SUPREME COURT OF THE STATE OF NEW YORK
COUNTY OF ALBANY

In the Matter of
HUDSON RIVER SLOOP CLEARWATER, Inc.,
ET AL.,
Petitioners-Plaintiffs,   Albany County
For a Judgment pursuant to Article 78 of the CPLR,   Index No. 07242-16
-against-
NEW YORK STATE PUBLIC SERVICE
COMMISSION, ET AL.,
Respondents-Defendants,
****

**MOTION OF COALITION FOR
COMPETITIVE ENERGY, ET AL., FOR
LEAVE TO FILE *AMICUS* BRIEF IN
SUPPORT OF PLAINTIFFS**
****

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Dated: March 31, 2017

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The Coalition for Competitive Electricity, Dynegy Inc., Eastern Generation, LLC, Electric Power Supply Association, NRG Energy, Inc., Roseton Generating LLC, and Selkirk Cogen Partners L.P. ("Proposed *Amici*") respectfully request leave to file the amicus brief attached as Exhibit A, in support of the plaintiffs/petitioners in this action.

Proposed *Amici* are independent power producers that compete with the Exelon-owned upstate nuclear power plants that are to receive $7.6 billion in ratepayer-paid ZEC subsidies under the challenged Tier 3 program of the PSC order (the "ZEC program"). The ZEC subsidies would severely depress interstate wholesale prices and give the subsidized generators an unfair competitive advantage in the FERC-regulated auction marketplace. Proposed *Amici* therefore have a direct financial interest in the outcome of this litigation. Proposed *Amici* do not seek to delay any proceedings in this matter.

For the reasons stated above, this motion for leave should be granted.

Dated: March 31, 2016

Respectfully submitted,

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By: /s/ Jonathan D. Schiller

CERTIFICATE OF SERVICE

I certify that I have caused to be mailed a copy of the above pleading to all counsel of record on this 31st day of March, 2017.

/s/ Jonathan D. Schiller

Exhibit A

SUPREME COURT OF THE STATE OF NEW YORK
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For a Judgment pursuant to Article 78 of the CPLR,   Index No. 07242-16
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NEW YORK STATE PUBLIC SERVICE
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AMICI CURIAE **MEMORANDUM OF**
COALITION FOR AFFORDABLE ENERGY,
ET AL., IN SUPPORT OF PLAINTIFFS
****

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Dated: March 31, 2017

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Amici curiae Coalition for Competitive Electricity, Dynegy Inc., Eastern

Generation, LLC, Electric Power Supply Association, NRG Energy, Inc., Roseton

Generating LLC, Selkirk Cogen Partners L.P. ("*Amici*") file this memorandum in

support of the plaintiffs/petitioners in this action.

I.   INTEREST OF *AMICI*

Amici are independent power producers that compete with the Exelon-owned

upstate nuclear power plants that are to receive $7.6 billion in ratepayer-paid ZEC

subsidies under the challenged Tier 3 program of the PSC order (the "ZEC

program").[1] *Amici* are the plaintiffs in a federal suit, *Coalition for Competitive*

Electricity, et al. vs. Zibelman, et al., no. 1:16-CV-8164, S.D.N.Y. This suit

alleges that the Tier 3 ZEC program is invalid under the Supremacy Clause and the

Commerce Clause of the U.S. Constitution. Wholesale electricity prices and sales

are regulated by the Federal Energy Regulatory Commission ("FERC"), which has

established a competitive auction-based market system for the sale of wholesale

electricity. The ZEC subsidies would severely depress interstate wholesale prices

and give the subsidized generators an unfair competitive advantage in the FERC-

regulated auction marketplace, and therefore the subsidy program is preempted by

federal law. However, these federal constitutional issues are not before this Court

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[1] Plaintiffs' suit and this *amici* brief challenge only the Tier 3 ZEC program enacted in the PSC's order of
August 1, 2016. Neither plaintiffs nor *Amici* contest the Tier 1 and Tier 2 programs adopted in that same
order.

in this case, in which the ZEC program is challenged by plaintiffs solely on state law grounds.

II. APPLICABLE LEGAL STANDARD

Although also raising procedural issues such as standing and prematurity, the PSC and Exelon primarily claim in their motions that the Amended Complaint "fails to state a cause of action," CPLR 3211(a)(7). The PSC does not even mention the strict standard for the granting of such a motion. Exelon concedes that the Court "must credit the petition's allegations as true" and deny the motion unless the alleged facts do not "fit within any cognizable legal theory," yet both the PSC and Exelon largely ignore plaintiffs' well-pleaded allegations and argue for dismissal based on their own contrary allegations of fact. Indeed, they attempt to contradict plaintiffs' allegations with over 1,000 pages of exhibits and declarations. This is improper, as the motion must be decided on the "four corners of the complaint." *511 West 232nd Owners Corp. v Jennifer Realty Co.,* 98 NY2d 144, 152 (2002). The Court must liberally construe the complaint, afford plaintiffs the benefit of "every possible favorable inference," and deny the motion if the factual allegations, "taken together, manifest any cause of action cognizable at law." *Id*.

III. THE TIER 3 ZEC PROGRAM WAS NOT VALIDLY ENACTED

Amici agree with plaintiffs that the Tier 3 ZEC program was not validly adopted under New York law and therefore should be held invalid and enjoined.

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Amici join in all substantive arguments raised by plaintiffs. Although the PSC tries

to prove that the ZEC program was adopted for bona fide "environmental

protection" reasons, it is obvious that the ZEC is not an environmental measure; it

is just a mechanism to provide out-of-market funding to three upstate nuclear

generators, for Exelon's benefit. Almost every environmental group that

commented on the proposed order strongly opposed the ZEC program,[2] yet the

PSC ignored their voices.

A. The PSC Did Not Follow Lawful Procedures

Agency action must be held invalid if made in violation of lawful procedure.

CPLR § 7803. It is undisputed that, in June 2015, the PSC opened a proceeding

entitled "In the Matter of the Implementation of a Large-Scale Renewable Program

and a Clean Energy Standard," case no. 15-E-0302 (the "LSR proceeding"). There

was no mention of the upstate nuclear plants or any type of ZEC program in the

initial notice of the LSR proceeding or in the accompanying paper entitled "Large

Scale Renewable Energy Development in New York: Options and Assessment,"

which was prepared jointly by the PSC's staff, the New York State Energy

Research and Development Authority ("NYSERDA"), and outside consultants.

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[2] See, e.g., http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=15-e-0302 (Filing No. 328) (comments of Alliance for a Green Econ. (AGREE), Council on Intelligent Energy & Conservation Policy (CICEP), Nuclear Info. & Res. Serv. (NIRS), Sierra Club-Atl. Chapter). Other groups filing objections to the ZEC program include Citizens' Environmental Coalition (Filing No. 320), Ampersand Hydro (Filing No. 331), the New York Association of Public Power (NYAPP) (Filing No. 333), the City of New York (Filing No. 338), the Public Utility Law Project (PULP) (Filing No. 343), and Promoting Health and Sustainable Energy (PHASE) (Filing No. 348).

