3. Nuclear is Affordable, Reliable, Low Carbon and Safe

Key Points

- Nuclear energy can be considered as the *least cost* solution to achieve Net Zero.
- Nuclear energy requires the *least total capital investment* to achieve Net Zero.
- Nuclear energy is the *least intensive* form of low carbon generation in terms of land and materials consumption.
- Nuclear energy offers the *greatest* low carbon reliability (24/7 dispatchability) & security of supply.
- Nuclear energy offers a *safe* form of generation, which has been proven over almost 7 decades.
- Nuclear energy offers the most *sustainable* pathway toward 2050 Net Zero.

Nuclear energy may be considered controversial in some countries for a number of well-understood and respected reasons, which includes reasonable concerns ranging from safety, proliferation of nuclear technologies and security, nuclear waste storage and disposal issues as well as affordability and accessibility issues. Despite all reasonable concerns and criticisms concerning nuclear energy, nuclear indisputably offers one of the lowest life-cycle carbon emissions generation technologies, and which is also proven to be highly affordable, reliable, scalable and safe. In current market contexts, nuclear also offers nations with security of supply. All nations considering whether to utilize nuclear energy as part of their 2050 net zero strategies, must carefully weigh both the real and perceived risks versus the tangible and proven benefits of nuclear generation relative to all other means of achieving full decarbonization of their power generation sectors and broader net zero and economic sustainability policy initiatives.

In the SAG's view, there are currently only two sustainable low-carbon generation technologies that can currently be considered to be proven, technologically and commercial feasible, affordable, scalable and safe. These two competing low carbon generation technologies are renewables and nuclear. The two categories of renewables are *variable/intermittent* VRE technologies (mainly solar and wind) and *dispatchable* technologies (mainly hydroelectric, biomass and geothermal). All forms of nuclear generation are, of course, *dispatchable*. Given existing technologies, the foreseen incremental worldwide *dispatchable* renewable energy resources (mainly economically viable hydrological and geothermal resources) are limited, and therefore their scalability is also limited. On the other hand, VRE technologies are proven, scalable, technologically and commercially feasible and safe. However, as the percentage of VRE generation (VRE penetration) increases in any electricity market, the system-related costs also increase exponentially. Under low-carbon generation strategies in most countries, balancing the ratio of VRE relative to nuclear will have profound long-term cost implications. Strategies to increase the nuclear share of generation relative to VRE will provide countries with dramatically lower energy costs, which will catalyze rather than inhibit sustainable economic growth.

Analysis of the question as to whether nuclear energy should be considered as "safe and sustainable" from an environmental and social sustainability standpoint is most prominent in the ongoing debate within the European Commission (EC) as to whether nuclear power generation should be included in the European Union's "taxonomy for sustainable activities". Here the critical element of the debate is whether it can be determined that nuclear energy "does no significant harm" to humans and the environment. While the EC's Joint Research Center (JRC) issued their *'JRC Science for Policy Report - Technical assessment of nuclear energy with respect to the 'do no significant harm' criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation')'*[28], which concluded that nuclear energy "does no more significant harm" relative to other generation technologies, the conclusions of the JRC remain under review and the EC has heretodate not approved nuclear as part of the EU sustainable activities taxonomy.

While the decisions taken within the EU with respect to nuclear safety are closely followed internationally, and whatever final decision is undertaken with respect to EU taxonomy will have impacts on global financial markets, each nation and their own capital markets institutions will need to evaluate the questions related to whether the unique risks related nuclear safety, security and safeguards can be managed to the extent that the benefits of nuclear (clean, secure and dispatchable energy) are well worth the risks. Below in Section 3.4 we discuss nuclear safety issues in greater detail.

Another argument often presented by nuclear opponents is that nuclear energy is *not affordable* relative to other lower carbon generation options and therefore should not be considered, irrespective of whether nuclear risks can be managed. There are numerous flaws with this argument that we will address in detail in Section 3.1 below. While it is certainly always recommendable that each nation evaluate the least cost options (LCO's) available for their low carbon energy generation mix, it is essential that such evaluations include the 'whole picture' including factors such as: (a) the additional systemic grid and storage "system costs" related to intermittency and lower capacity factors (associated with a high penetration of VREs); (b) whole life-cycle costs and the cost of life-cycle carbon emissions[29]; (c) opportunity costs of land consumption and materials intensities, energy feedstocks (such as changing hydrological systems due to climate change and silting and cost and sustainability of production and diversion of biomass feedstocks away from food and other sustainable materials production and regenerative agricultural practices) required for many renewable generation technologies; and, (d) costs related to the uncertainty of future technological developments (such

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[28] Source: [18]. JRC's conclusions have subsequently been independently reviewed and commented on by two independent groups: The Scientific Committee on Health, Environmental and Emerging Risks (SCHEER) and the Group of Experts referred to in Article 31 of the Euratom Treaty on June 29th and June 20th, 2021 respectively. A coalition of EU states (AT, DE, DK, LU, ES) also subsequently submitted a letter to the EC urging the Commissioners not to approve nuclear in the taxonomy, based mainly on nuclear safety concerns.

[29] Including the relevant construction, production, operation and decommissioning value chains relating to each generation technology.

as energy densities and costs of long-duration grid-scale battery storage, emerging grid and CCUS technologies).

Finally, an argument also used by many nuclear critics is that nuclear is not yet a *proven* technology. This is obviously entirely false, as the nuclear fission-based power generation technologies are proven, mature and have been in continuous existing large-scale commercial operations for almost seven (7) decades. This argument has emerged, and has been propagated by certain interested parties, based on the thinking that current nuclear generation technology and business models (e.g. conventional large reactor technologies) are no longer viable and should not be considered. Proponents of this line of reasoning often convey that next generation (generation IV) advanced reactors and small modular reactor designs are “just around the corner” and once commercially proven that these new technologies will solve most of the perceived “problems” (ranging from nuclear safety, anti-proliferation, high-level radioactive waste, etc.) inherent with existing nuclear reactor designs. Many of these emerging nuclear technologies are indeed very promising and in due course, may provide numerous enhancements, increased flexibility, applicability and adaptability relative to current proven generation III/III+ reactor technologies. However, these new technologies may realistically take years or even decades to emerge as proven, technically and commercially viable and affordable technologies that can be deployed globally, at scale.

While IBNI will strongly support (both directly and indirectly) the development and demonstration of these new and innovative nuclear technologies, the Bank’s immediate focus must be with respect to supporting its member states who are pursuing the rapid implementation, deployment and scaling of existing and proven nuclear technologies (such as generation III and III+ reactor designs). The climate crisis requires nothing short of immediate action and the nations of the world cannot wait decades or even years for new and promising technologies to emerge. However, when they do, IBNI will be there to support their widespread global deployment. The immediate focus must be on implementing existing and proven low-carbon generation technologies which are ready to be deployed today.

3.1 Nuclear as a Least Cost Low Carbon Generation Technology

Full and rapid decarbonization of the power generation sector is the primary underlying element of any 2050 net zero pathway scenario. However, achieving this objective will most likely not be possible, at the required global scale, in the case that significant increased energy costs are required to achieve such decarbonization. Access to affordable energy is fundamental to all modern societies. United Nations Sustainable Development Goal 7[30] asserts that all nations should have “access to affordable, reliable, sustainable and modern energy for all”. Worldwide expenditures on energy already accounts for approximately 8% of aggregate gross national product[31]. Therefore, any material increased costs of energy (and increasingly significant component will be the cost of electrical energy *and electricity-derived energies such as hydrogen and electrofuels*, as the world’s energy systems are projected to become significantly more electricity intensive)

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[30] https://sustainabledevelopment.un.org/content/documents/195532018_background_notes_SDG_7Final1.pdf

[31] Source [20] - pg. 24.

will have a profound and predictably negative impact on global economic development and quality of life. If the world is to continue on its current trajectory towards global population growth, robust global economic development, poverty eradication and sustained improvements in quality of lives of all human beings, then *low carbon* energy (and particularly, electricity) must be made available at the *least possible cost*. The "clean premiums" or "clean spreads" of low carbon forms of generation must be minimized and preferably negated relative to the cost of carbon intensive forms of fossil fuels generation technologies (*before* any carbon pricing is considered). Therefore, in the drive to achieve global 2050 net zero, it is abundantly clear that the world must not consider *affordability and cost minimization* of decarbonization as an afterthought, but rather as a central aim of any net zero pathway option.

While each nation of the world will need to make its own long-term policy decisions as to what level of decarbonization costs its future generations should be willing to bear, the SAG is very concerned that extremely high levels of VRE penetration (such as the 2050 worldwide VRE penetration of ca. 70% set forth in IEA's 2050 NZE pathway scenario) may lead to unsustainably high-cost burdens upon society in increasingly electricity-intensive world market environments. Such high-cost burdens related to decarbonization of the power sector will not only directly impede global economic development and industrialization objectives, but it will also promote significant resistance to increased electrification of other sectors, such as industry, transportation and the built environment and transition to hydrogen and electrofuels adaptations. Significant global-scale electrification targets will only be possible if the cost of electricity (and derived hydrogen and electrofuels) are cost-competitive with current carbon-intensive energy resources.

Although it may be technically possible for a very limited number of the world's wealthiest nations' future generations to bear the "luxury" cost of very high VRE penetration rates (presumably with their populations and industries subscribing to the argument that these significant additional costs are worthwhile in order to achieve decarbonization objectives while also avoiding the perceived risks of nuclear power), it is predictable that the vast majority of both advanced/industrialized countries and in particular the lower income and developing countries will reject such cost-intensive high-VRE penetration scenarios, which would significantly inhibit their economic development, increased quality of life and global competitiveness objectives.

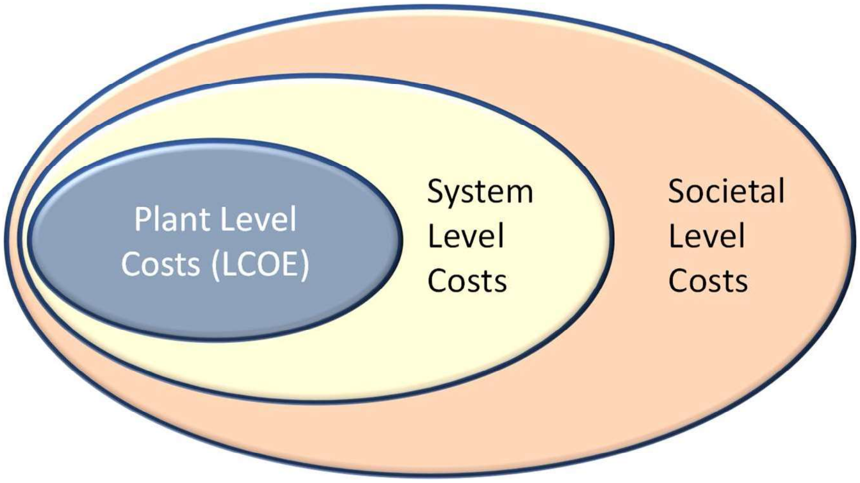
Evaluating Nuclear and Renewables Using Value-Adjusted Levelized Cost of Electricity (VALCOE)

As discussed above, amongst the other common criticisms facing nuclear energy is that it is *too expensive*, and therefore results in less affordable power generation costs relative to other competing low-carbon generation technologies. Unfortunately, this affordability argument is often used by nuclear critics to dismiss nuclear generation's role as the potential principal net zero pathway option, even before the technology's merits and risks can be properly considered and debated. The underlying affordability arguments are often based on the erroneously comparison of only the "plant level costs" of different generation technologies such as nuclear to VRE, using the *levelized unit cost of electricity (LCOE)* methodologies (which is an appropriate cost metric only for comparing one baseload generation technology to another).

It is certainly true that the "plant level" costs of some competing low carbon generation technologies such as VRE technologies (in particular PV solar and wind generation) have drastically decreased in recent years and decades and may very well continue to decrease further. This has resulted in median plant level whole life VRE generation costs (as measured by LCOE) that can now be shown to be as low or in some cases even lower than median nuclear and unabated fossil fuels plant level costs. However, this is far from the 'whole picture' with respect to true cost of VRE generation technologies. Recent studies, including those by the IEA and Massachusetts Institute of Technology (MIT)[32] have clearly demonstrated that the costs of increasingly high VRE penetration in power markets results in the directly correlated exponential increase in energy grid-related "systems costs". These "system costs" are real and tangible increased costs borne by the public (e.g. utility rate payers and/or to taxpayers, via subsidies).

For the proper evaluation the true comparative costs of VRE vs. dispatchable generation technologies, energy economists have devised a methodology called Value Adjusted Levelized Cost of Energy (VALCOE). VALCOE considers the "plant level", "system level" and "societal level" cost categories of different forms of generation. Therefore, when policymakers consider their least cost generation options available to achieve decarbonization objectives, VALCOE should be applied in order to more effectively compare the disproportionately higher "system costs" associated with VRE. The figure below illustrates the three levels of costs included in the VALCOE metric.

