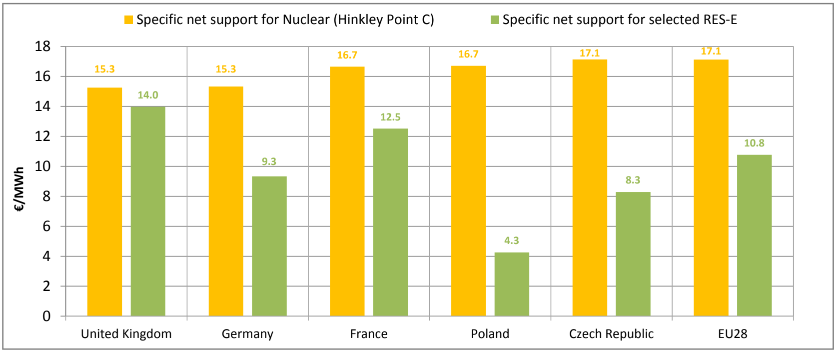

Fig. 3 Comparison of overall cost-effectiveness: Specific net support for assessed RE technologies and nuclear power by assessed countries and at EU28 level according to the Green-X scenario of dedicated RE support (Source: Own assessment (Green-X))

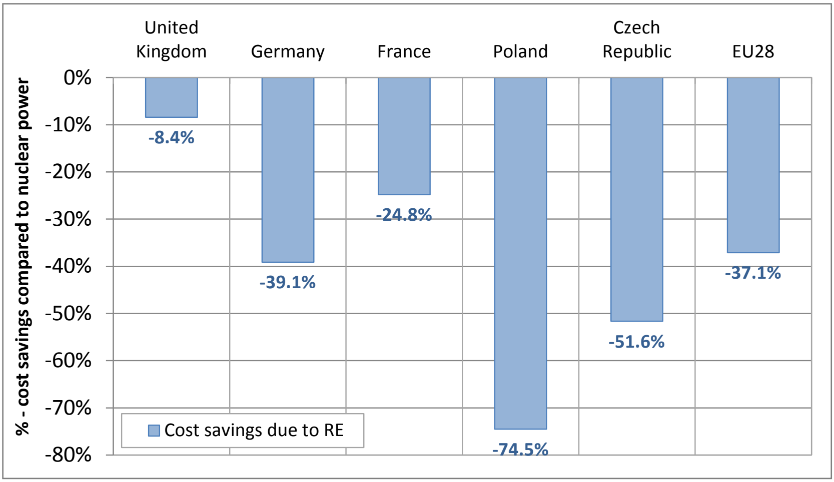

Fig. 4 Comparison of overall cost-effectiveness: Cost savings due to RE compared to nuclear power by assessed country and at EU28 level according to the Green-X scenario of dedicated RE support (Source: Own assessment (Green-X))

We would like to highlight the following As discussed above, net support is generally defined as the difference between total remuneration and the market value of the fed in electricity. If a new nuclear power plant like the one planned for Hinkley Point C is built in another country under similar support conditions as planned for the UK (i.e. same FIT level as set in the UK), the net support level would differ because of different electricity wholesale prices that in the case of nuclear power serve as determinant for its market value. In future years lower electricity prices than in the UK are expected for countries like France, Poland, the Czech Republic and the whole EU28 on average. Thus, a new nuclear power would consequently require significantly higher net support in these countries than in the UK. This would strongly increase the burden for consumer and/or the society, respectively.

Results on specific net support as shown in Fig. 4 point out that supporting a basket of RE technologies as analyzed in this assessment leads to a higher cost-effectiveness than the planned support for the nuclear power plant at Hinkley Point C that served as nuclear comparator throughout this exercise. This statement is valid for all assessed countries as well as for the EU28:

- Highest cost savings due to RE can be observed for Poland where following a RE pathway instead of nuclear would lead to savings in support expenditures of 74.5%.
- On second place follows the Czech Republic where savings due to RE are in size of 51.6%.
- Germany ranks as third among the assessed countries with respect to feasible cost savings that come along with following the renewable pathway. Support expenditures can be reduced by 39.1% through targeting support to RE technologies compared to the nuclear alternative.
- At EU28 level on average savings in support expenditures are in range of 37.1%.
- A slightly lower figure can be observed for France where savings are in magnitude of about 25%.
- Last on the list of assessed countries is the UK. However also in that country following a RE pathway instead of a nuclear appears beneficial – i.e. cost savings of 8.4% are identified for the UK.

5 Conclusions

The level of financial support paid to a nuclear or a RE power plant is a core characteristic of the related policy intervention. Support instruments need to be *effective* in order to increase the penetration of energy sources (in this case RE and/or nuclear) and *efficient* with respect to minimising the resulting public cost, i.e. the transfer cost for consumers (society) over time.

This study assesses the effectiveness and efficiency of support schemes in selected European countries for nuclear and specific renewables (wind, hydro, PV and biomass) using two distinct approaches; a static and a dynamic comparative assessment.