Shortly thereafter, in July 2015, the State Energy Planning Board promulgated a

State Energy Plan ("SEP") with a goal that 50 percent of all electricity used in the

state should by 2030 be generated from renewable energy sources. The SEP also

does not mention the upstate nuclear plants or any type of ZEC program.

Then, in January 2016, the PSC expanded the scope of the LSR proceeding

and ordered its staff to develop a white paper with recommendations to keep the

upstate nuclear generators open. Just four days later, the staff released a white

paper proposing, *inter alia*, that the PSC adopt a ZEC program to save New York

nuclear generators facing "financial difficulties." The white paper proposed that

ZECs be issued "based upon the difference between the anticipated operating costs

of the units and forecasted wholesale prices."   The proposed ZEC program was "to

provide qualifying nuclear plants with support payments, reflective of their going

forward costs of operation, to ensure they continue to operate." The total cost of

the program was estimated at less than $700 million.[3]

After months of comments and discussions, on July 9 the staff issued a so-

called "Responsive Proposal" that radically changed the cost and terms of the

proposed ZEC program. The cost suddenly ballooned to an estimated $7.6 billion

– over a 1000% increase.[4] And instead of basing ZEC prices on "the difference

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[3] http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=15-e-0302,
Filing no. 112 at 84 (gross cost $59 to $658 million to 2023)
[4] http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=15-e-0302,
Filing no 328 at 16.

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between the anticipated operating costs of the units and forecasted wholesale prices," as originally proposed, the Responsive Proposal switched the price to one based the price on the "social cost of carbon," with the amount of the subsidy also tied to wholesale electricity prices. With no hearing, and giving just two weeks for comments, the PSC adopted the Responsive Proposal on August 1, over the objections of several environmental groups (whose goals were purportedly being served by the ZEC program) and others.

Incredibly, Exelon claims (Br. at 27-28) re-notice was not required because this was not a "substantial revision" of the original proposal. Exelon concedes that a change is a substantial revision if it "materially alters" the effect of a proposal, yet somehow insists that a more than 1000% price increase and a completely different pricing formula are not material. Obviously these were material changes, and plaintiffs should be allowed to prove it.

Moreover, New York law requires a hearing if a utility proposes to raise its rates in an amount that would raise its aggregate revenues by 2.5% or more. The PSC asserts that no hearing was required because the ZEC program was proposed by itself, not by Exelon, but this is a difference without legal significance.

B. There Is No Environmental Justification for the ZEC Program

Although a state agency has discretion within its area of competence, this Court can and should enjoin an agency's order if it is arbitrary, capricious, an

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abuse of discretion, or is not supported by substantial evidence. CPLR § 7803.

Here, the PSC wanted to keep the upstate nuclear plants open so it concocted an

"environmental need" for ZECs without even considering the record evidence.

Amici do not dispute that the reduction of carbon emissions is vitally

important, and *amici* support New York's "50 by 30" goal – at least 50% of New

York's electricity to be produced by clean, renewable-powered (solar, wind, hydro,

etc.) by 2030. Exelon, however, concedes nuclear generation is not renewable.[5]

Nevertheless, the PSC claims the nuclear plants must be kept open with

subsidies until 2029 to prevent "backsliding" on efforts to reduce carbon

emissions. ZEC Order at 143, 145. Without citing any evidence, and without

addressing the contrary evidence submitted by several environmental groups, the

PSC stated: "Losing the carbon-free attributes of nuclear generation, before the

development of new renewable resources between now and 2030, would

undoubtedly result, based on current market conditions, in significantly increased

air emissions due to heavier utilization of existing fossil-fueled plants or the

construction of new gas plants." *Id*. at 128. This conclusion is unsupported, and

cannot be accepted as true. Indeed, a recent study has shown that by spending on

renewables just a portion of the $7.6 billion that the PSC would like ratepayers to

pay to keep the nuclear generators afloat until 2029, New York could replace the

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[5] Exelon Br. at 2 n.4.

electricity from the nuclear plants with clean, green electricity from solar, hydro, and wind-powered renewable generators that will remain in operation for many years beyond 2029.[6]

In fact, just a few months after enacting the ZEC Order, the State admitted that nuclear power is not needed to achieve New York's environmental goals. Governor Cuomo announced on January 13, 2017, an agreement to close the Indian Point nuclear power plant by 2021. Indian Point is a profit-making plant that has not sought any state subsidy. State officials said that Indian Point is not needed because, "by the time Indian Point is shut, there will be plenty of energy alternatives available to pick up the slack," including clean hydro power from Quebec and clean wind power from wind farms.[7] Obviously, if Indian Point can be closed and replaced with renewable generation by *2021*, there is no need to subsidize the upstate nuclear generators until *2029*.

Exelon contends (Br. at 5-6) that the ZEC program is "modeled on" and is "similar to" New York's Renewable Energy Credit ("REC") program, which provides support for actual renewable generators that produce clean, safe renewable energy. In fact, they are not at all comparable. Under the REC

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[6] "In sum, in all cases examined, subsidizing the three upstate nuclear reactors to stay open increases both CO2 and costs relative to the renewable scenarios." Cebulla & Jacobson, *Alternative renewable energyscenarios for New York* (2016) at 1, available at http://web.stanford.edu/group/efmh/jacobson/Articles/I/NYNuclearVsRenewables.pdf (copy attached as Exhibit 1).

[7] *See* http://www.lohud.com/story/news/investigations/2017/01/13/indian-point-power/96442628/.

program, load-serving entities are obliged to purchase a portion of their electricity from renewable sources. LSEs may satisfy this obligation by purchasing RECs. Unlike ZECs, which are only available to certain preferred nuclear plants, RECs are generally available to all renewable generators. Moreover, unlike ZECs, which each LSE must purchase from NYSERDA, RECs are competitively traded on public markets, and LSEs can purchase from anyone they so choose. The labeling of the nuclear subsidies as an "environmental credit" was arbitrary and an abuse of discretion, an effort to hide a multi-billion bailout of one private company with an environmental cover.

CONCLUSION

For the reasons stated above and by plaintiffs in their memoranda, the PSC's and Exelon's motions to dismiss should be denied.

Dated: March 31, 2017

Respectfully submitted,

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By: /s/ Jonathan D. Schiller

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I certify that I have caused to be mailed a copy of the above pleading to all counsel of record on this 31st day of March, 2017.

/s/ Jonathan D. Schiller

Exhibit 1

Alternative renewable energy scenarios for New York

By Felix Cebulla[1] and Mark Z. Jacobson[2]

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November 8, 2016

ABSTRACT

This case study compares the cost of maintaining a proposed subsidy for New York's three upstate nuclear power plants (Fitzpatrick, Nine Mile Point Unit 1, and Ginna) with the cost of replacing the plants with renewable technologies over the time period from 2016 to 2050. Three alternative renewable scenarios are compared with two nuclear scenarios in terms of overall system costs, which comprise all capital and operating expenditures (CAPEX, OPEX[1]) as well as Zero Emission Credit (ZEC) subsidies for nuclear power plants[2].