FIGURE 8 - COMPONENTS OF VALCOE GENERATION COST METHODOLOGY



Source: [19].

The three primary categories of costs relating to the provision of electricity are defined by IEA to be the following:

- **Plant Level Costs (LCOE).** "The LCOE indicates the discounted lifetime costs for different baseload technologies, averaged over the electricity generated. It has its purpose for informing the investment

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[32] Sources: [14], [19], [20] & [21].

choices of electric utilities in regulated electricity systems, but it is less pertinent in deregulated electricity systems where revenues vary from period to period over an electricity generator's lifetime. LCOE is also unable to capture the system costs of certain technologies [such as intermittent VRE]"[33].

- **System Level Costs.** The system level costs are incremental grid-related costs attributable to a particular type of generation technology. In particular, high percentages of VRE penetration within the electrical grid can result in escalating grid related system levels costs. These grid-related costs can be further allocated across the following categories:
  - **Profile (Utilization) Costs.** Profile or utilization costs relate to the variability or intermittency of a generation technology such as VRE (such as solar and wind generation), whereby the higher the VRE penetration, the greater the cost for providing the residual load during periods of time when VRE sources are not sufficiently producing.
  - **Balancing Costs.** Balancing costs are related to the uncertainty of power production due to unforeseen outages or to forecasting errors that require a more significant level of spinning reserves. Uncertainties in VRE power production often leads to an increase in ramping and cycling of other dispatchable power plants on the grid, and to inefficiencies in plant scheduling and, overall, to higher costs for the system.
  - **Transmission and Distribution (T&D) Costs.** T&D costs include the incremental costs related to the transmission and distribution grid infrastructure due to the locational constraint of generation plants. While all generation plants have some siting restrictions (including nuclear plants), the impacts are more significant for VRE. Because of their geographic location constraint, it is often necessary to build new transmission lines or to increase the capacity of existing infrastructure (grid reinforcement) in order to transport the electricity from centers of production to load demand centers. High shares of VRE may also necessitate greater interconnectivity with adjacent grid systems. Also, high shares of distributed PV resources may require significant investment into the distribution network, in particular to allow the inflow of electricity from the producer to the grid when the electricity generated exceeds demand.
  - **Connection Costs.** Connection costs are the costs of connecting the power plant to the nearest connecting point of the transmission grid. These costs can also be significant, especially if distant and dispersed generating resources have to be connected, as is sometimes the case for offshore wind farms. Also, in the case of very high VRE penetration, wind and solar plants may need to be located in more remote locations and at increasingly greater distances from established grid infrastructure and energy demand centers, which further increases connection costs.
- **Societal Costs.** Societal costs (also known as externalities) include all other indirect societal costs related to the provision of electricity by a certain type of generation technology. These other cost elements may include costs related to the following:

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[33] Source: [19] – pg. 16.

- **Climate Change Costs.** As discussed earlier, fossil fuels-based power generation has been a major source of CO_2 emissions, which is a primary GHG (accounting for approximately27% of annual total GHG emissions). Low carbon generation technologies such as renewables and nuclear generation technologies are also responsible for small quantities of CO_2-eq. emissions, typically through their whole "life cycle" including materials, production, construction, operations, fuel cycle, decommissioning and dismantling phases. Many economists debate what is the optimal societal carbon price that should be charged to carbon-intensive industries such as fossil fuels generation plants. In the IEA's *Projected Cost of Generating Electricity (2020)*, a flat carbon price of US $ 30/tCO_2 is included in the LCOE calculations[34]. We have maintained this as our baseline assumption in our own analysis in this report.
- **Pollution Costs.** Quantifiable pollution costs are costs related to the probability of human mortality, human morbidity, environmental and ecological issues associated with atmospheric air, water and soil pollution (in additional to GHG emissions). Fossil fuels used in the power generation sector have been a major source of air pollution including sulphur oxides (SO_x), nitrogen oxides (NO_x), ozone (O_3), volatile organic compounds (VOCs), heavy metals and other particulate matter ($PM_{2.5}$ and PM_{10}) air emissions. In addition to emissions of CO_2 from fuel combustion in gas-fired power plants, the process of extracting natural gas also releases significant quantities of "fugitive gas" emissions, mainly comprised of methane (CH_4) which is another GHG with 25 times the greenhouse effect in comparison to CO_2. The process of extraction, processing and transport of fuels (including coal, gas, oil and uranium[35]) as well as raw materials used in manufacturing and construction of various generation technologies, including concrete, steel, glass, silicon, copper, nickel, lithium, cobalt, lead, silver, neodymium, terbium, indium, dysprosium, and praseodymium and other 'rare earth' metals are each energy-, land- and GHG-intensive in their extraction and processing phases and pose numerous pollution risks. The respective value chains related to each of these fuels and materials can also lead to significant prospects for additional air, water and soil pollution (including the potential discharge of toxins such as mercury, barium, chromium, and cadmium into soil and water resources), resource depletion, increased cost and cost volatility and social issues (such as those related to "conflict minerals"). In addition to producing virtually no emissions during operations, nuclear generation provides amongst the lowest ratios of fuel, materials and land inputs relative to energy outputs. In comparison to nuclear, VRE technologies require significantly higher inputs of raw materials in their production processes relative to life-cycle energy outputs. VRE technologies such as

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[34] Source: [21] – pg. 39.

[35] The entire nuclear fuel cycle (including mining, milling, conversion, enrichment, fabrication, recycling, storage, transport and disposal) represents one of the world's most highly regulated industries. In comparison with the fuel and materials value chains related to other forms of generation, the comparatively high level of concentration, multilateral oversight and regulation of the entire nuclear fuel cycle tends to limit the risk of detrimental environmental, human and social issues.

depleted PV solar panels also contain significant amounts of toxic materials, such as cadmium, lead and mercury and other toxins, which can be a source of further pollution within their life cycles (if not dismantled and recycled properly, which must be considered as a part of their decommissioning costs). All thermal power plants (including nuclear and fossil fuels) can also produce unacceptably high amounts of waste heat pollution from their cooling water discharge. Waste heat must be economically utilized and managed for all categories of thermal power plants (including solar). Each type of pollution can be quantified based on probabilistic mortality and morbity costs to humans, animals and other impacts on the environment.

- **Major Accident Costs.** All generation technologies pose some level of risk for major accidents impacting humans and the environment. Risks of major accidents emanate from the entire value chains for each generation technology. Operating nuclear[36] and hydroelectric plant specific accidents can be extremely severe within a localized area or region, but such major accidents are extremely rare and infrequent and are therefore responsible for far fewer deaths, injuries and environmental contamination issues than other forms of generation on a per kWh basis. The comparatively higher frequency and human and environmental cost of major accidents related to coal and gas production and processing activities, as well as with raw materials extraction throughout the more resource-intensive value chains of both fossil fuels and renewables generation technologies renders these technologies also susceptible to major accident costs, which in most cases, has not been fully accounted for in their generation tariffs. Based on the probability and consequential losses, the expected value costs of each type of major accident can be quantified.
- **Costs of Land Use Change and Natural Resource Depletion.** Different forms of generation technologies have profoundly different impacts on land use requirements, ecosystem and biodiversity impacts and depletion of non-renewable resources and competition for renewable resources (such as biomass and hydrological resources). Because of their significantly lower capacity factors and intermittency, in comparison to most dispatchable technologies VRE generation technologies (predominantly PV solar and wind generation) consume vastly more quantities of land and resources for generation facilities[37] in order to

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[36] It should be further noted that in accordance with existing international accords, nuclear power plant operators must maintain requisite amounts of nuclear accident liability insurance from multinational insurance pools. Therefore, unlike other forms of generation, the quantifiable social costs of potential nuclear accidents are already largely included in the generating cost of nuclear power.

[37] While wind farms consume significant amounts of land and aquatic resources, they can allow for certain simultaneous land and aquatic uses (mainly agriculture in the case of land and fishery and shipping in the case of aquatic resources) to continue throughout their operations. Wind farms and their related T&D infrastructure may be incompatible with and may pose severe limitations on other forms of non-agricultural land-uses, such as residential and commercial development and recreation (which may also impact land values, tax revenue, quality of life, social and public policy issues). PV solar can be installed within the built environment, on rooftops, over transportation infrastructure, etc. However, both CSP and increasingly PV solar compete with other land uses,

generate each unit of electrical output. These technologies also consume additional amounts of land and resources required for incremental grid infrastructure and energy storage, which should also be fully accounted for. Both PV solar and wind are also very material-intensive, as they each require significant quantities of land for raw materials mining and processing necessary in their production and supply chains. Nuclear generation is amongst the least land and materials-intensive form of generation[38], which results in the minimal use of land and non-renewable resource inputs per kWh of energy production output. Fossil fuels generation plants require significantly more quantities of land for fuel (coal, oil and gas) extraction, processing and transporting than nuclear plants require for the entire nuclear fuel cycle. Hydroelectric resources can compete for both land and watershed resources, and may have related negative biodiversity, environmental and ecological consequences. Biomass generation can compete against agricultural land used for food production (for humans and animals) as well as alternative uses of the biomass energy feedstocks (such as for building materials, soil regeneration and other uses). Each of these items has a cost, which is challenging to quantity as there is a wide range of variability with respect to local land costs, resource costs and value for alternative uses of land and resources.

While the four categories above describe the relative "societal level costs" related to the various forms of electricity generation, no analysis would be complete without also considering the "societal level *benefits*" of each technology. Societal level benefits may include elements such as: security of supply of energy generation; direct, indirect and induced employment; local and regional industrial and economic development; taxation revenue; reduction of health care costs; innovation; research & development; and other societal level benefits. Existing research on the comparative societal level benefits of generation technologies has largely focused on comparative labor and economic-related benefits. With respect to labor-related aspects, nuclear compares quite well to other technologies in that it creates significant numbers of well-paying jobs during both the construction and operations phases of NPPs.

Based on current available research and electricity grid system models, the estimated system level costs related to any specific generation technologies varies significantly between non-dispatchable technologies, such as VRE relative to dispatchable technologies such as nuclear, hydro, biomass and fossil fuels. The major distinction between technologies is that as the total penetration (percentage of total generation mix) increases for intermittent VRE technologies, the estimated system costs tend to increase disproportionately. Conversely, as dispatchable generation sources increase in total penetration (percentage of total generation mix), the system costs remain relatively constant or slightly decrease. Figure 9 below illustrates a

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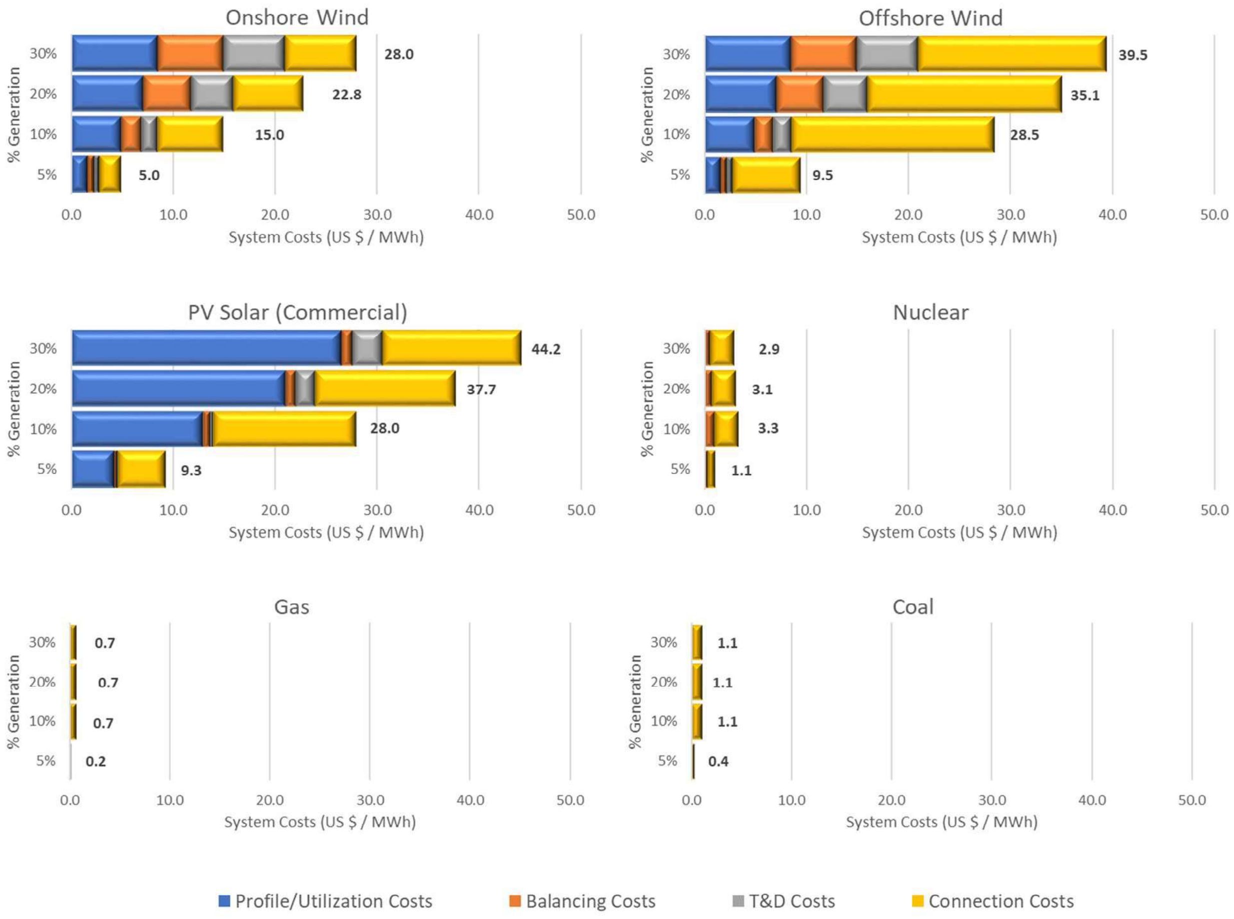
when installed outside of the built environment, which is often a motivation in order to benefit from lower land access costs and alleviate public resistance such as the "not in my backyard" phenomenon. As renewable energy penetration is ramped-up to higher percentages, the potential pressures for competitive land, agriculture, water and resource-related conflicts and costs will also become increasingly more intensified.

