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TECHNOLOGY SELECTION IN AUCTIONS: LESSONS LEARNED FROM INTERNATIONAL EXPERIENCE

Scaling Up Renewable Energy Project
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TECHNOLOGY SELECTION IN AUCTIONS: LESSONS LEARNED FROM INTERNATIONAL EXPERIENCE

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TECHNOLOGY SELECTION IN AUCTION DESIGNS

When choosing how to allocate auction demand and volumes, countries must decide which technologies should compete in the auction. Based on the policy objectives and the stage of the auction program, countries can choose to implement auctions from a broad spectrum of technology differentiation.

On that spectrum, countries can choose between technology-neutral and more technology-differentiated designs, such as multi-technology and technology-specific auctions. Technology-neutral auctions refer to competitive bidding processes that do not place restrictions based on technology type; *i.e.* both conventional and renewable energy technologies may participate. In RE technology-neutral auctions, countries exclude conventional thermal technologies from participation. As a result, all RE technologies compete against each other. Multi-technology auctions allow countries to tailor demand to procure only a certain subset of RE technologies, usually based on their assumed characteristics, such as costs, dispatchability, local industry creation, weather and location dependency, and the system-friendliness of their feed-in profile. At the end of the spectrum, technology-specific auctions limit participation to only one desired RE technology. Figure 1 provides a high-level overview of the spectrum of technology neutrality and technology differentiation in auctions.

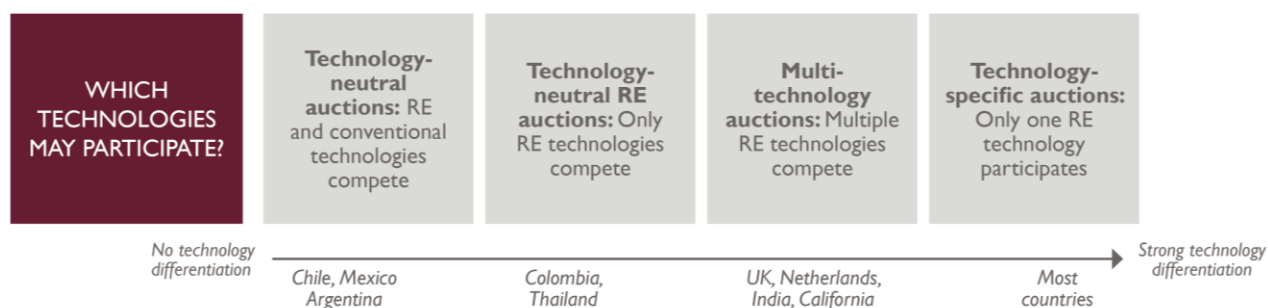


Figure 1. The spectrum of technology differentiation in auctions

The technology specification should be consistent with the objectives of the larger auction program. Countries often begin implementing technology-specific auctions to gather information on a technology's costs and performance and provide an incentive to the market to develop the industry in all desirable technologies. Based on integrated resource planning, they procure capacity while considering the technology's impact on grid integration and geographic dispersion. Integrated resource planning becomes particularly important if remote regions are developed for their solar, onshore wind, or offshore wind potential and the transmission usage to these sites is optimized for a specific technology.

As auction programs mature, the technology choice becomes less relevant, and low prices and other objectives are likely to drive the technology choice. Instead of predetermining the technology, governments instead specify the power characteristics they intend to procure, such as the system-friendliness of electricity fed into the grid, its location, and the value of power. For example, if the auction design favors technologies able to deliver electricity during peak periods, governments are more likely to award combined technologies, such as solar-wind hybrids or solar-plus-storage installations.

Some countries rely on fully technology-neutral auctions to procure generation capacity at lowest cost, whether from conventional energy sources or RE (e.g., Mexico). At the same time, many countries have set ambitious RE targets with the aim to reduce greenhouse gas emissions, increase energy security, and promote power system modernization. To meet these targets, countries (e.g., Colombia) introduced RE-exclusive technology-neutral auctions. While countries might move to a higher level of technology neutrality as their power systems mature, it is complex to design a level-playing field for different technologies in such auctions.

POLICY OBJECTIVES IN THE TECHNOLOGY SELECTION

The four design approaches to technology selection achieve different objectives. Table I provides an overview of objectives for technology-neutral, RE-exclusive technology-neutral, multi-technology, and technology-specific auctions.