The results show that the two nuclear scenarios (Scenario 1, keeping nuclear operating with subsidy until 2050 and Scenario 2, keeping nuclear operating with subsidy until 2028, then replacing it with wind and solar) are the most expensive scenarios, resulting in overall system costs of $32.4 billion and $31.0 billion, respectively, in $2014[3]. The least expensive option, on the other hand, is to shut down the nuclear plants today and replace them with onshore wind capacities, saving $7.9 billion compared with Scenario 1. Substituting nuclear with a combination of wind and utility-scale photovoltaics (Scenario 5) would save $6.6 billion compared with Scenario 1. A mix of wind, utility-scale and rooftop Photovoltaics save $0.8 billion (Scenario 4). If we assumes a lower average capacity factor of nuclear generation from 2016 to 2050 (0.85 instead of 0.91) due to higher maintenance requirements over time and compensate the lower power generation with a mix of wind and PV, the system costs are slightly more expensive than in Scenario 1.

The four renewable scenarios lead to 20.1 to 27.4 Mt CO_2 greater emission reductions between 2016 and 2050 than with the two nuclear scenarios. In addition, re-investing the cost savings of the renewable scenarios into additional wind capacities increase CO_2 savings up to 32.5 Mt.

In sum, in all cases examined, subsidizing the three upstate nuclear reactors to stay open increases both CO_2 and costs relative to the renewable scenarios.

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[1] CAPEX include the annuities over an economic lifetime of 20 years of the capacity specific overnight investment costs. OPEX on the other hand comprise fuel costs as well as fixed and variable operation and maintenance costs.
[2] Although nuclear power emits lower CO_2, than fossil fuels during operation during the mining and refining of uranium, ZEC include social costs of carbon due to their externalities.
[3] All costs are given in US $ 2014.

1. Introduction

The installed capacity of the nuclear power plants Fitzpatrick, Nine Mile Point Unit 1, and Ginna is 2.1 GW [2], providing 16,330 GWh electricity per year (which equals approximately 11% of New York's overall electricity demand). Replacing these plants with 100% renewable systems would require either (a) 7.5 GW of onshore wind capacity, (b) 3.7 GW of onshore wind capacity and 4.4 GW of utility-scale PV capacity, or (c) a combination of 3.7 GW onshore wind, 2.2 GW of utility-scale PV, and 2.7 GW of rooftop PV. The decommissioning of nuclear power plants and replacement through renewable energies has been analyzed for other cases as well. In PG&E Joint Proposal Testimony for the retirement of the Diablo Canyon power plant [1], the estimated costs for an alternative, 55% renewable scenario were found to be lower than all of the nuclear scenarios.

The current generation portfolio in New York State (as of 2015) is shown in Figure 1. The most significant capacity is provided by gas fired system (natural gas, landfill gas) and nuclear power plants, followed by hydropower (conventional + pumped) and petroleum liquids.
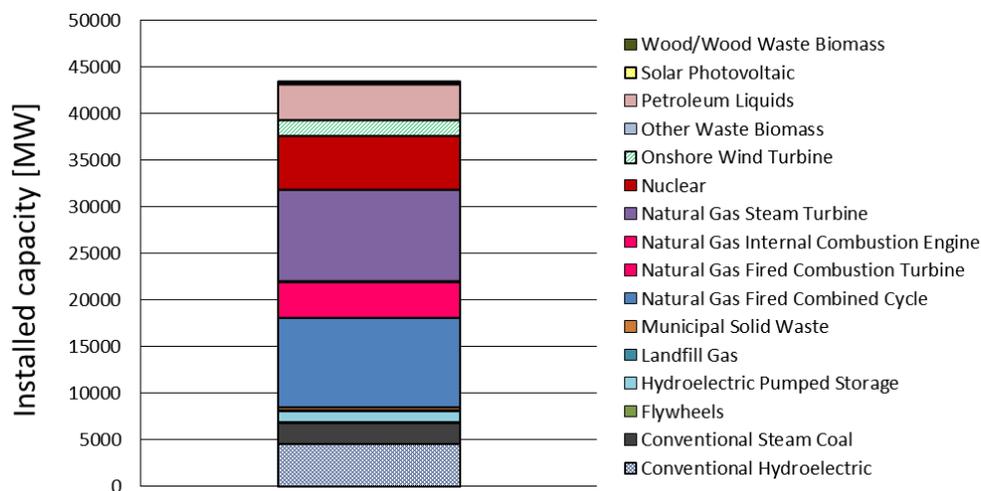

Figure 1: Technology specific installed capacity in New York [2].

2. Scenarios

Scenario 1 ("BAU"): The nuclear power plants Fitzpatrick, Nine Mile Point Unit 1, and Ginna are assumed to stay open from 2016 until 2050. Their annual electricity generation of 16,330 GWh is assumed to stay constant during that period. It is assumed that any alternative scenario[4] (except Scenario 6) has to provide the same electric energy annually. The proposed nuclear subsidy, which runs out in 2028, is assumed to continue at the rate of the last year of the subsidy.

Scenario 2 ("Nuc until 2028"): Nuclear is assumed to stays open until the end of 2028, when the current proposed subsidy runs out, and is then replaced by onshore wind. The installed capacity of wind turbines needed to provide 16,330 GWh/yr with a capacity factor[5] (CF) in New York of 25% (average CF 2013 [7]) is 7.5 GW. The investment for the wind turbines already occurs in 2025 as the construction and planning time has to be considered.

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[4] Except in Scenario 6 where a decrease of the capacity factor of nuclear implies a change in annual electric energy generation.
[5] The capacity factor describes the utilization of a generation technology. It is defined as the potential amount of energy of a generation if operated at nominal capacity for every hour of the year.

Scenario 3 ("Wind"): Nuclear closes as soon as possible (end of 2020) and is replaced by onshore wind. It is assumed that electricity generation from wind power starts in 2021, with the delay due to construction and planning time, while the investment begins to take place in 2017. In that case, the nuclear subsidy continues until the end of 2020.

Scenario 4 ("Wind/PV"): Nuclear closes as soon as possible (end of 2020) and is replaced by wind, utility scale PV and residential rooftop PV (investment starts in 2017, first operating year is 2021). Capacity factors of utility scale PV and rooftop PV are 21% and 17% and based on the 2015 mean values of the lower and upper CF range NREL's ATB Cost and Performance Summary [9]. 50% of the overall electricity generation (16,330 GWh/yr) is provided by onshore wind (8,165 GWh/yr at 3.7 GW), while utility scale PV and rooftop PV provide 25% each, resulting in a required installed capacity of 2.2 GW and 2.7 GW.