[38] Source: [31] – Slide 18, Figure 22.

comparative analysis of the various VRE related estimated incremental system costs relative to those estimated for dispatchable generation technologies.

FIGURE 9 - ESTIMATED INCREMENTAL SYSTEM COSTS RELATED TO VRE AND DISPATCHABLE GENERATION TECHNOLOGIES

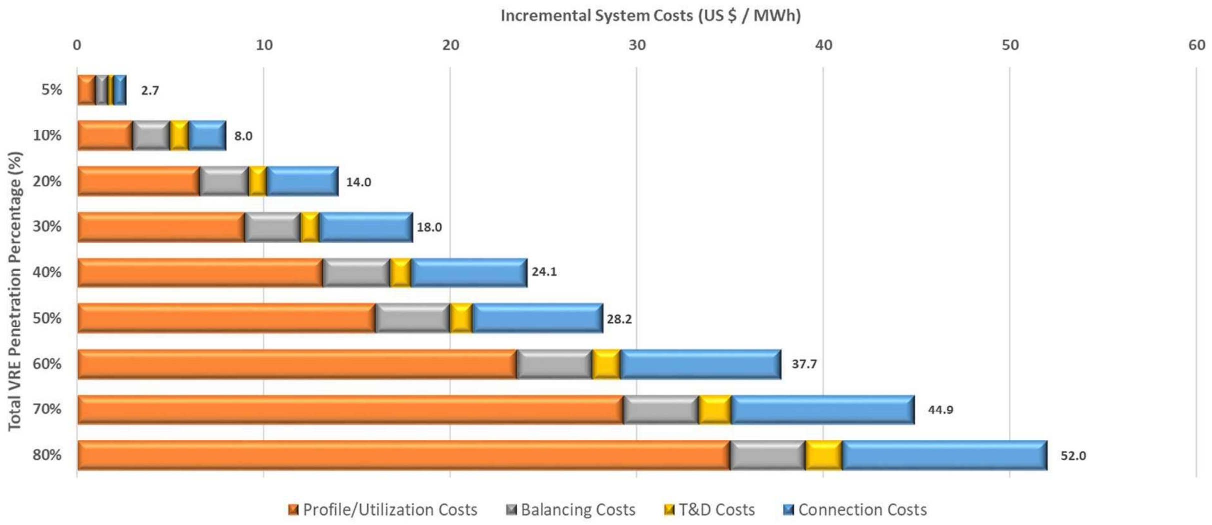


Data Source: [14] (data adapted). System costs related to 5% and 20% penetration levels have been interpolated based on referenced data sets available.

It is noted and acknowledged that potential technological and commercial advances in energy storage technologies (including grid-scale long-term battery storage; hydrogen and electrofuels production, transport and storage; thermal heat and compressed gases production and storage; and similar related technologies), together with emerging grid technologies and energy demand management may serve to reduce the current estimated system level cost gaps between VRE and dispatchable generation technologies. However, the SAG maintains the view that it is highly unlikely that the very significant "system level" cost gaps will be fully closed for high levels of VRE penetration. The world should not depend on unproven and speculative technological breakthroughs. Policymakers are well advised to rely on current proven technologies and associated costs and adapt their strategies, if and when new low carbon technologies emerge as commercially feasible options.

Figure 10 below illustrates the estimated total system costs (additional electricity cost burden on the public) related to increasingly higher VRE penetration rates (percentage of the total generation mix).

FIGURE 10 - ESTIMATED TOTAL INCREMENTAL SYSTEM COSTS ASSOCIATED WITH INCREASED VRE PENETRATION RATES



Data Source: [19] (data adapted). System costs related to 5%, 20%, 60%, 70% and 80% VRE penetration levels have been interpolated based on referenced data sets available.

Clearly as VRE generation shares (dominated by wind and solar) reach significantly higher percentages of the overall generation mix in a market, the total system level costs and the overall energy cost burden to the public tend to escalate significantly. As it relates to the overall strategy of decarbonization of the energy sector in an affordable and economically sustainable manner, policymakers are well advised to consider optimizing the balance of VRE with all other available *dispatchable* low carbon generation technologies, such as nuclear, hydro, geothermal and biomass.

SAG's review of existing economic studies related to "societal level costs" for various forms of electricity generation technologies has determined that this is still an area of research in its very early stages. However, across all studies that we have reviewed[39], the most prominent component of "societal level costs" is the climate change impact (e.g. GHG emissions) component. We therefore regard whole life-cycle carbon cost of each generation option as the main "societal level cost" that should be analyzed. As discussed above, there is significant debate amongst economists as to what is the most appropriate price for carbon emissions, which would fully compensate society for future damages relating to climate change. While we accept the IEA's carbon price assumption of US $ 30 / tCO_2, we have also analyzed higher carbon pricing including US $ 65 / tCO_2 and US $ 100 / tCO_2 carbon pricing levels. Based our conclusion that existing research on non-

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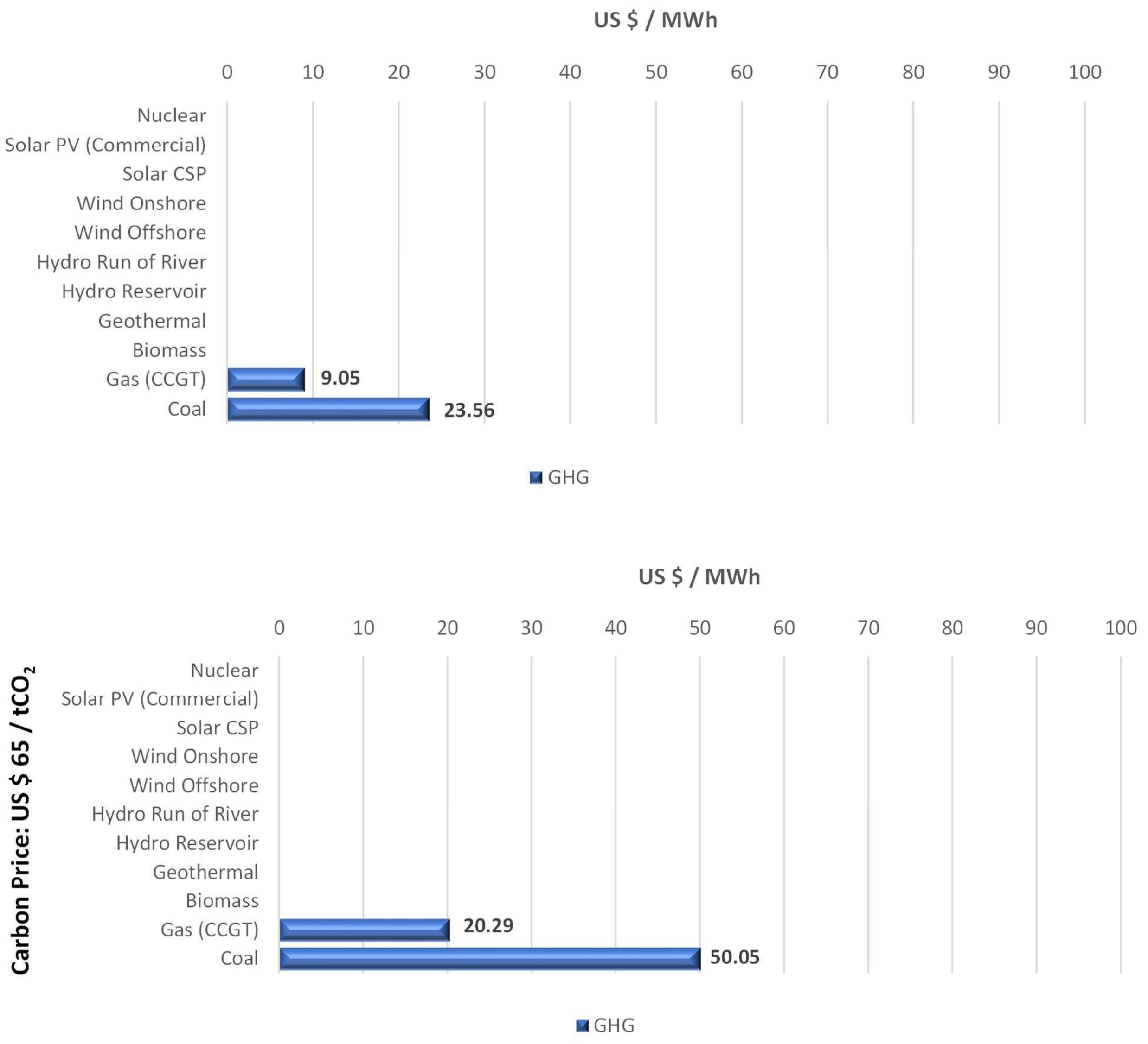
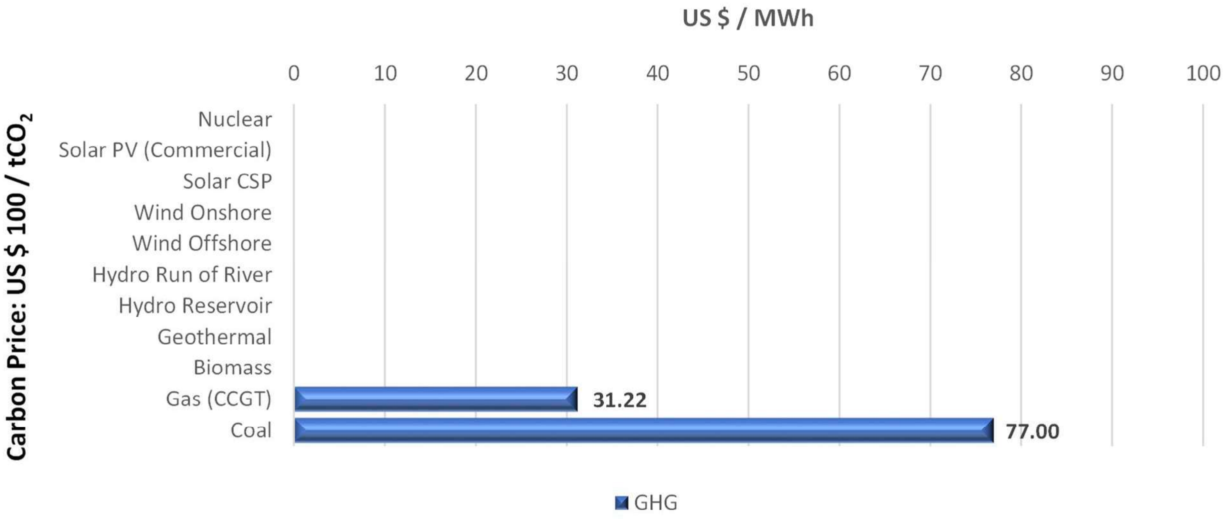
[39] Source: [19] & [22]

climate change components of “societal level costs” are inconclusive, we represent the data extracted from existing studies as a wide range in the component “non-GHG societal costs”.

The following charts in Figure 11 illustrate our analysis of the “societal level costs” related the climate change impact (CO_2 pricing) at various carbon pricing levels.