TABLE I. OBJECTIVES TO BE ACHIEVED BY TECHNOLOGY NEUTRALITY VS. TECHNOLOGY DIFFERENTIATION IN AUCTIONS

OBJECTIVES	TECHNOLOGY-NEUTRALITY	RE-EXCLUSIVE TECHNOLOGY NEUTRALITY	MULTI-TECHNOLOGY	TECHNOLOGY-SPECIFICITY
Minimization of generation costs	✓✓	✓✓	✓	✓
Compliance with regulation demanding no discrimination between technologies	✓✓	✓✓	✓	✗
Preselection of RE technologies to minimize total system costs and/or develop specific regions	✗ ¹	✗	✓	✓
Reduction of windfall profits for cheaper technologies	✗	✗	✓✓	✓✓
Compliance with renewable portfolio standards (RPS), emission reduction targets, and/or deployment goals for specific RE technologies	✗	✓	✓✓	✓✓
Promotion of secondary policy objectives (e.g., local RE industry development, steering capacities toward a more balanced regional distribution, supporting the longer-term potential of a preferred new technology)	✗	✗	✓✓	✓✓

- ✓✓ Very suitable solution for meeting policy objectives;
- ✓ Suitable solution for meeting policy objectives;
- ✗ Only achievable through additional design measures.

¹ Note that the design of technology-neutral (RE) auctions may nonetheless incorporate elements promoting technologies with system-friendly attributes, e.g., in terms of their ability to produce electricity during peak periods. The following two sections provide more details on how to incorporate such elements in technology-neutral and multi-technology auctions.

MINIMIZATION OF GENERATION COSTS

The main argument for technology-neutral auctions is the minimization of generation costs, since various conventional and/or RE technologies compete against each other. As a result, technologies with the lowest generation costs, and thus bid prices, win the awards. Higher levels of competition between a larger number of bidders promote the efficient procurement of existing technologies in technology-neutral auctions.

COMPLIANCE WITH REGULATION DEMANDING NO DISCRIMINATION BETWEEN TECHNOLOGIES

In some cases, the regulator explicitly requires technology-neutral auction designs. Examples include the technology-neutrality requirement prescribed by the Philippines mandate that utilities procure all electricity (both conventional and RE) at “least cost” while at the same time achieving a target RE share to comply with renewable portfolio standards (RPS). In the European Union, member state subsidies are subject to state aid law, which requires, in principle, that countries procure RE on a technology-neutral basis, although most EU countries make use of exemptions for small markets or specific system needs. In conclusion, technology-neutral designs tend to promote the efficiency of auction results (*i.e.*, the minimization of generation costs) and allow for compliance with regulations requiring technology neutrality.

However, policymakers have several reasons to consider differentiating between technologies as part of the auction design. These include the minimization of total system costs, the reduction of windfall profits for cheaper technologies, the achievement of RE deployment goals and/or emission reduction targets, and the promotion of secondary policy goals.

PRESELECTION OF RE TECHNOLOGIES TO MINIMIZE TOTAL SYSTEM COSTS

Individual RE technologies incur costs that usually are not limited to generation costs and are passed on to consumers. They include additional system integration costs, such as balancing, grid, and backup capacity costs.² As long as these external costs are not passed on to project developers, they are not reflected in bid prices and therefore will not be considered in the selection process of fully technology-neutral auctions. Since technologies incur very different system integration and grid expansion costs, the deployment of technologies with the lowest generation costs will not necessarily result in the lowest system costs.

For example, in countries where solar electricity production largely coincides with high demand, solar photovoltaic (PV) plants produce electricity with a high system value.³ In such contexts, it may be useful to further procure PV plants, even if other RE technologies such as onshore wind have lower generation costs. Auctions differentiating between technologies are, therefore, one way to streamline the deployment of different technologies in line with the minimization of overall system costs. Policymakers also consider overall system costs when RE development is concentrated in a specific location to meet power system development objectives, *e.g.*, if a specific area requires a minimum capacity to justify major transmission investments (*e.g.*, offshore wind in Europe, Chinese wind in the northwest, India’s large-scale solar farms and zones).

² <https://www.neon-energie.de/ueckerdt-Hirth-Luderer-Edenhofer-2013-System-LCOE-Costs-Renewables.pdf>

³ https://www.researchgate.net/publication/279183731_Renewable_energy_auctions_Goal-oriented_policy_design

REDUCING WINDFALL PROFITS FOR CHEAPER TECHNOLOGIES

Windfall profits can occur if projects of both significantly lower- and higher-cost technologies are needed to meet an auction round's demand. Bidders of the lower-cost technology anticipate a situation in which higher-cost technologies will be awarded which reduces the price competition. In a pay-as-bid auction, bidders of the lower-cost technology are then incentivized to submit bids above their true costs as there is a higher chance that they will be awarded. Since the off-taker needs to purchase power at the marked-up price, consumers are subject to higher electricity prices as a result of excess revenues to bidders. Differentiating between technologies with different costs can help reduce this potential overcompensation of lower-cost technologies.