Scenario 5 ("Wind/PV utility"): Nuclear is replaced by a combination of wind onshore (8,170 GWh/yr at 3.7 GW) and utility scale PV (8,170 GWh/yr at 4.4 GW). Wind and PV generation start in 2021. The nuclear subsidy ends at the end of 2020, as with the other cases.

Scenario 6 ("Nuc moderate CF"): This scenario assumes that the 2015 capacity factor (CF) of the three nuclear power plants averaged between 2016 and 2050 (0.91) decreases to 0.85. The rationales behind this assumption is that older nuclear plants require greater maintenance and higher penetration levels of renewable systems imply less utilization of nuclear power. As a consequence, the electric power generation from nuclear declines from 16,330 GWh/yr to 15,316 GWh/yr. In order obtain the comparability to the other scenarios (i.e. same annual electricity generation of 16,330 GWh/yr) the difference (1,013 GWh/yr) is generated by a mix of onshore wind, utility-scale PV, and rooftop PV (231 MW, 138 MW, 170 MW).

Throughout the scenarios a discount rate of 4.5% and an economic life time of 20 years are assumed. Sensitivity tests are run to test the effects of 3% and 6% discount rates.

The following specific life cycle CO_2 emissions are assumed (based on [3,4] and updated values from [5]); nuclear: 66 g-CO_2/kWh$_{el}$, wind: 10 g-CO_2/kWh$_{el}$, PV (no differentiation between utility-scale and rooftop): 30 g-CO_2/kWh$_{el}$.

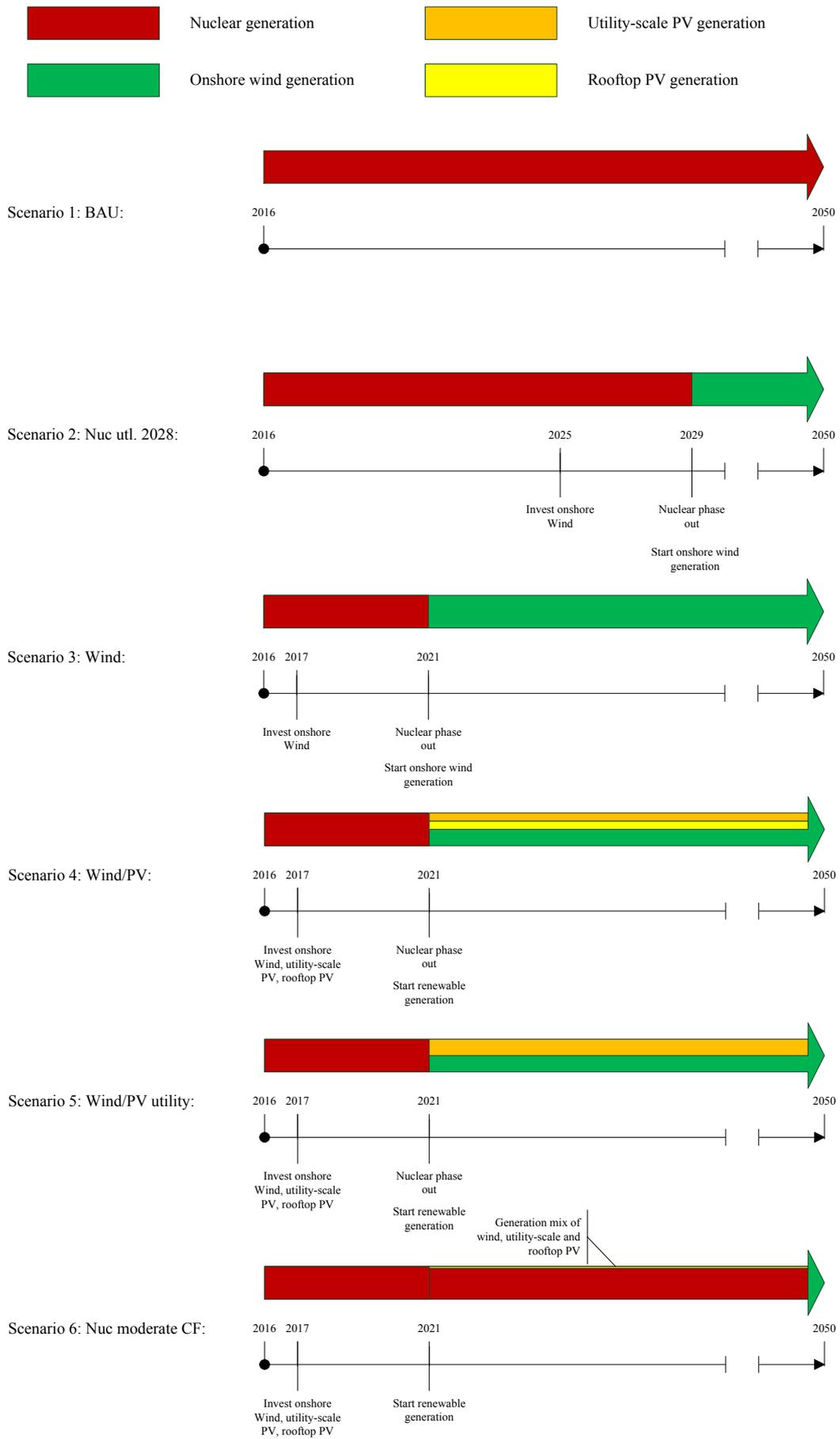The temporal sequence of investments and power generation until 2050 is summarized in Figure 2.

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Figure 2: Timeline of investments and power generation of the main scenario.

3. Results

3.1. Cost savings

Figure 3 shows the overall system costs and life cycle CO_2 emissions for each scenario, disaggregated into CAPEX, OPEX, and subsidies for nuclear power. In Section 3.2 a comparison of CO_2 emissions is provided for the case where the costs depicted in Figure 3 are instead invested in additional wind capacity.
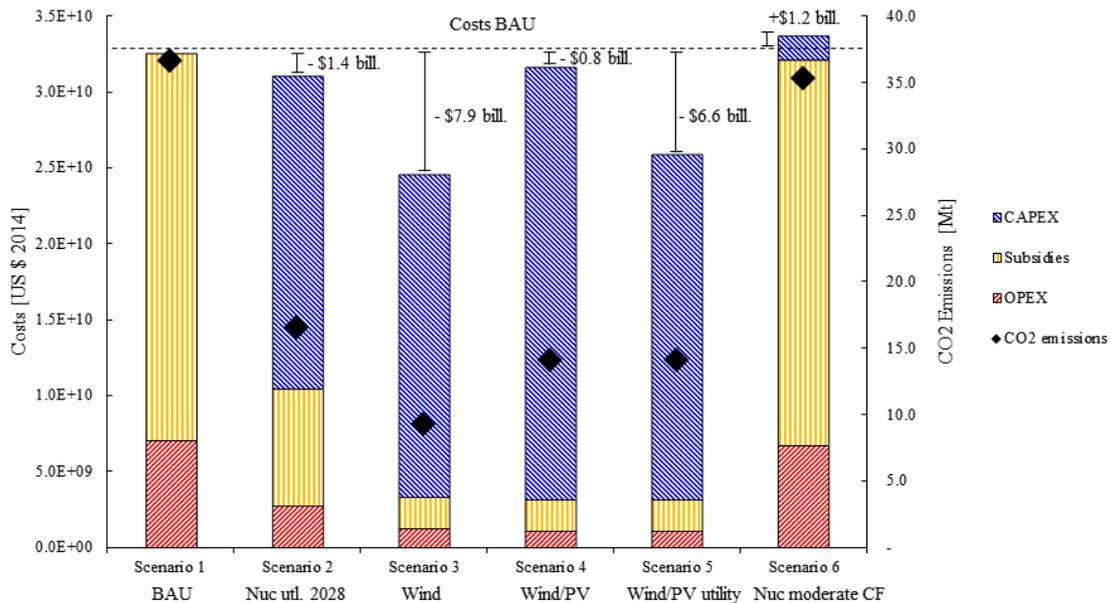