FIGURE 11 - CLIMATE CHANGE COSTS BASED ON VARIOUS CARBON PRICING LEVELS

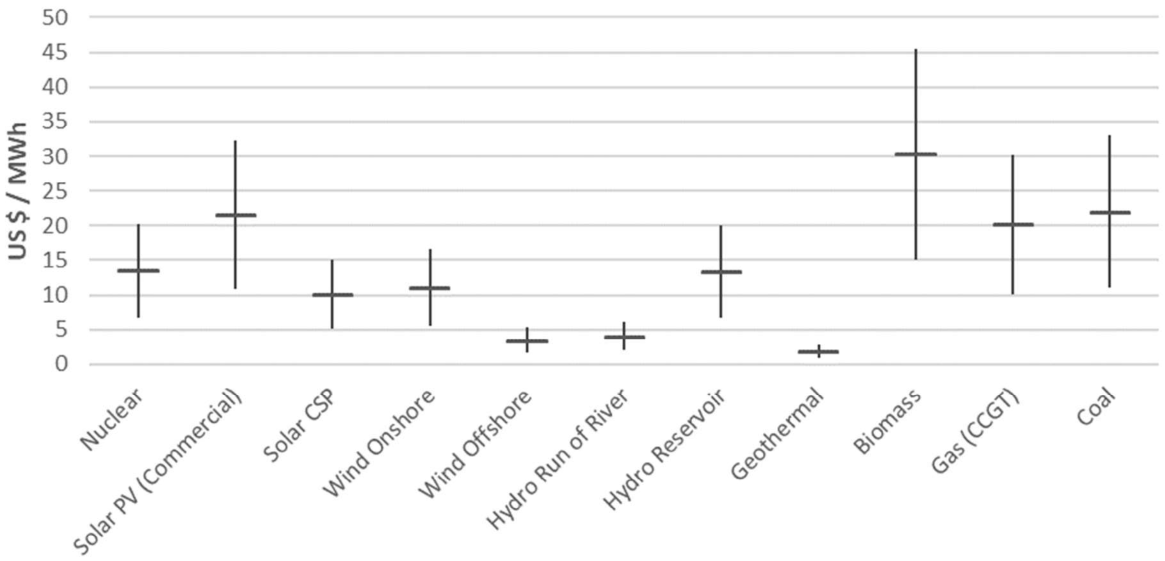




Data Source: [23] – Table A.III.2 - pg. 1335 (data adapted). Note that all low-carbon technologies each produce low median levels of GHG emissions on a life-cycle basis (typically associated with their production and supply chains, construction, O&M and decommissioning activities). See Section 3.4 below. However, over the whole life energy outputs, the GHG emissions of each of these technologies result in a de minimis unit cost, which is indiscernible.

Given the current status of the research related to non-GHG related “societal level costs” do not reflect any widely accepted consensus views on the global median levels of these costs, the chart below in Figure 12 illustrates the potential indicative ranges of these “societal level costs” based on the best available current research and data available.

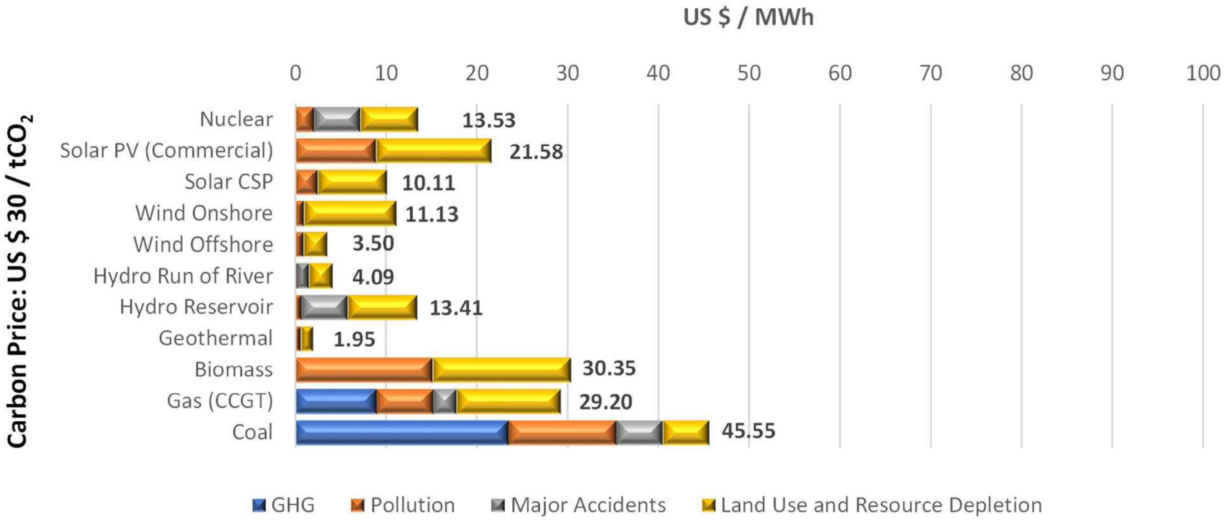
FIGURE 12 - INDICATIVE RANGES OF ADDITIONAL NON-GHG SOCIETAL LEVEL GENERATION COSTS FOR VARIOUS TECHNOLOGIES

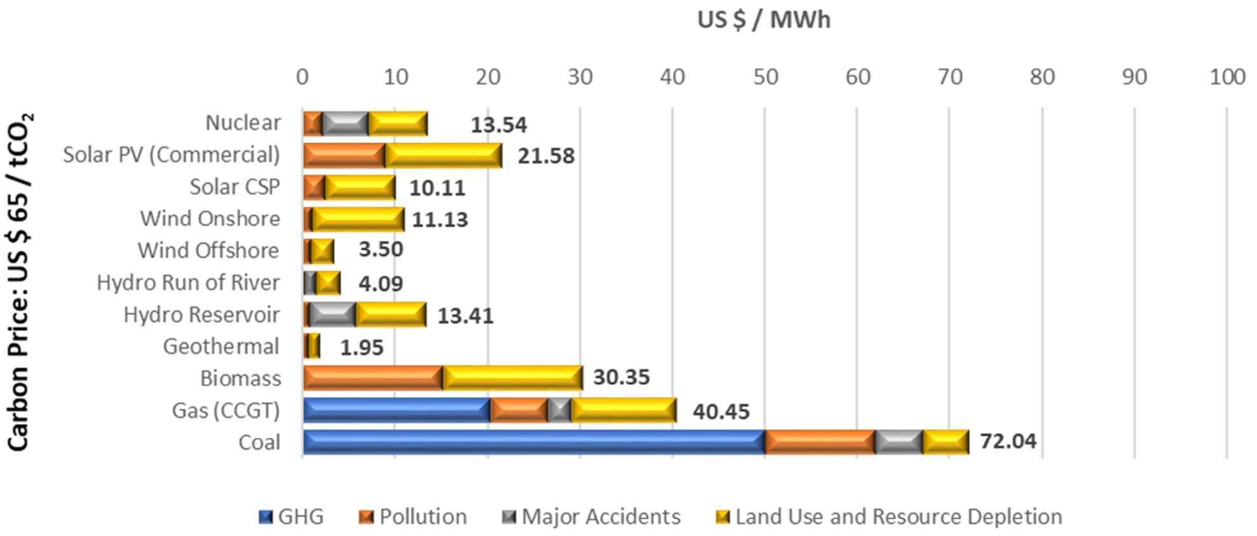


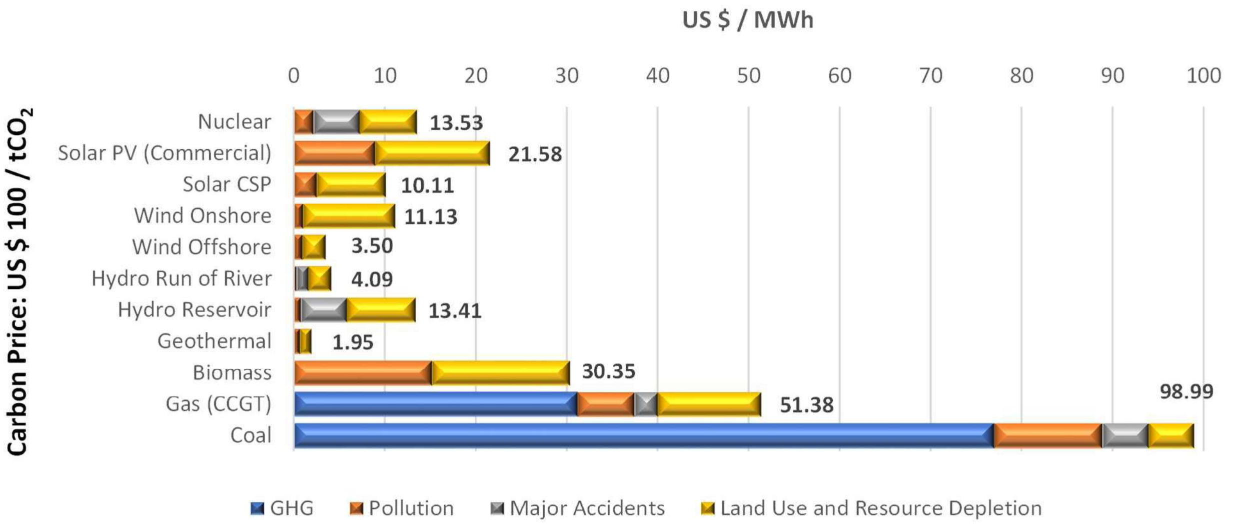
Data Sources: [19] & [22] (data adapted). Vertical bars represent the indicative ranges for non-GHG related societal costs. Horizontal bars represent the indicative midpoints for non-GHG related societal costs.

Figure 13 below illustrates the effects of combining both climate change (GHG-related) and non-GHG related societal costs, when various levels of carbon pricing are taken into consideration.

FIGURE 13 - INDICATIVE LEVELS OF TOTAL SOCIETAL COSTS RELATED TO VARIOUS GENERATION TECHNOLOGIES



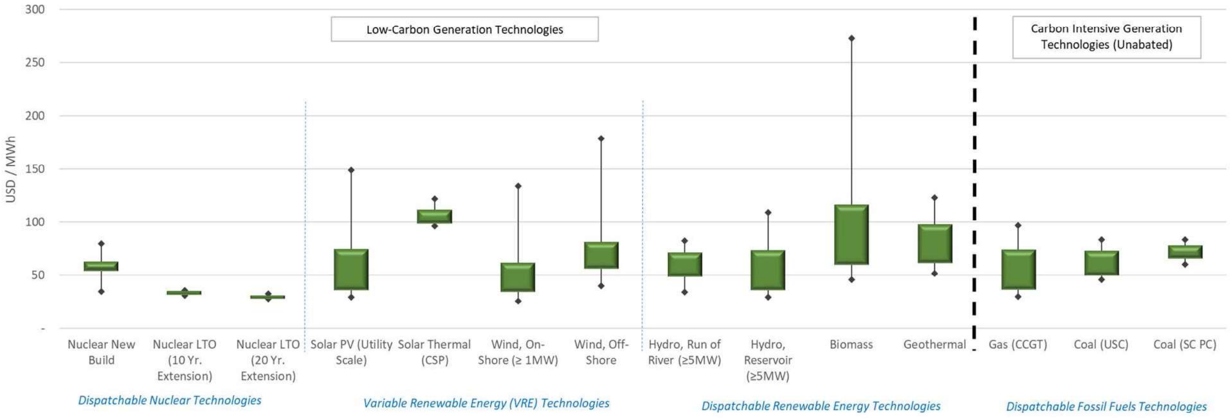




Data Sources: [19], [22] & [23] – (data adapted).

Based on the above methodologies and available source data, SAG has conducted an independent VALCOE assessment of the total costs of nuclear generation relative to VRE (non-dispatchable) and dispatchable renewable generation technologies as well as fossil fuels. We have not included any comparison to CCUS technologies as these technologies are currently largely unproven from both a technical and commercial standpoint. From this VALCOE comparative analysis, we have then derived the comparative "clean premia" or "clean spreads" relative to unabated fossil fuel generation (before including carbon pricing).

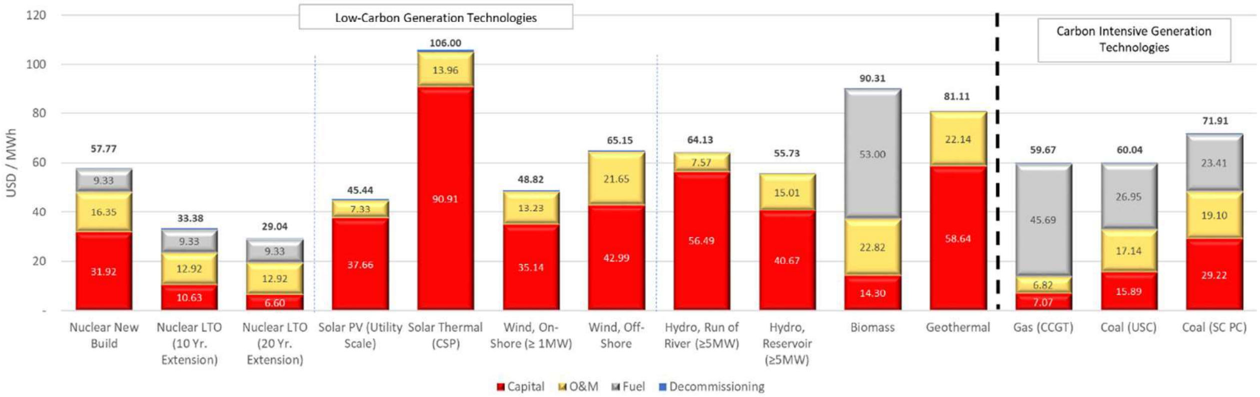
FIGURE 14 - COMPARATIVE WHOLE LIFE PLANT LEVEL COSTS (LCOE) NOT INCLUDING CARBON COSTS



Data Source: [21] (data adapted). Green boxes indicate +/- 50% of the global data cases above or below the global medians. Whisker lines and end points indicate global outlier cases outside the +/- 50% range for each technology. Assumes 5.0% median cost of capital across all generation technologies.