Figure 2 illustrates this effect for the example of limited hydro projects and solar PV projects competing in an auction. The first graph indicates that the extent of potential windfall profits depends on the cost differences between the lower-cost (hydro) and the higher-cost technology (solar PV). If there are more low-cost projects than demand in the auction, there are fewer windfall profit risks, as bidders in the lower-cost technologies compete with each other. The second graph shows that in technology-neutral auctions technology-specific ceiling prices can help to reduce windfall profits of the lower-cost technologies.

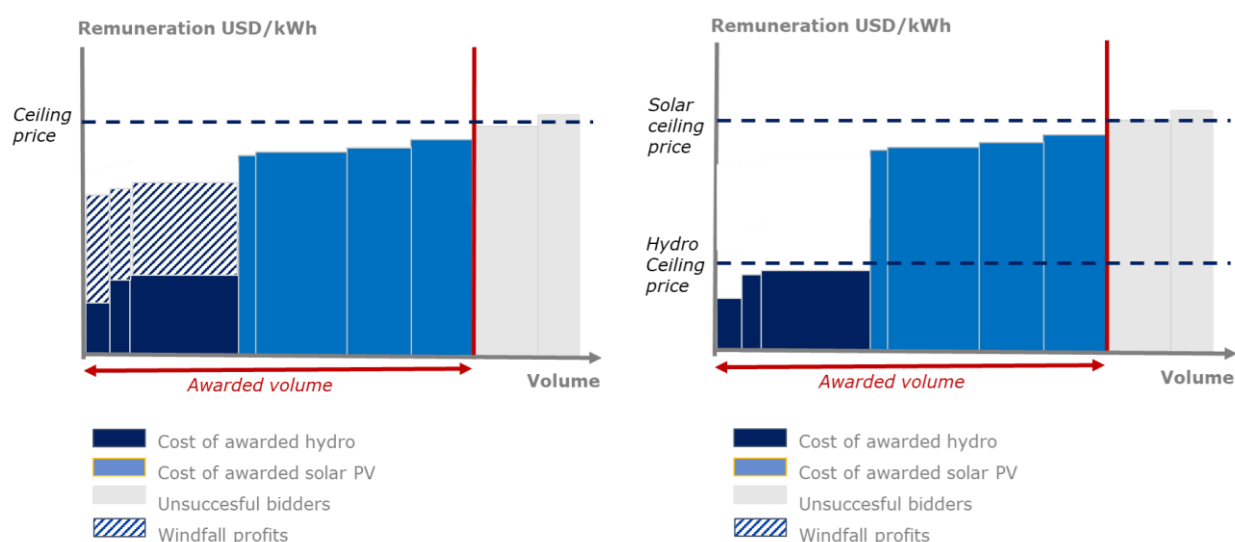


Figure 2. Illustration of windfall profits in pay-as-bid technology-neutral auctions

RELIABLY ACHIEVING DEPLOYMENT GOALS AND/OR EMISSION REDUCTION TARGETS

Many countries have implemented CO₂ emission reduction targets, RPS, and/or deployment goals for specific RE technologies. Effectively achieving the desired technology mix can be challenging in the following contexts:

- If a country has emission reduction targets or RPS in place but decides to implement technology-neutral auctions open to both conventional and RE technologies, or
- If technology-specific RE targets are set but the country implements technology-neutral auctions open to all RE technologies.

PROMOTING SECONDARY POLICY OBJECTIVES

Creating a technology mix in line with certain policy objectives is difficult in technology-neutral auctions. In the past, secondary policy objectives motivating technology differentiation have included (i) fostering local value chains and industries and avoiding boom-and-bust cycles (e.g., India, Morocco, Portugal, South Africa, China), (ii) steering capacities toward a more balanced regional distribution (e.g., Germany with industrial load in the south but wind concentration in the north), or (iii) supporting the longer-term potential of a preferred new, innovative technology (such as offshore wind in Europe) by avoiding less expensive, more mature technologies that would crowd out more expensive technologies with cost-reduction potentials in the future (e.g., United Kingdom (UK), Netherlands).