Figure 3: Comparison of all costs (primary ordinate) and CO_2 emissions (secondary ordinate) for each scenario. Operating costs (OPEX) include fuel costs as well as fixed and variable operation and maintenance costs. Subsidies refer to Zero Emission Credits (ZEC) for nuclear power plants. All exact values can be found in Table A.2. in the Appendix.

Scenario 1 ("BAU"): The overall costs are $32.4 billion (in $2014), mainly consisting of subsidies for nuclear power. For the first 12 years, nuclear will receive a cumulative subsidy of $7.6 billion, with increasing yearly amounts, capping at $805 million/yr in 2028. In this scenario, we assume that, the subsidy continues at $805 million/yr for the remaining 22 years past 2028 until 2050, totaling an additional $17.7 billion from 2028 to 2050 or $25.3 billion ($7.6 + 17.7 billion) over the entire 34 years from 2016 to 2050. Operating costs, mainly fuel costs, are around $7.0 billion (22% of the total costs) during this period. The total life cycle CO_2 emissions are the highest among all scenarios, resulting in 37 Mt CO_2 until 2050.

Scenario 2 ("Nuc until 2028"): The overall costs are $31 billion. Around 66% ($20.6 billion) are CAPEX of the newly installed wind turbines, while 25% of the cost ($7.7 billion) is subsidy to the nuclear power plants, which operate until 2028. OPEX account for only 9% ($2.7 billion). Although the costs do not differ substantial from the BAU costs, this scenario saves 20 Mt of CO_2 emissions until 2050 compared with BAU.

Scenario 3 ("Wind"): This scenario has the lowest overall system cost ($24.5 billion) and CO_2 emissions (9 Mt CO_2). Most of the cost reduction is achieved by avoiding the subsidy for nuclear power. Some subsidies ($2.1 billion), however continue during the period between planning and initial investment (2017) and operation (beginning of 2021) of the wind farms. The biggest cost component

is CAPEX for the new onshore wind capacities. OPEX are insignificant and consist of fixed operating and maintenance costs (variable operating costs for renewable systems are assumed to be zero).

Scenario 4 ("Wind/PV"): This scenario is only slightly less expensive than BAU, resulting in system costs of \$31.6 billion, saving around \$0.8 billion. The additional cost, compared with scenario 3 ("Wind"), arises due to the lower capacity factor and higher cost of PV (utility + rooftop) versus onshore wind in New York. Yet again, the scenario mitigates CO_2 emissions by 23 Mt (compared with BAU). As for scenario 3, the initial years after the investment into renewable capacities, nuclear power plants still need to be kept online for the duration of the construction time.

Scenario 5 ("Wind/PV utility"): The second least-costly scenario results in system costs of \$25.8 billion, reducing costs by \$6.6 billion and CO_2 emissions by 23 Mt compared with BAU. When compared with scenario 4 ("Wind/PV"), where 25% of the electricity is provided by rooftop PV, the lower CAPEX and higher CF of utility-scale PV leads to lower overall system costs. The total CO_2 emissions are identical, as the same lifecycle emissions per kWh for utility-scale and rooftop PV were assumed (see Section 2).

Scenario 6: Assuming a lower CF of nuclear power plants, while renewable technologies compensate the difference in power generation is slightly more expensive the Scenario 1 (+ \$1.2 billion). However, due to renewable generation, around 1.4 Mt of CO_2 can be mitigated compared to Scenario 1.

3.2. CO_2 savings

It was shown that all renewable scenarios lead to system costs savings. Subsequently, it is analyzed how CO_2 emissions are affected if these savings are invested into additional wind power capacities after 2050. It is assumed that these additional capacities substitute grid electricity with a specific CO_2 factor of 535 g-CO_2/kWh$_{el}$ [6]. Figure 4 illustrates the CO_2 savings of all scenarios compared with BAU with and without re-invest into wind capacities. CO_2 emissions w/o re-invest equal the numbers shown in Figure 3.
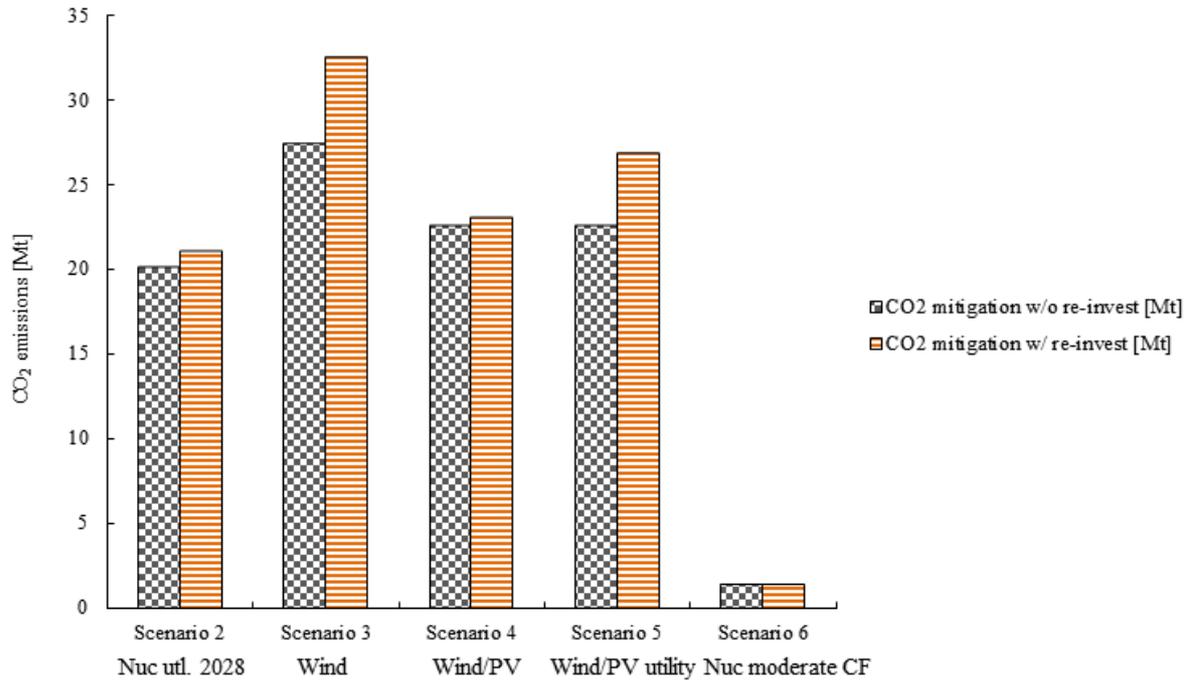
Figure 4: Comparison of CO_2 emission mitigation compared to BAU for each scenario with and without re-invest of the cost savings into additional wind capacities.