The above chart indicates that based on global median data, nuclear generation (plant level LCOE costs) already offers amongst the least cost generation technologies compared across both competing low -carbon generation technologies as well as fossil fuel generation technologies. This is before even considering the additional system level and societal level costs. The below chart illustrates the composition of the comparative global median plant level LCOE costs for the various technologies.

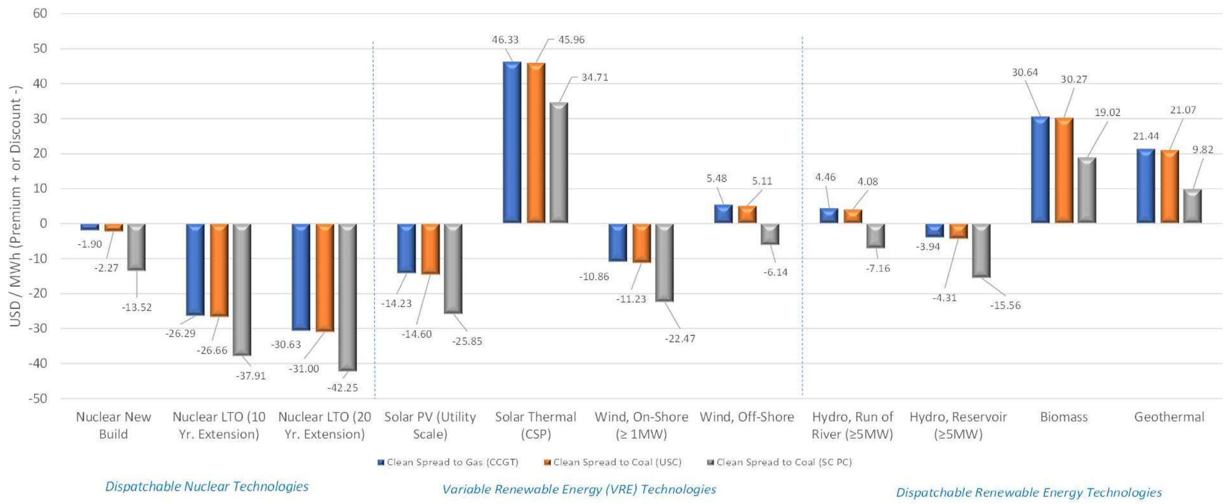
FIGURE 15 - COMPOSITIONS OF GLOBAL MEDIAN WHOLE LIFE PLANT LEVEL (LCOE) COSTS FOR ALTERNATIVE GENERATION TECHNOLOGIES, WITHOUT CARBON PRICING



Data Source: [21] (data adapted). Assumes 5.0% median cost of capital across all generation technologies. Capital costs include capital invested and return on capital invested.

The global median "clean spreads" of all forms of nuclear generation are shown to be negative relative to unabated gas and coal generation technologies, before considering either carbon pricing or "system level costs". The following chart illustrates the comparative low carbon "clean spreads" prior to carbon price and system level costs.

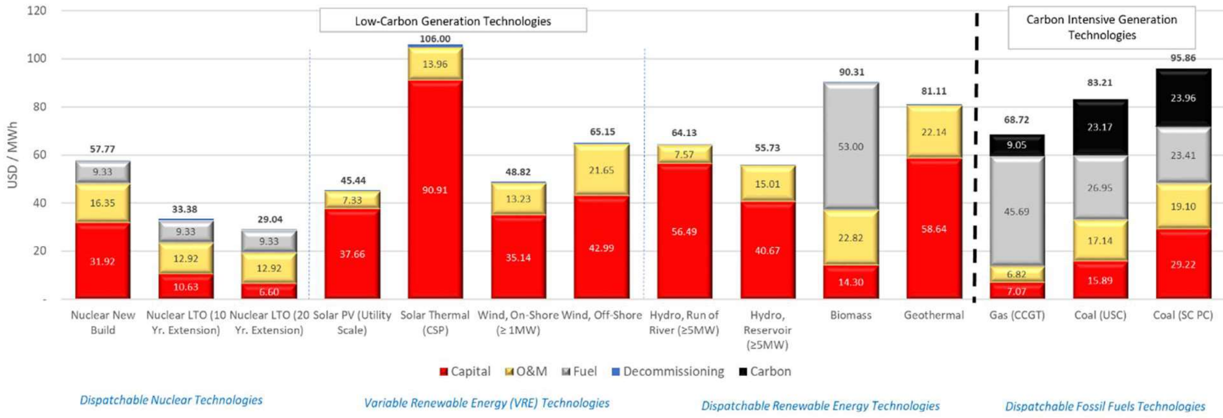
Figure 16 - Comparative Clean Spreads for Various Low Carbon Generation Technologies Relative to Unabated Fossil Fuel Technologies, without Carbon Pricing



Data Source: [21] (data adapted). Assumes 5.0% median cost of capital across all generation technologies.

While nuclear new build tends to be capital-intensive relative to gas fired generation, all other forms of low carbon generation (except, in some cases, biomass) are also similarly capital intensive. It should also be noted that life extensions and renewals (LTO) of the existing nuclear fleet offer the most cost competitive and least capital-intensive plant level costs across all generation technologies. Therefore, the existing fleet of nuclear reactors should be extended to their maximum safe total extended operational lives (which will be an IBNI supported priority objective).

Figure 17 - Compositions of Global Median Whole Life Plant Level (LCOE) Costs for Alternative Generation Technologies, Including Carbon Pricing

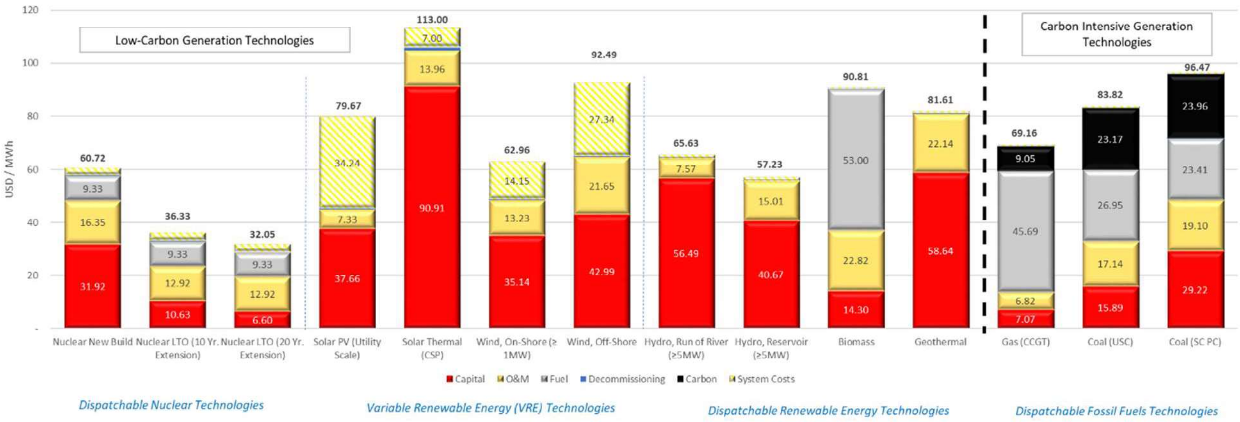


Data Source: [21] & [23] (data adapted). Assumes 5.0% median cost of capital across all generation technologies. Capital costs include capital invested and return on capital invested. Assumes US $30 / tCO_2 carbon price.

When considering reasonably significant carbon pricing levels, both median nuclear new build plant level (LCOE) costs as well as PV solar and wind are increasingly attractive relative to fossil fuels. Life extensions and renewals of existing reactors (LTO) clearly offer the least cost generation across all technologies.

It is not until we look into the "system level" and "societal level" costs under the VALCOE methodology that nuclear new build costs can be clearly shown to be materially less relative to PV solar and wind generation costs. The chart under the below Figure 18 clearly demonstrates the *least cost advantage* of nuclear relative to other competing generation technologies, including incremental "system level costs" in the case where VRE penetration reaches 50% of the global generation mix by 2050. Note that if we consider VRE penetration levels above 30%, the additional "system level" costs related to VRE will be significantly higher.

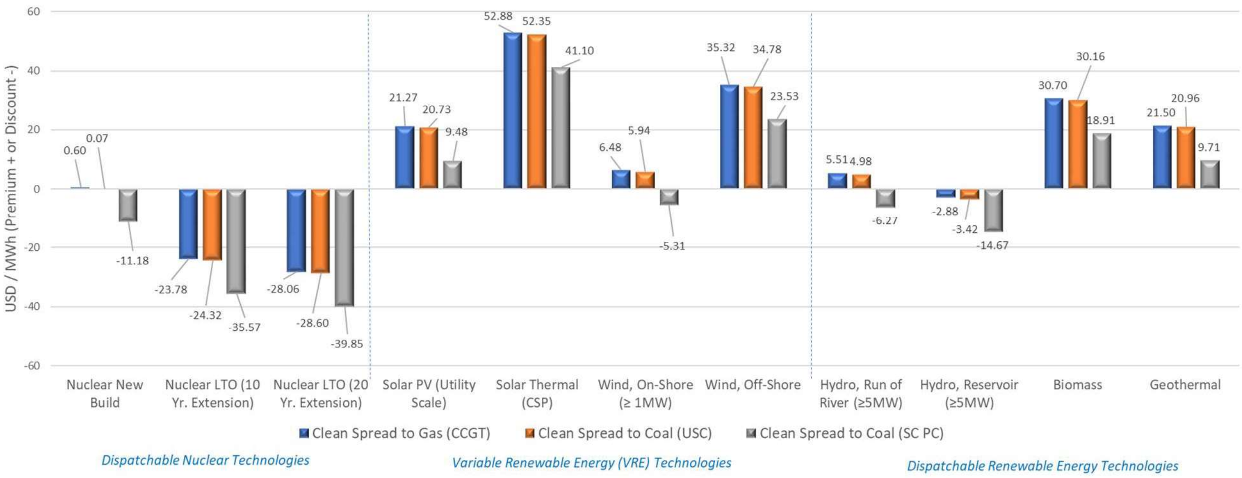
Figure 18 - Composition of Global Median Whole Life Value Adjusted (VALCOE) Generation Costs for Alternative Generation Technologies, <u>Including</u> Carbon Pricing and System Costs with <u>50% VRE Penetration</u>



Data Sources: [19], [21], [22] & [23] (data adapted). Assumes 5.0% median cost of capital across all generation technologies. Capital costs include capital invested and return on capital invested. Assumes US $30 / tCO_2 carbon price.

After taking into account the "system level costs", the "clean spreads" of nuclear generation are shown to be increasingly attractive relative to competing VRE technologies. The following charts illustrate comparative "clean spreads" of nuclear relative to other low carbon technologies with 50% VRE penetration (32% nuclear).

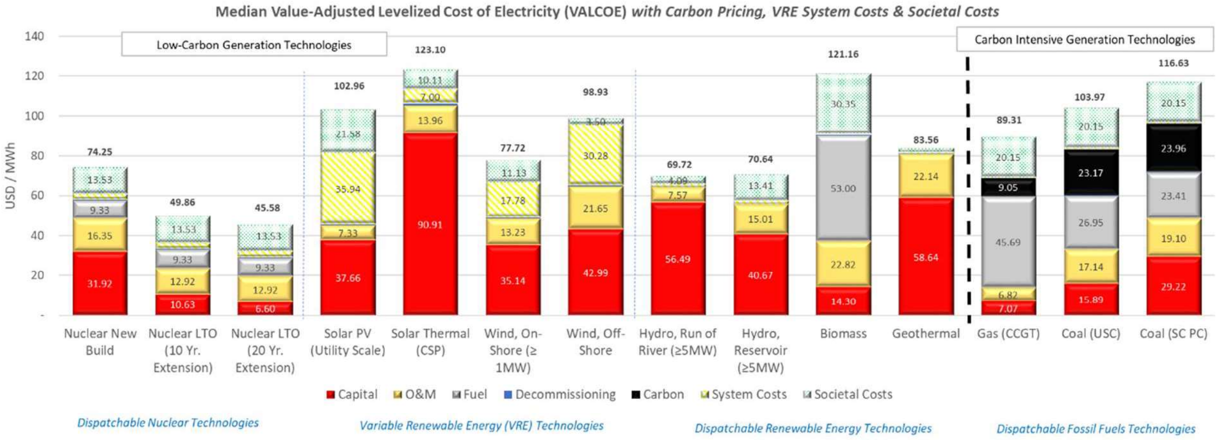
FIGURE 19 - COMPARATIVE CLEAN SPREADS FOR VARIOUS LOW CARBON GENERATION TECHNOLOGIES RELATIVE TO UNABATED FOSSIL FUEL TECHNOLOGIES, <u>WITH</u> SYSTEM COSTS AND <u>WITHOUT</u> CARBON PRICING (<u>50% VRE PENETRATION</u>)



Data Sources: [19], [21], [22] & [23] (data adapted). Assumes 5.0% median cost of capital across all generation technologies. Capital costs include capital invested and return on capital invested.