HOW TO DESIGN TECHNOLOGY-NEUTRAL AND TECHNOLOGY-DIFFERENTIATED AUCTIONS

Designing fully technology-neutral auctions is complex. Creating a level playing field for technologies may require certain discriminatory design elements to consider technology specifics. Different technologies are characterized by different project development cycles and thus may be affected differently by auction design elements such as prequalification requirements, penalties, realization periods, and ceiling prices. For example, while the realization of offshore wind projects may take up to several years, solar PV projects can sometimes be realized within a few months. This discrepancy in realization times may provide an argument to differentiate design specifications in order to level the playing field between technologies, e.g., by setting technology-specific realization periods. On the other hand, policymakers may refrain from such measures if the aim is to select projects and technologies with the shortest delivery times despite the potential competitive disadvantages for some technologies. Long uniform grace periods in contracts increase the risk that investors for technologies with short realization periods will speculate on decreasing costs and delay projects.

International experience shows that countries have often implemented various degrees of technology differentiation as part of their auction design. Figure 3 provides an overview of design elements to differentiate between technologies in auctions on a continuum from low to high technology differentiation along with corresponding country examples. The most straightforward way to differentiate between technologies in the auction design process is to restrict the participation to certain technologies. Technology-neutral RE auctions exclude the participation of conventional technologies and let all RE technologies compete. Multi-technology auctions restrict participation to a specific, defined subset of RE technologies such as solar and wind. Technology-specific auctions, which are most common globally, limit participation to one RE technology only. The most pronounced types of technology-specific auctions are project-specific auctions, where the site and technology are predetermined; technology-neutral auctions are the least discriminatory.



Figure 3. Auction design elements to differentiate between technologies

Technology-neutral auctions including conventional and RE technologies have been particularly strong in several Latin American countries (e.g., Chile, Argentina, Mexico), even though some countries, such as Brazil and Colombia, have recently begun to shift toward the introduction of RE-exclusive technology-neutral auctions to support the introduction of RE (Box 1).

By contrast, RE-exclusive auctions have been more common in Europe, and most countries have implemented higher degrees of technology differentiation, such as technology-specific auctions where only one RE technology competes (e.g., Germany, France, and Denmark). In Africa, most energy auctions are not just technology specific but also project specific (e.g., Zambia, Uganda, Morocco). In Asia, many auctions are technology specific or even project specific (e.g., Malaysia, Cambodia, planned auction in Vietnam), but several countries such as India and Thailand have experimented with types of RE-only technology-neutral auctions.

To incorporate some of the benefits of more technology-differentiated designs without formally restricting the participation to one single technology, countries may also apply additional design elements that implicitly differentiate, e.g., through the project or energy characteristics, or explicitly differentiate between technologies. Two main options are feasible:

- (1) Qualification requirements that restrict participation and
- (2) Technology specifications or other criteria that guide the winner selection process.

IMPLEMENTATION OF QUALIFICATION REQUIREMENTS RESTRICTING PARTICIPATION

By setting qualification requirements for participating projects, projects of different technologies can be grouped according to certain technology characteristics, such as technology maturity level (e.g., in the United Kingdom) or generation profile (e.g., in California and Chile). Colombia (Box 1) has implemented qualification requirements that favor the participation of renewable energy projects that contribute to the reduction of CO₂ emissions. Countries like India (Box 2) and Thailand (Box 3) have implemented minimum qualification requirements on the firmness of electricity supply to be provided by winning projects, with an effect on the selection of awarded technologies.

TECHNOLOGY DIFFERENTIATION AS PART OF THE WINNER SELECTION PROCESS OR MULTI-CRITERIA AUCTIONS

Countries may also opt to implicitly or explicitly favor certain technologies or balance out technology differences as part of the winner selection process. This can be done by setting technology-specific minimum or maximum quotas, granting bonus payments for certain technologies, or imposing technology-specific price ceilings. Quotas or bonuses increase the competitive pressure on the stronger, *i.e.*, cheaper, technology group because they reduce the demand for this group (in the case of a quota) or increase the price competitiveness of the weaker group (in the case of a bonus). In theory, bonuses and quotas are equivalent: every price-based bonus can be implemented as a quantity-based quota with the same result as the bonus and vice versa. In practice, however, correctly calibrating a bonus is more difficult than setting a quota. In addition, quotas provide a clear signal to investors regarding available auction volumes. Technology-specific price ceilings can limit bid prices and thereby reduce the potential for windfall profits for lower-cost technologies. For example, the Netherlands (Box 4) incorporates technology-specific ceiling prices in their multi-technology RE auctions.