The figure shows that re-investing the cost savings into onshore wind can save up to 5.1 Mt of additional CO_2 emissions (compared with the scenarios w/o re-investments). There are no differences in CO_2 mitigation in Scenario 6 since the scenario does not result in any cost saving which could have been re-invested.

Table 1. Assumptions and results with respect to CO_2 emissions if cost savings are re-invested into further wind capacities.

Scenario	Savings [$ billion]	Add. wind cap. [GW][a]	Generation of add. caps [GWh/yr][b]	CO_2 mitig. w/ re-invest [Mt]	CO_2 mitig. w/o re-invest [Mt]	Add.CO_2 mitig.[Mt]
BAU	-	-	-	-	-	-
Nuc until 2028	1.4	0.8	1,776	20.1	19.2	0.9
Wind	7.9	4.4	9,710	27.4	22.3	5.1
Wind/PV	0.8	0.5	1,036	22.5	22.0	0.5
Wind/PV utility	6.6	3.7	8,105	22.5	18.3	4.3
Nuc moderate CF	-	-	-	1.4	1.4	-

[a] Assuming an onshore wind CF of 0.25 in 2050.
[b] Assuming a CAPEX for onshore wind of $1,787/kW based on [9].

4. Sensitivity analysis

The robustness of the results is tested against variations in the assumed discount rates and different capacity factors (CFs) for each of the five main scenarios. Variations in the CF for wind and PV foster a change in the required installed capacities of these technologies (as we require that PV and wind must always provide the same annual electric energy as nuclear, i.e. 16,330 GWh/yr). The assumptions are shown in Table 2.

Table 2. Overview of the sensitivity cases and their main assumptions.

Sub-scenario	Discount rate [%]		Capacity factor [-]		
Reference	4.5	[8], scenario HCLB	Wind:	0.25	Average CF 2013 [7]
			Utility PV:	0.21	Mean 2015 of CF Range [9]
			Rooftop PV:	0.17	Mean 2015 of CF Range [9]
CF low[a]	4.5	[8], scenario HCLB	Wind:	0.22	Scenario LCHB [8]
			Utility PV:	0.18	Scenario LCHB [8]
			Rooftop PV:	0.14	Scenario LCHB [8]
CF high[b]	4.5	[8], scenario HCLB	Wind:	0.33	Mean 2015 of CF Range [9]
			Utility PV:	0.21	Mean 2015 of CF Range [9]
			Rooftop PV:	0.18	Own assumption
Discount low	3.0	Own assumption	Wind:	0.25	Average CF 2013 [7]
			Utility PV:	0.21	Mean 2015 of CF Range [9]
			Rooftop PV:	0.17	Mean 2015 of CF Range [9]
Discount high	6.0	Own assumption	Wind:	0.25	Average CF 2013 [7]
			Utility PV:	0.21	Mean 2015 of CF Range [9]
			Rooftop PV:	0.17	Mean 2015 of CF Range [9]

[a] Due to the lower CF, the following changes in the required capacity occur (assuming 16,330 GWh/yr); wind: 8.4 GW, PV utility: 10.4 GW, PV rooftop: 13.3 GW.
[b] Due to the higher CF, the following changes in the required capacity occur (assuming 16,330 GWh/yr); wind: 5.6 GW, PV utility: 8.9 GW, PV rooftop: 10.4 GW.

The influence of the different CF assumptions on the overall costs is illustrated in Figure 5.
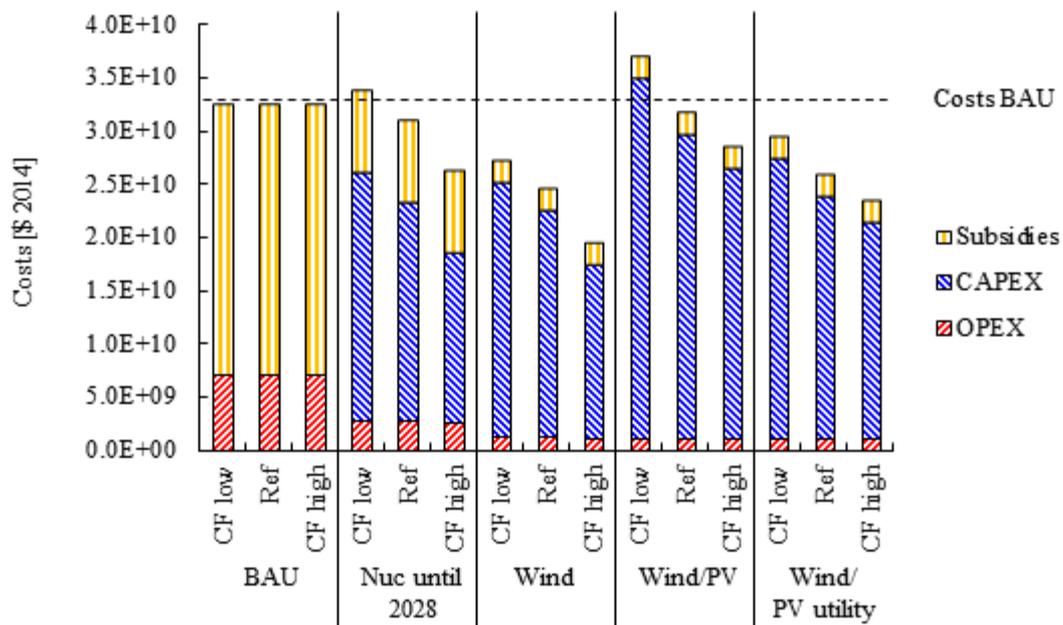

Figure 5: Comparison of the system costs of the four main scenarios with different capacity factors (CF) for wind and PV systems.