If non-GHG related "societal costs" are to be included in the analysis, comparing to VRE (at a relatively large 50% total 2050 VRE penetration rate), nuclear exhibits its clear cost advantage. The chart below in Figure 20 demonstrates that nuclear remains amongst the least cost forms of low carbon generation when considering "plant level", "system level" and "societal level" cost elements (assuming a relatively large 50% VRE penetration by 2050). This is illustrative that as VRE penetration rates increase over 30% of the global generation mix, then the associated "system level costs" increase significantly, which render new build nuclear as the clear least cost low carbon option.

FIGURE 20 - COMPOSITION OF GLOBAL MEDIAN WHOLE LIFE VALUE ADJUSTED (VALCOE) GENERATION COSTS FOR ALTERNATIVE GENERATION TECHNOLOGIES, <u>INCLUDING</u> CARBON, SYSTEM AND NON-GHG SOCIETAL COSTS WITH 50% VRE PENETRATION

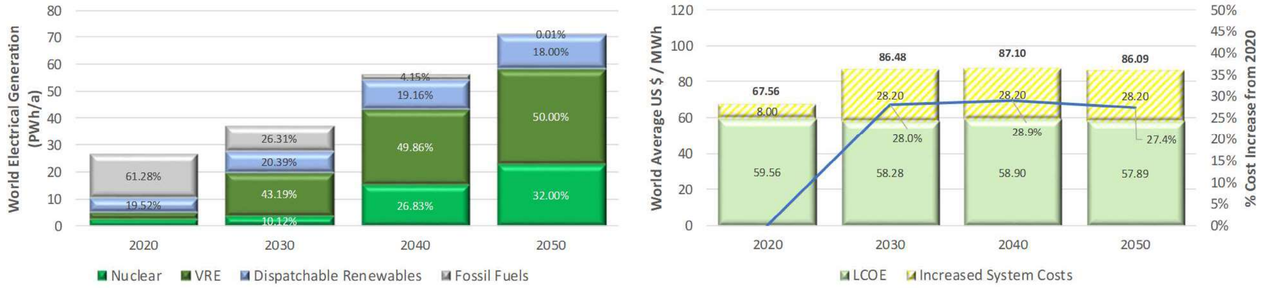


Data Sources: [19], [21], [22] & [23] (data adapted). Assumes 5.0% median cost of capital across all generation technologies. Capital costs include capital invested and return on capital invested. Assumes US $30 / tCO$_2$ carbon price.

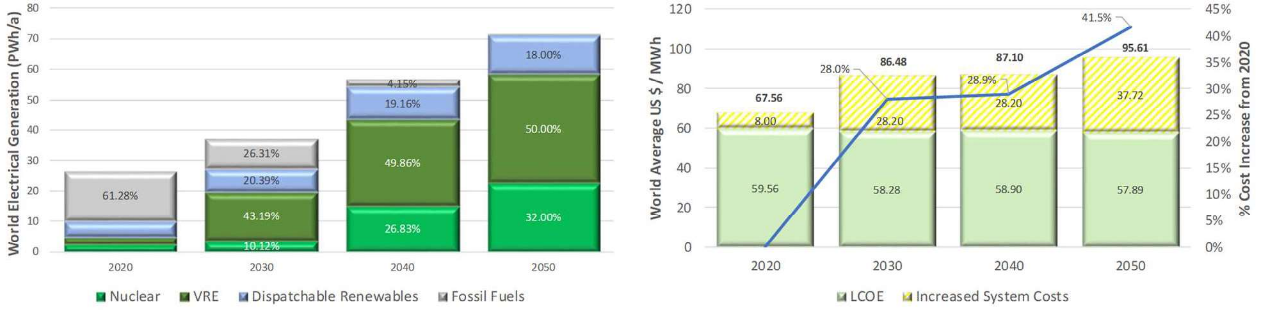
One of IBNI's core missions will be to minimize the cost of low carbon generation by supporting a significant expansion of global nuclear capacities. The following charts below in Figure 21 illustrate the potential direct and tangible increased cost impacts related to increasingly higher VRE penetrations. By significantly scaling-up nuclear generation, the world will be able to avoid electricity generation cost increases that could potentially almost double by 2050. Please note that IEA's NZE 2050 pathways scenario envisages 70% VRE penetration in 2050.

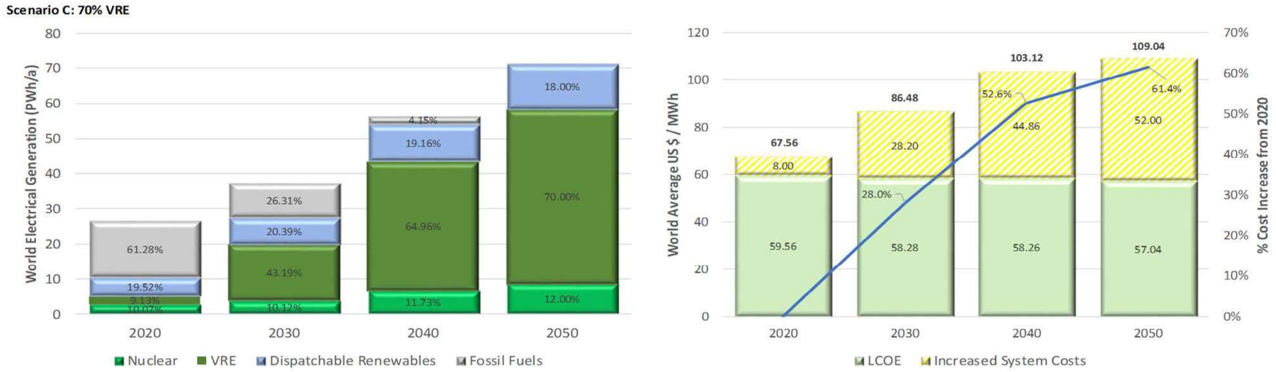
FIGURE 21 – ILLUSTRATION OF POTENTIAL 2020 – 50 WORLD GENERATION MIX EVOLUTION SCENARIOS FOR LOW CARBON GENERATION AND UNIT COST IMPLICATIONS

Scenario A: 22% VRE



Scenario B: 50% VRE





Data Sources: [19], [21], [22] & [23] (data adapted). Assumes 5.0% median cost of capital across all generation technologies. Capital costs include capital invested and return on capital invested.

The analysis above assumes current global median levelized costs and estimated system cost (stated in nominal 2020 US $ values) assumptions and results set forth previously. The analysis ignores potential future decreases in the overnight and investment costs related to various generation technologies. The of costs PV solar and wind generation costs, battery storage and hydrogen and electrofuels technologies are all predicted by many industry experts to decrease over future years and decades, which could certainly drive down competing VRE plant level and system level costs. However, amongst IBNI's main objectives will also be to drive significant global demand for nuclear technologies and scaling-up of nuclear production and supply chains, increasing competition, innovation and R&D investments across the nuclear industries and their value chains. With IBNI support and catalyzation, the cost of nuclear generation technologies, driven by IBNI's support, is also expected to decrease at rates proportionate to those seen in VRE and storage sectors.

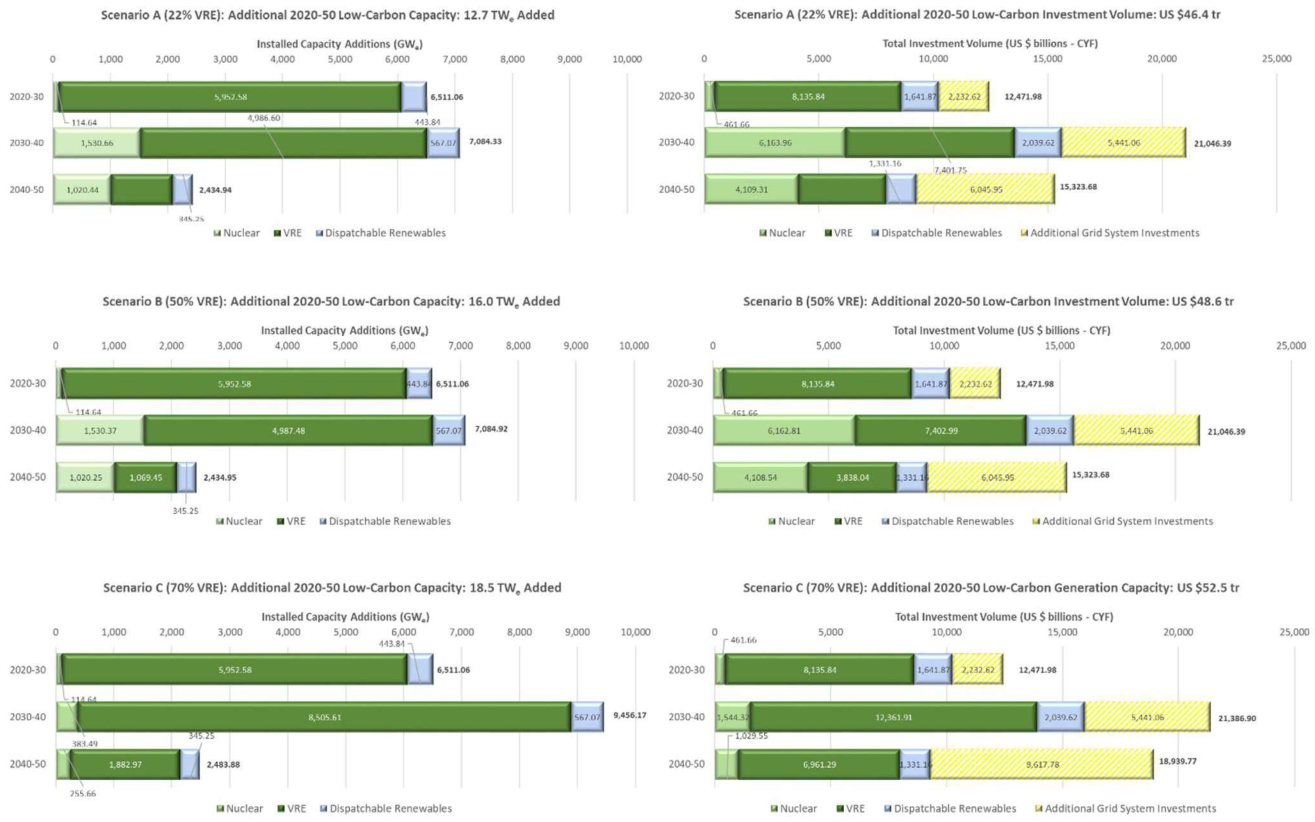
Clearly, from the perspective of minimizing the global cost of generating electricity (and avoiding significant increases in "system level costs") nuclear generation capacity should be maximized. IBNI targets an aggressive goal to achieve at least 60% nuclear share of the global generation mix by 2050 and therefore limiting the need for VRE to no more than 25% of the generation mix.

Capital Investments in Generation Plants and Grid Systems Required to Achieve 2050 Net Zero

Achieving 2050 net zero in the power generation sector, requires not only the massive additional investments related to the replacement of world's existing fossil fuels generation fleet with low carbon generation technologies, but it also entails an even greater investment in additional low carbon generation capacity to meet a potential doubling, tripling or even quadrupling in electricity demand by 2050. As already demonstrated above, the types of low carbon generation technologies that the nations of the world choose to deploy will be critical from an electricity affordability perspective. However, the sheer volume of capital investment that will need to be funded and financed by the world's governments and global capital markets is also daunting. Therefore, we also need to address differences in the total capital investment requirements for different forms of generation pathways and assess whether such volumes can realistically be funded and financed.

Increasingly higher percentages of VRE penetration will require both disproportionately higher installed generating capacities (consuming escalating quantities of land and resources) and direct capital investments in both generating plants and grid system infrastructure. The charts below in Figure 22 illustrate the incremental installed electrical capacity requirements and capital investment cost burden related to increasingly higher VRE penetration rates.

FIGURE 22 - WORLD GENERATION CAPACITIES AND GENERATION AND GRID CAPITAL INVESTMENT REQUIREMENTS RELATED TO VARIOUS VRE PENETRATION SCENARIOS



Data Sources: [19], [21], [22] & [23] (data adapted). Assumes 5.0% median cost of capital across all generation technologies. Capital costs include capital invested and return on capital invested. Assumes that 60% of the additional system level revenues related to capital expenses. Capital requirements are calculated based on an assumed cost of capital of 5.0% over a 15 year pay-back time horizon.