The **static comparative assessment** of the envisaged state aid scheme for the UK's planned nuclear power plant at Hinkley Point C contrasted with today's support incentives for renewables leads to the following conclusions:

Onshore wind and small hydropower plants (with the exception of the Czech Republic) represent the "least cost" option from today's perspective in all the countries analyzed. Consequently, if the planned annual support expenditures for Hinkley Point C were channeled into these RE options, then more carbon-free electricity could be generated. In contrast to above, PV and offshore wind can be classified as the most costly options from today's perspective (with the exception of Poland).

If Hinkley Point C were to be built in the assessed countries and under similar support conditions as those planned for the UK (i.e. same feed-in tariff level), then the net level of support would differ from country to country because of varying electricity wholesale prices. Wholesale electricity prices in the UK are currently among the highest in Europe. Prices in the Czech Republic and Poland are lower. Consequently, under the same feed-in tariff level as set in the UK, a new nuclear power plant would require significantly more net support (i.e. defined as the difference between remuneration and wholesale electricity prices for nuclear) in Poland or the Czech Republic than in the UK. In turn, this would strongly increase the burden for consumer and/or society.

The static assessment, as discussed above, compares today's incentives for RE with a planned aid scheme for nuclear power that may become effective in ten years. As some significant cost reductions in RE technologies have been achieved over the past decade, we can expect that growing technological experience in this field will trigger more cost reductions and, consequently, will reduce the need for RES-E support in coming years. Therefore this study also takes a **dynamic approach**: building on the Green-X scenario of dedicated RE support and its outline for the deployment of renewables in the EU28, future RE support has been compared with the planned subsidy for Hinkley Point C for all the assessed countries.

This analysis leads us to the following conclusions:

- *A constant level of remuneration, as guaranteed for nuclear power at Hinkley Point C in the UK, may lead to a high consumer burden in the early years, but thanks to expected increases in fossil fuel and carbon prices, net support will decrease over time.*
  During the early years of operation at Hinkley Point there will be a significant gap between remuneration level and market value, in this case determined by the yearly average wholesale electricity price. However, this gap will reduce with time thanks to the expected increase in wholesale electricity prices (which goes hand in hand with an increase in fossil fuel and carbon prices over time).
- *Two opposing trends determine the need to support renewables: cost reductions resulting from technological progress lead to decreasing remuneration, whilst increasing deployment of variable RE technologies cause reductions in their market value. The need for net support depends on the country and technology-specific circumstances.*
- *Generally, the need to incentivise deployment of renewables falls thanks to technological learning. Technological progress and related cost reductions go hand-in-hand with ongoing market deployment of a technology. This has been impressively demonstrated, for example, by the uptake of PV in Germany and other countries, and the corresponding, significant decline in capital costs. But the massive cost decline for PV is certainly not exceptional; it affirms a general empirical observation, i.e. technological learning theory.*
  In contrast, the ongoing market deployment of various renewables including solar and wind demonstrates an opposing tendency that may ultimately cause an increase in the need for financial support: the market value of the generated electricity that is fed into the grid. For these technologies it is becoming apparent that in future years (with ongoing deployment) a unit of electricity will be less valuable than that produced by a dispatchable renewable energy technology such as biomass where the plant may interrupt operation during periods of oversupply and wholesale power prices are correspondingly low.
  Thus the net level of required support is determined by the difference between remuneration and market value. Whether the cost decreases resulting from technological learning outweigh the need for increased support as a result of the decreasing market value, or vice versa, depends on the country and technology-specific circumstances.
- *The assessment at country and at EU levels confirms that remuneration for renewables is expected to decline over time. This decrease is strong in the early years, followed by a slowdown and stagnation in later years. Contrarily, market*

values for variable renewables are expected to more strongly decouple from average wholesale electricity prices.

The analysis, which considers selected EU Member States as well as the EU28 as a whole, indicates a strong decline in remuneration levels for renewables in the early years as a result of expected technological progress across all the RE technologies considered. Thanks to their dominance, this positive trend is driven by cost trends for onshore and offshore wind and photovoltaics. With increasing deployment in later years, the merit order effect and the related decrease in market value of variable renewables applies. Offshore wind is then mainly responsible for the small remaining gap, where average RE remuneration is higher than the market value, both at EU-28 level as well as in some of the assessed countries.

- *If we compare cumulative electricity generation and corresponding support expenditures we can draw an overall conclusion regarding the cost effectiveness of the two distinct pathways (i.e. nuclear vs. RE). Results for specific net support clearly indicate that supporting a basket of RE technologies is more cost-effective than the planned support for the nuclear power plant at Hinkley Point C that has served as the nuclear comparator throughout this exercise. This statement is valid for all the assessed countries as well as for the EU28.*

  The highest cost savings achieved through RE can be observed in Poland where following a RE pathway instead of nuclear would lead to savings in support expenditures of 74.5% whereas average savings in support expenditures for the EU28 as a whole are in the range of 37.1%. Finally, the UK comes last in the potential savings ranking, yet even in the UK it is economically beneficial to follow a RE pathway rather than the nuclear option, with cost savings of 8.4%.

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