Figure 6 depicts the influence of the different discount rate assumptions on the overall costs.
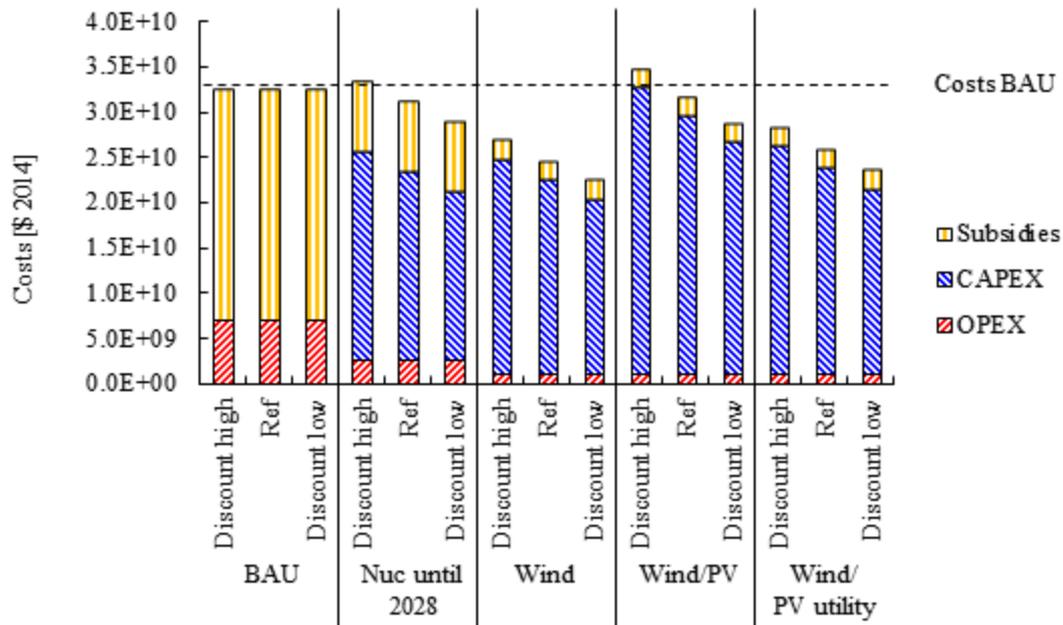
9

Figure 6: Comparison of the system costs of the four main scenarios with different discount rates for wind and PV systems.

Figure 5 and Figure 6 support that the key result that most of the renewable scenarios are cheaper than BAU. Only if assuming very low CFs or high discount rates, the scenarios 2 ("Nuc until 2028") and 4 ("Wind/PV") will be slightly more expensive than BAU. Yet, scenario 3 ("Wind") and 5 ("Wind/PV utility") will always be less expensive than BAU. It has to be emphasized that all renewable scenarios might be more cost beneficial than depicted in this analysis for the following reasons:

- It is assumed here that the investments of nuclear power plants are fully depreciated.
- We use rather high CFs for nuclear power (0.91 and 0.85 in Scenario 6). However, it is likely that the CF of nuclear will decrease even more with increasing penetration of renewable generation.
- All three nuclear power plants are rather old (Nine Mile: 1969, Fitzpatrick: 1976, Ginna: 1970) and require maintenance, replacement, or retrofit at some point. These costs are not included in the analysis at hand.

Appendix

1. Further assumptions

Projected fuel costs (see Figure A.1.) for uranium are based on [8]. $ 2012 are converted to $ 2014 via a price deflator ratio for electricity costs of 1.031. To conclude from $/MMBtu to $/MWh a heat rate of 10.48 MMBtu/MWh is assumed.
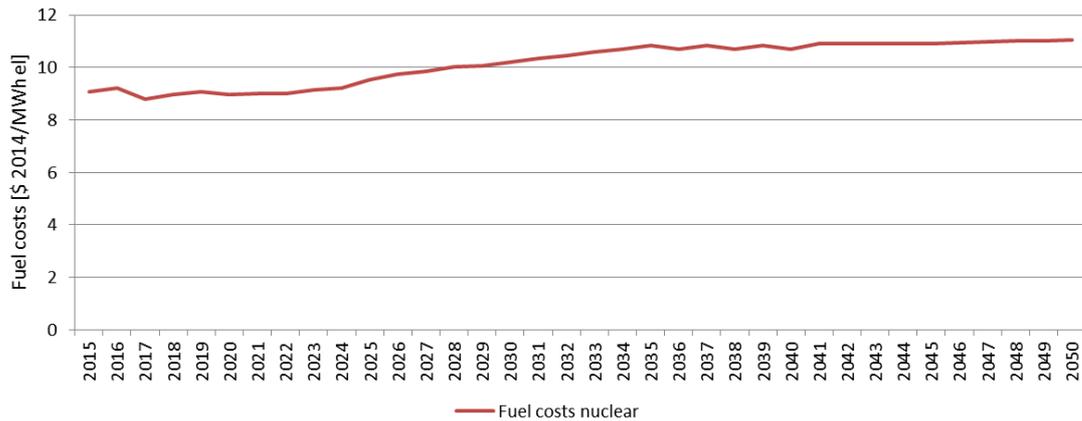

Figure A.1. Fuel cost projections for nuclear power plants.
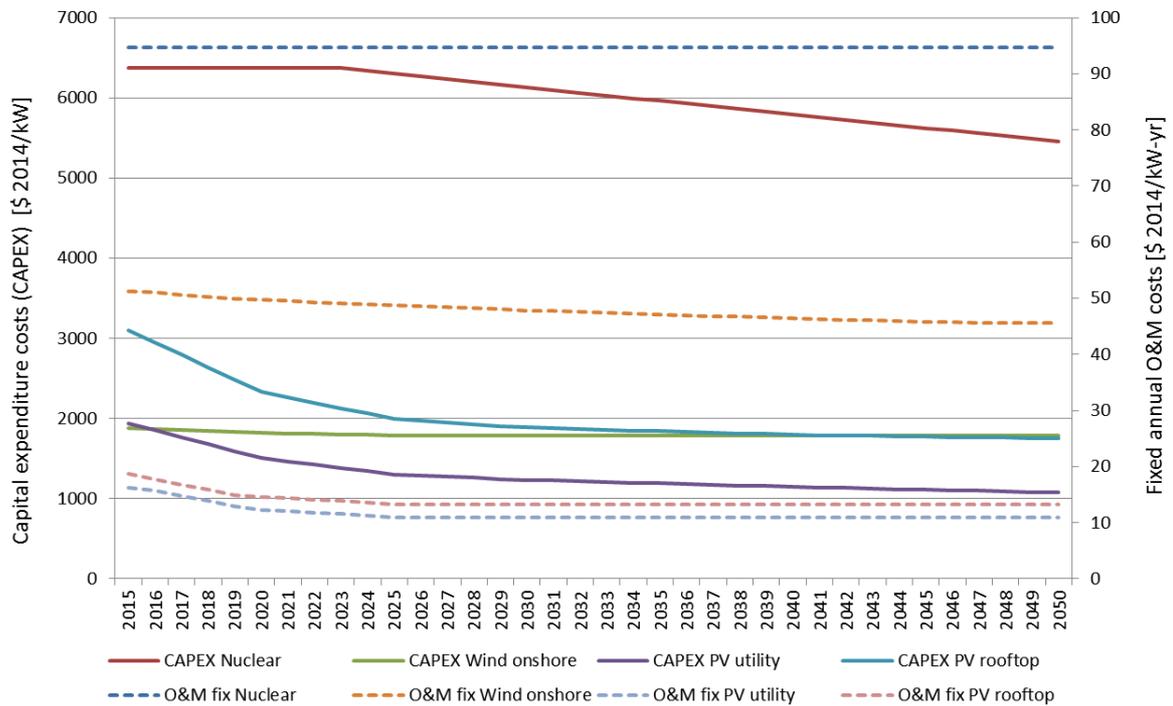
Figure A.2. Cost projections of capital expenditure costs (CAPEX) on the primary ordinate and of the fixed annual operation and maintenance costs (O&M) on the secondary ordinate. Values are based on [9].