The illustrated 'Scenario A' (22% global VRE penetration) above results in an overall additional generation and grid system capital investment requirement that is over 13% lower than in 'Scenario C' (70% VRE penetration), alleviating the need for approximately US $ 6.1 trillion in additional required capital investments over the next thirty years.

It should be further noted that the above capital investment requirements do not consider additional potential *direct cost* impacts such as land and materials resource requirements and costs (and the competition for and opportunity costs related to the use of those scarce resources). 'Scenario C' (70% VRE penetration) entails approximately 16.3 TW_e of additional VRE capacity to be added before 2050. This scenario would require approximately 1.76 million additional square kilometers of the earth's land areas (about 1.7% of earth's total habitable land areas) to be converted to solar and on-shore wind production and an additional 3.7 million square kilometers of the earth's coastal areas would need to be converted to off-shore wind production[40]. Significant amounts of additional land area will also need to be consumed for grid related infrastructure and energy storage.

IBNI to Drive Further Affordability, Cost Reductions and Efficiencies in Nuclear Power

While it has already been demonstrated in this IRAP that nuclear power is the least cost low carbon technology, it is evident that nuclear technology is currently significantly more costly than it could (or should) be. The cost inefficiencies associated with nuclear power over the past decades are well known and documented. The nuclear power industry has clearly suffered from the following issues over past decades:

- **Cost overruns and delays:** it is widely known that many recent NPP projects, particularly in the USA and Europe have experienced very significant cost-overruns and delays which has in some cases resulted in much-higher-than anticipated costs borne by utilities, governments, shareholders and electricity consumers, or in other cases the cancellation or abandonment of projects due to escalating costs.
- **Lack of Access to Affordable Financing:** The dominating nuclear development and financing model in Europe and North America has been one where electric utilities finance NPPs as system assets, on-balance sheet. Much of the rest of the world relies on state-supported financing models. Given the very high up-front capital costs of developing NPP's, very few utilities in the world have sufficient balance sheet capacity to self-finance single, multi-billion dollar assets like nuclear plants. Unlike almost all other infrastructure asset classes, utilities, governments and other NPP sponsors have not been able to attract commercial project lenders and long-term debt and equity capital (such as pension funds, insurance companies, infrastructure funds, sovereign wealth funds, etc.) to finance NPPs on a project level basis.
- **Lack of Robust NPP Construction Demand.** Over the past three decades, there has been a significant downturn in the quantities for new nuclear reactors being developed worldwide (with exceptions in certain markets such as China and South Korea). This has significantly eroded the nuclear industry's global production and supply chains, where human capital resources in nuclear

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[40] Assumes that of the 16.3 TW_e of additional VRE capacity, 33% is PV solar, 15% is on-shore wind and 20% is off-shore wind, where surface area requirements average 10 ha/MW_e, 50 ha/ MW_e and 100ha/ MW_e, for PV solar, on-shore wind and off-shore wind, respectively. Of the total 149 million km^2 of earth's surface area, approximately 71% is habitable (approximately 104 million km^2) - *source:* https://ourworldindata.org/land-use. VRE generation under 'Scenario A' would consume approximately 1.1 million km^2 of surface land and 120 million km^2 of coastal areas. (corresponding to approximately a 35% reduction in required surface land area and 67% reduction in required coastal areas needed for VRE production).

engineering and related specialized fields have become increasingly concentrated scarce and there are fewer nuclear qualified and experienced contractors available in many markets. The lack of resources in the global production and supply chains, combined with lack of experience and "learning by doing" in developing "nth of a kind" nuclear reactor designs has led to many cost overruns and delays. Only a robust and sustained global order flow for nuclear reactors will solve this problem. Under the appropriate market conditions (where there is a market for repeatedly delivering similar reactor designs, in a similar regulatory and market environment) the nuclear industry has demonstrated its capability to deliver on-time and within budget in many cases, including in the USA and Europe in the 1970s and 1980s, in Japan and S. Korea in the 1980's – 2000's, and currently now in China.

- **Lack of Appropriate Risk Allocation:** In many cases, projects have been structured with inappropriate risk allocation, where project risks have been allocated to either to contractor, utility and/or governmental entities. In many cases, these risk allocation structures have resulted in the disproportionate burden on rate payers, contractors, utilities and governments. Inappropriate risk allocation has also contributed to construction cost overruns and delays as well as cancellation and abandonment (in some cases due to contractor bankruptcy).
- **Deregulated Market Models ("Market Failure"):** As many nations have or are now attempting to liberalize their energy markets, in many cases, capital-intensive, base load generation plants have come under significant market pressure when competing against gas fired generation and VRE. NPPs investments require long-term stable and predictable revenues, under such market models where the plant operator is compensated for dispatchable available capacity.
- **Evolving Nuclear Safety Regulations.** In numerous recent cases, well-intentioned nuclear safety regulations have changed during the construction period of NPP projects, resulting in extensive and costly delays and related design changes. While nuclear regulators are independent organizations responsible to the public for nuclear safety, NPP developers cannot and should not be held responsible for the very serious risks of cost increases due to changes in the applicable nuclear safety standards made mid-way through a project construction cycle. In such cases, governments need to provide the appropriate "change-in-law/regulation" compensation provisions to compensate impacted NPP project owner/developers.

IBNI's programs will be focused on making nuclear an even more affordable and lowest cost generation technology by remedying the above deficiencies.

First, IBNI will drive significant global demand-side growth for nuclear generation technologies, creating robust demand for varied nuclear technologies, which will be manifested in terms of escalating order flows for all nuclear equipment and supply chain vendors. IBNI will also promote and foster competition and innovation withing the global nuclear sector. Such demand-side catalytic effect will drive growth in the global nuclear production and supply chains and will also promote investment in nuclear innovation and R&D. The end result will be that the global nuclear industry will be able to deliver significantly lower costs and markedly improved on-time and on-budget performance with respect to delivering "nth of a kind" (NOAK) reactor technologies and designs (and potentially future modularized reactor designs).

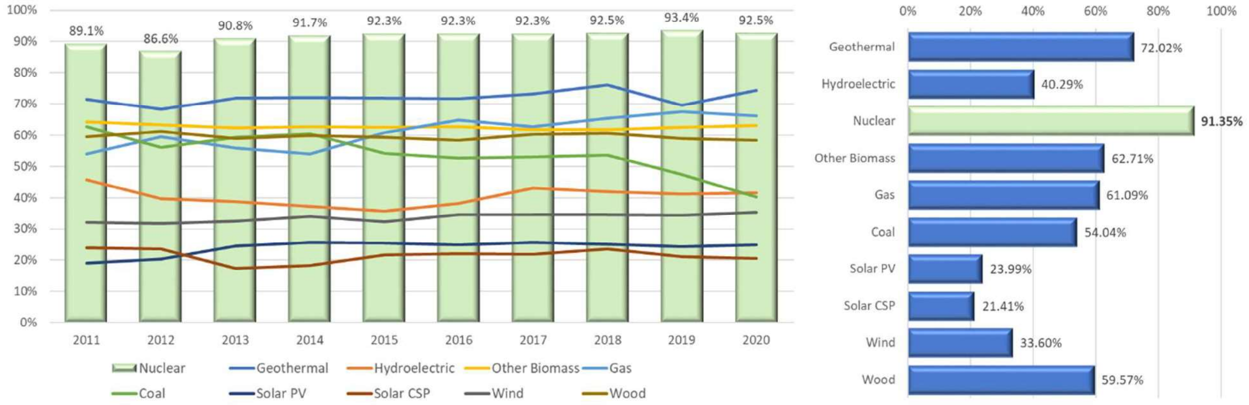
Second, IBNI will directly provide very low cost of capital available for qualified nuclear projects. IBNI's participation will also catalyze participation from other capital markets providers of low-cost long-term capital into nuclear programs. Given that nuclear projects are capital intensive, significant reductions in cost of capital will result in significantly reduced generation costs.

Third, the implementation of IBNI's rigorous standards and criteria (see Section 5) and the creation of a global competitive market framework for scarce IBNI support will drive market and regulatory reform in each country pursuing IBNI's support for their nuclear projects. As many countries realize that IBNI support will be critical (or compulsory) for the success of their nuclear energy and decarbonization programs, policymakers will enact tough decisions that are necessary for support and long-term sustainability of their nuclear programs and achievement of their net zero commitments.

3.2 Nuclear is Reliable & Proven for Grid Scale On-Demand Generation

The nuclear power generation sector has demonstrated, over many decades to offer one of the most reliable sources of dependable "base load" power generation. Year in and year out, nuclear power outperforms all other generation technologies in terms of reliability. After commissioning, modern nuclear power plants can offer design lives of more than sixty (60) and in some cases more than eighty (80) years, thereby providing dependable low-carbon generation 24 hours a day 7 days a week, regardless of whether the sun is shining, or the wind is blowing. Typically, nuclear power reactors only need to be shut down for refueling every 18 to 24 months and perform with very few maintenance outage periods, outside scheduled refueling and maintenance outage periods. Modern nuclear reactors routinely offer average availability and capacity factors of more than 90%, which as can be seen below in the US market (for example) has outperformed every other generation technology in that market.

FIGURE 23 - COMPARISON OF NUCLEAR AND OTHER TECHNOLOGIES CAPACITY FACTORS IN USA (2011 - 20)



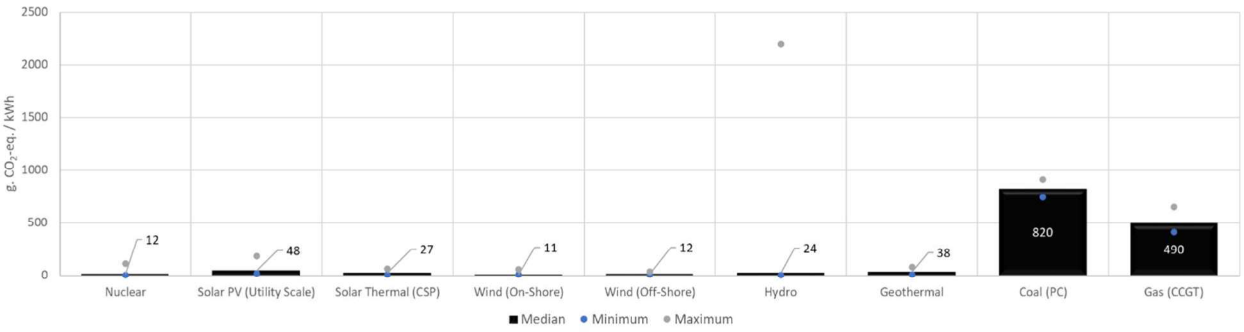
Data Source: [32]

Globally, the World Nuclear Association (WNA) has reported global average nuclear power plant capacity factors have been 83.1% and 80.3% in 2019 and 2020, respectively[41]. One of the main reasons that global nuclear capacities factors were reduced in 2020 was due to lower world electricity demand due to the COVID-19 pandemic. While nuclear availability factors are expected to remain quite high, in many markets, nuclear power plants are increasingly being called upon for “load following” operations as increasingly higher percentages of VRE are introduced into those markets. This suggests that nuclear capacity factors will continue to decrease in those markets until nuclear reactors can be used to generate electricity and heat energy for hydrogen and electrofuels production, heat, cooling and desalinated water during periods where there is lower residual energy demand.

3.3 Nuclear Energy Offers Lowest Whole Life Carbon Emission

Nuclear power and hydroelectricity have the lowest life cycle greenhouse gas emissions of electricity generating technologies[42]. Figure 24 below provides a comparative analysis median values as well as the minimum and maximum observed ranges for GHG emissions of different generation technologies.

FIGURE 24 - COMPARISON OF WHOLE LIFE CYCLE CARBON EMISSIONS FOR VARIOUS GENERATION TECHNOLOGIES



Data source: [23]– Table A.III.2 - pg. 1335.

Data in the chart above are on a ‘life cycle’ basis, and an understanding of the ‘life cycle’ concept is critical to conducting comparative analyses of the greenhouse gas (GHG) emissions per kWh arising from different generating technologies – their respective ‘carbon intensities’. Broadly, the life cycle concept stresses the need to consider the GHG emissions produced at all stages of a given technology’s existence - ‘from cradle to grave’ – including emissions generated during the technology’s resource procurement, construction, deployment, operation and decommissioning phases. Nuclear power plants produce virtually no greenhouse gas emissions or any other pollutants during their operation and only very low emissions over their full life cycle (per kWh generated over their operating lives).

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[41] Source [33] – Section 1.2 - pg. 6

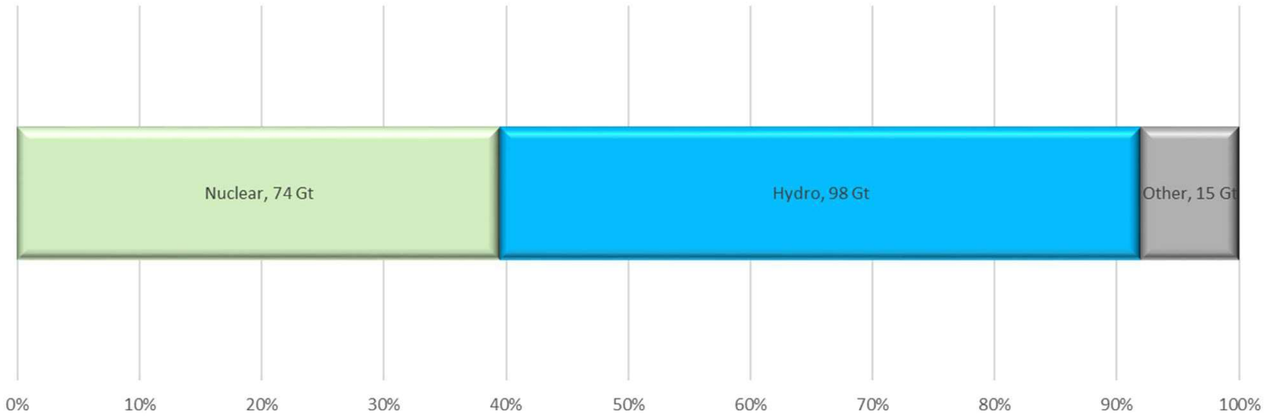
[42] Source: [3] – Section 2.2.1

We have not included Carbon Capture Utilization (CCUS) and Storage technologies in our analyses as these emerging technologies are unproven from both a technological and commercial perspective. It is important to note that emissions associated with Carbon Capture Utilization and Storage (CCUS) on fossil fuel technologies and for biofuel (BECC) are both subject to considerable uncertainty – given the state of development of this technology – but such technology is not expected to capture all emissions (while quoted figures often suggest capture rates of around 85%[43] – other analysis of CCUS technologies are more skeptical[44]).

Nuclear power now provides approximately 10% of the world's electricity, but it contributes almost 30% of all low carbon electricity. Given that the energy sector is currently responsible for approximately two-thirds of global greenhouse gas emissions (see Figure 6)[45], an enhanced role for nuclear power will be essential for achieving the low carbon future which world leaders have agreed to strive for, but which current commitments are not set to deliver[46].

Nuclear power, currently being generated in 32 countries[47], is already reducing carbon dioxide emissions by about two gigatonnes per year. That is the equivalent of taking more than 400 million cars off the road — every year[48]. Only hydropower has played a greater role in avoiding carbon emissions over the past 50 years[49].

FIGURE 25 - AVOIDED ELECTRICITY SECTOR GHG EMISSIONS (1971 - 2018)



Data source: [31]– pg. 4

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[43] Source: [24] – Table 8.1 – pg. 343
[44] Source: [25]
[45] References: [6] – pgs. 13, 48 & 92, [26], [27], [28] – pg. 60, [29] – Fig. 12, pg. 14
[46] Source: [6] – pg. 29
[47] Source: [30]
[48] Source: [3] - Foreword
[49] Source: [31] – Section 1.2

As shown above in Figure 25, nuclear power is a low-carbon energy source that has avoided about 74Gt of CO_2 emissions over this period, nearly two years' worth of total global energy-related GHG emissions.

3.4 Nuclear Energy is Amongst the Safest Generation Technologies

Over the past nearly seven decades of continuous commercial production, the world's nuclear power plant operators have demonstrated an extremely remarkable track record of safety. Nuclear energy is responsible for far fewer human fatalities and human morbidity issues, per unit of generation output, than many other sources of power generation. Aside from human casualties, the discussion about nuclear safety should encompass the broader topic of nuclear 'safety, security and safeguards'. Below we investigate the following areas of concerns:

- Human fatality rates related to power generation technologies
- Environmental contamination related to power generation
- Nuclear security and safeguards issues

The analysis of (and the ongoing debate) related to nuclear safety is perhaps most well established by the *'JRC Science for Policy Report - Technical assessment of nuclear energy with respect to the 'do no significant harm' criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation')'* (the "EU Taxonomy Report"). The ultimate conclusion of the JRC's EU Taxonomy Report can be best summarized as follows *"The analyses did not reveal any science-based evidence that nuclear energy does more harm to the human health or to the environment than other electricity production technologies already included in the [EU Environmental Sustainability] Taxonomy as activities supporting climate change mitigation."*[50]

Fatality Rates Related to Nuclear and Other Power Generation Technologies

When considering any generation technology's risk to human health, one must first consider the risks of human fatalities and human morbidity (illness and health issues) directly related to any particular generation technology's activities throughout its entire life cycle (including materials and fuels, construction, operations decommissioning and disposal/repository/recycling). For example, fossil fuel generation technologies have led to considerable levels of human fatalities and morbidity issues through air, water and soil pollution (in addition to accidents throughout their respective value chains). It is more difficult to assess the true impacts of PV solar and wind generation technologies as each technology, being extremely resource intensive, involve global supply chains including raw materials extraction and mining activities whether the human costs of such activities may not be well accounted for. Based on best available data, the following chart illustrates the total number of human fatalities directly caused by a certain form of generation, nuclear generation has amongst the lowest fatalities per TWh of generation and is similar to renewables.

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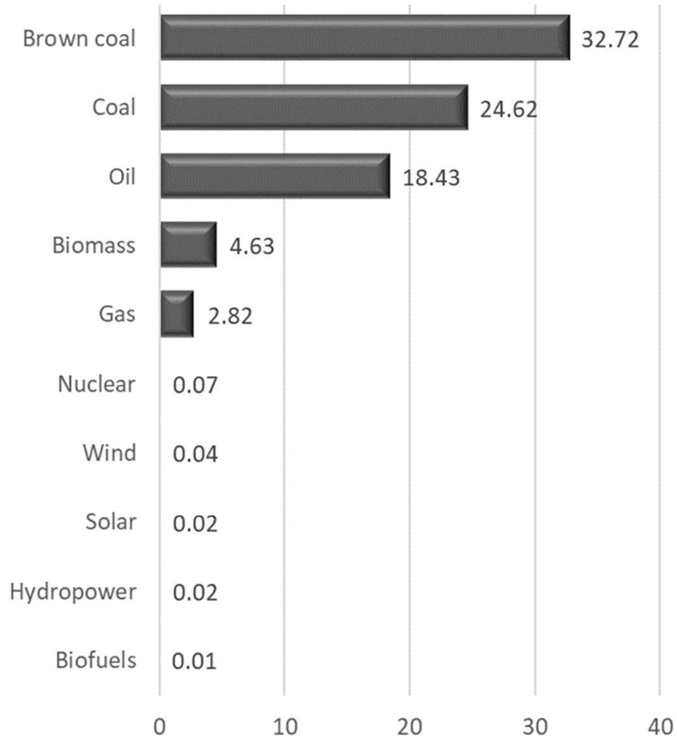
[50] Source: [18] – pg. 182

FIGURE 26 - HUMAN FATALITIES PER TWH OF POWER PRODUCTION



Data source: [34], with data adapted from [35] & [36].

While nuclear power plant accidents are very rare, their local and regional impacts on humans (fatalities and morbidity caused by exposure to high levels of ionizing radiation) can be severe and have long-lasting implications. Over the nuclear power industry's nearly seven decades of operating history, there have been only three major nuclear accidents in the world: Three Mile Island (USA, 1979), Chernobyl (Ukraine, USSR, 1986) and Fukushima Daiichi (Japan, 2011). In terms of direct deaths, the Chernobyl accident was the worst[51]. However, as disastrous as these three accidents each were within the impacted regions, the rates of human fatalities and morbidity are far less than many other forms of generation (in particular, in comparison to the human impacts related to fossil fuels generation).

After the Chernobyl accident in 1986, the global nuclear industry responded by becoming increasingly focused on major safety enhancements in "generation III" (Gen III) reactor designs. In their 'taxonomy' report, the EU's JRC wrote, *"After the Chernobyl accident, international and national efforts focused on*

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[51] Source: [36] World Health Organization (WHO) – the most-widely cited figure – estimates that approximately 4,000 people have, or will die, from the Chernobyl disaster. This includes the death of 31 people as a direct result of the disaster and those expected to die at a later date from cancers due to radiation exposure. Although estimation this is considered to be too high by several other researchers, including a later report by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

developing Gen III nuclear power plants designed according to enhanced requirements related to severe accident prevention and mitigation. The deployment of various Gen III plant designs started in the last 15 years worldwide and now practically only Gen III reactors are constructed and commissioned. These latest technology developments are reflected in the very low fatality rate for the Gen III EPR design ($\approx 8 \cdot 10^{-10}$ *fatalities/GWh). The fatality rates characterizing state-of-the art Gen III NPPs are the lowest of all the electricity generation technologies."*[52]

Aside from the above widely known nuclear disasters mentioned above, there have not been any significant known incidents where involving human fatalities and human morbidity implications related to excessive radiation exposure or environmental contamination issues related to operating nuclear power plants, decommissioning and within the nuclear fuel cycle.

Part of the reason that the nuclear industry demonstrates such a strong track record of safety is that the nuclear industries are amongst the most regulated industries in the world (and this also includes the nuclear fuel cycle industries, from mining and milling to waste storage and disposal). *"Nuclear regulation is a mix of international and national laws. The International Atomic Energy Agency (IAEA) works to provide a strong, sustainable, and visible global nuclear safety and security framework for the protection of people, society, and the environment. This framework provides for the harmonized development and application of safety and security standards, guidelines, and requirements; but it does not have the mandate to enforce the application of safety standards within a country. [which is the regulatory mandate of the given country's nuclear regulatory authority]"*[53].

As nuclear safety is largely underpinned by very strong regulatory conditions, IBNI will reinforce global best practices through its standards and conditions (see section 5) that will be applied and enforced throughout the entire value chain related to nuclear programs and projects supported. Such standards and conditions will compel project sponsors to implement not only the minimum required safety, security and safeguards standards, but to achieve international best practices in term of "smartest" regulatory standards designed to further minimize the possibility of future nuclear accidents.

Environmental Issues Related to Nuclear and Other Power Generation Technologies

It is widely known and accepted that nuclear power plants have virtually zero emissions of air and water[54] pollutants during their operational phases. Virtually all life-cycle emissions of GHGs and all other potential GHG, particulate and chemical emissions of NPPs over their whole life cycles are derived from their materials, construction, maintenance, decommissioning and fuel-cycle activities.

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[52] Source: [18] – pg. 1

[53] Source: [39] – pg. 106

[54] However, as set forth in the EU Taxonomy Report, potential thermal heat pollution from NPP's is an identified issue of concern. This issue relates both to NPP siting as well as technology and cooling system requirements.

During proper operations, radiation exposure levels to workers within NPP facilities, and to the public near such facilities have been demonstrated to be orders of magnitude less than many other common atmospheric and environmental sources of very low-level radiation exposures that people and animals are routinely exposed to. However, the potential for release into the environment of radiation from an NPP or within the nuclear fuel cycle, of course, cannot be entirely excluded. Potential exposure to excessive amounts of radiation exists at all points in the nuclear fuel cycle, from mining and milling until long-term repository.

With respect to the risks related to any potential radiation contamination related to many elements of the nuclear life cycle, the EC's JRC Taxonomy report also reveals the following conclusions of their analysis:

"Management of radioactive waste and its safe and secure disposal is a necessary step in the lifecycle of all applications of nuclear science and technology (nuclear energy, research, industry, education, medical, and other). Radioactive waste is therefore generated in practically every country, the largest contribution coming from the nuclear energy lifecycle in countries operating nuclear power plants. Presently, there is broad scientific and technical consensus that disposal of high-level, long-lived radioactive waste in deep geologic formations is, at the state of today's knowledge, considered as an appropriate and safe means of isolating it from the biosphere for very long time scales."

"Measures to ensure that radioactive waste does not harm the public and the environment include a combination of technical solutions and an appropriate administrative, legal and regulatory framework. Although there remain contrasting views, it is generally acknowledged, that the necessary technologies for geological disposal are now available and can be deployed when public and political conditions are favourable. No long-term operational experience is presently available as technologies and solutions are still in demonstration and testing phase moving towards the first stage of operational implementation. Finland, Sweden and France are in an advanced stage of implementation of their national deep geological disposal facilities, which are expected to start operation within the present decade[55]. The radiological impact of nuclear energy lifecycle activities, including radioactive waste management and disposal, is regulated by law in the [EU] Member States, setting the maximum allowed releases and radioactivity exposure to the professionally exposed groups, to the public and to the environment. Respecting these limits, establishing the boundaries below which no significant harm is caused to human life and to the environment, is a precondition for any nuclear lifecycle activity to be authorized and is subsequently monitored by independent authorities."[56]

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[55] Note that Finland has since broken ground on their Deep Geological Repository (DGR) project.

[56] Source: [18] – pg. 8