Variable operation and maintenance costs for renewable systems (wind onshore, PV utility-scale, PV rooftop) are assumed to be zero; for nuclear power plants $2/MWh were used [9]. The projected fuel costs for nuclear power plants are based on [9].

Table A.1. Cost assumptions of subsidies for nuclear power.

Dates	Upper limit of ZEC [MWh/yr]	Adjusted social costs of carbon (SCC) [$/MWh]	Annual costs	Total costs
04/17 - 03/19	27,618,000	17.70	$488,838,600	$977,677,200
04/19 - 03/21	27,618,000	19.81	$547,112,580	$1,094,225,160
04/21 - 03/23	27,618,000	21.60	$596,548,800	$1,193,097,600
04/23 - 03/25	27,618,000	24.05	$664,212,900	$1,328,425,800
04/25 - 03/27	27,618,000	26.67	$736,572,060	$1,473,144,120
04/27 - 03/29	27,618,000	29.37	$811,140,660	$1,622,281,320
04/29 – 12/50	-[a]	-	$805,000,000	$17,710,000,000

[a] After 03/29 subsides must continue at a minimum rate of $805 million/yr until 2050

2. Detailed results

Table A. 1: Cumulated costs in $ 2014 from 2016 to 2050 of each of the main scenarios disaggregating into the different technology options and cost components.

	Invest. costs [$]	Fuel costs [$]	O&M$_{var}$ costs [$]	O&M$_{fix}$ costs [$]	Subsidies [$]
Scenario 1	-	$5,800,742,600	$1,240,263,500	$189,426,844	$25,887,689,800
Nuclear	-	$5,800,742,600	$1,240,263,500	$189,426,844	$25,887,689,800
Scenario 2	$13,369,721,461	$1,954,374,400	$460,669,300	$528,268,319	$8,177,689,800
Nuclear	-	$1,954,374,400	$460,669,300	$180,921,966	$8,177,689,800
Wind	$13,369,721,461	-	-	$347,346,353	-
Scenario 3	$13,809,662,100	$737,626,100	$177,180,500	$514,261,211	$2,560,740,960
Nuclear	-	$737,626,100	$177,180,500	$162,365,867	$2,560,740,960
Wind	$13,809,662,100	-	-	$351,895,344	-
Scenario 4	$18,487,396,793	$737,626,100	$177,180,500	$399,710,432	$2,560,740,960
Nuclear	-	$737,626,100	$177,180,500	$162,365,867	$2,560,740,960
PV rooftop	$7,656,743,554	-	-	$36,787,825	-
PV utility	$3,925,822,190	-	-	$24,609,069	-
Wind	$6,904,831,050	-	-	$175,947,672	-
Scenario 5	$14,756,475,429	$737,626,100	$177,180,500	$366,831,950	$2,560,740,960
Nuclear	-	$737,626,100	$177,180,500	$162,365,867	$2,560,740,960
PV utility	$7,851,644,379	-	-	$49,218,137	-
Wind	$6,904,831,050	-	-	$155,247,946	-
Scenario 6	$998,801,435	$5,486,482,741	$1,174,279,572	$202,425,326	$25,887,689,800
Nuclear	-	$5,486,482,741	$1,174,279,572	$189,426,844	$25,887,689,800
PV rooftop	$315,126,655	-	-	$2,014,733	-
PV utility	$255,102,530	-	-	$1,347,747	-
Wind	$428,572,250	-	-	$9,636,001	-

Table A.2. Detailed costs (in $ 2014) and CO_2 emissions for each main and sub-scenario. The CO_2 emissions for each sensitivity case do not differentiate, since technology specific, annual electricity generation is identical.

Scenario	Sub-scenario	OPEX [$]	CAPEX [$]	Subsidies [$]	CO_2 emissions [Mt]
Scenario 1	Reference	$7,041,308,249	-	$25,398,851,200	37
Scenario 2	Reference	$2,745,682,445	$20,556,252,732	$7,688,851,200	17
Scenario 3	Reference	$1,212,882,137	$21,232,671,534	$2,071,902,360	9
Scenario 4	Reference	$1,098,331,358	$28,424,795,681	$2,071,902,360	14
Scenario 5	Reference	$1,065,452,876	$22,688,418,697	$2,071,902,360	14
Scenario 6	Reference	$6,674,062,944	$1,535,680,065	$25,398,851,200	35
Scenario 1	CF low	$7,053,485,584	-	$25,398,851,200	37
Scenario 2	CF low	$2,800,417,890	$23,141,494,039	$7,688,851,200	17
Scenario 3	CF low	$1,265,733,750	$23,902,982,130	$2,071,902,360	9
Scenario 4	CF low	$1,142,205,958	$33,636,046,688	$2,071,902,360	14
Scenario 5	CF low	$1,103,524,617	$26,204,920,322	$2,071,902,360	14
Scenario 1	CF high	$7041,308,249	-	$25,398,851,200	37
Scenario 2	CF high	$2,665,525,594	$15,812,502,102	$7,688,851,200	17
Scenario 3	CF high	$1,131,675,519	$16,332,824,257	$2,071,902,360	9
Scenario 4	CF high	$1,055,684,281	$25,320,848,796	$2,071,902,360	14
Scenario 5	CF high	$1,030,349,315	$20,238,495,058	$2,071,902,360	14
Scenario 1	Discount low	$7,041,308,249	-	$25,398,851,200	37
Scenario 2	Discount low	$2,745,682,445	$18,489,735,161	$7,688,851,200	17
Scenario 3	Discount low	$1,212,882,137	$19,098,153,663	$2,071,902,360	9
Scenario 4	Discount low	$1,098,331,358	$25,567,254,450	$2,071,902,360	14
Scenario 5	Discount low	$1,066,392,630	$20,407,554,741	$2,071,902,360	14
Scenario 1	Discount high	$7,041,308,249	-	$25,398,851,200	37
Scenario 2	Discount high	$2,745,682,445	$22,761,382,426	$7,688,851,200	17
Scenario 3	Discount high	$1,212,882,137	$23,510,362,662	$2,071,902,360	9
Scenario 4	Discount high	$1,098,331,358	$31,474,007,122	$2,071,902,360	14
Scenario 5	Discount high	$1,066,392,630	$25,122,272,105	$2,071,902,360	14

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