Moreover, multi-criteria auctions, with additional criteria other than bid prices—such as CO₂ footprint, geographic location, local content, or system-friendliness—influencing the bidder's score during the winner selection process, are able to incorporate additional policy objectives that influence the procured technology mix.

BOX 1: TECHNOLOGY-NEUTRAL AUCTIONS IN COLOMBIA SINCE 2019



Colombia conducted its first technology-neutral auction in February 2019 favoring variable RE participation via emission reduction qualification requirements to be fulfilled by participants before entering the auction.⁴ Key drivers included falling RE prices, greenhouse gas emission targets, and the diversification of a hydro-based power system vulnerable to droughts. However, due to antitrust requirements set to ensure sufficient competition, the auction resulted in no awards. Colombia relaunched this auction in October of the same year, limiting participation to VRE and increasing bid flexibility for buyers and sellers by introducing three time blocks for bidding, which did result in awarded energy.

BOX 2: SYSTEM-FRIENDLY RE AUCTIONS IN INDIA WITH DIFFERENT DEGREES OF TECHNOLOGY NEUTRALITY



Recently, India has held several system-friendly RE auctions with different degrees of technology neutrality. In January 2020, Solar Energy Corporation of India (SECI) successfully conducted a 1.2 gigawatt (GW) time-block tender⁶ open to solar, wind, and energy storage projects with guaranteed peak power supply. The tender was oversubscribed by 420 GW and resulted in bid prices with a weighted average as low as INR 4.04/kilowatt-hour (kWh) (5.7 cents/kWh).⁷ SECI refined the tender design to increase the system-friendliness of procured power. SECI allowed the use of energy storage or any other RE generation available during peak hours to make RE more dispatchable. SECI also prescribed time-based incentives to help match RE generation with the demand curve through the incorporation of peak and off-peak tariffs and strict capacity utilization factor (CUF) limits of at least 35 percent to ensure a certain power availability to off-takers. These changes were informed by a white paper on system-friendly procurement options for India⁸ developed by the U.S. Agency for International Development (USAID) Partnership to Advance Clean Energy Deployment (PACE-D 2.0 RE) program in consultation with SECI, state-level procurement agencies, distribution companies, renewable energy project developers, and the Ministry of New and Renewable Energy.

BOX 3: TECHNOLOGY-NEUTRAL RE AUCTIONS FOR FIRM ENERGY IN THAILAND



In 2017, Thailand's Ministry of Energy introduced a technology-neutral RE auction scheme with the aim of ensuring a continuous supply of electricity even during peak hours and increasing the uptake of RE. Participating projects of any RE technology needed to guarantee the delivery of 100 percent of contracted capacity, including a ± 2 percent tolerance margin during peak times (Monday–Friday, 9 a.m.–11 p.m.) and 65 percent of contracted capacity at all other times (off-peak). Non-compliance with the qualification requirement triggers a penalty of roughly 1.10 cents/kilowatt-hour (kWh), equivalent to 20 percent of the feed-in tariff of 5.48 cents/kWh. Due to their ability to provide firm energy at any time, most awarded bidders (300 megawatts (MW) total) were (dispatchable) biomass projects.⁵

BOX 4: TECHNOLOGY-SPECIFIC CEILING PRICES IN THE DUTCH MULTI-TECHNOLOGY RE AUCTIONS



Since 2011, the Netherlands has been conducting multi-technology auctions open to all RE technologies except offshore wind (for which separate auctions are organized) with the aim of a least-cost RE deployment.⁹ To account for different technology costs and limit potential windfall profits with adverse effects on consumer prices, technology-specific ceiling prices are implemented and adjusted per auction round.

⁴ https://www.usaid.gov/sites/default/files/documents/1865/SURE-Colombia_Energy-Auction_Bidding-Rules_01-2019_English-Unofficial.pdf

⁵ <https://d2oc0ihd6a5bt.cloudfront.net/wp-content/uploads/sites/837/2018/06/Khomgrich-Tantravanich-Competitive-Biddings-Renewable-Energy-Projects-in-Thailand-SPP-Hybrid-Firm.pdf>

⁶ Time blocks are supply commitments which require producers to guarantee continuous delivery during certain times or otherwise face penalties and require producers to purchase the missing electricity.

⁷ <https://mercomindia.com/greenko-renew-win-seci-solar-wind-auction-with-storage/>

⁸ <https://dec.usaid.gov/dec/GetDoc.axd?ctID=ODVhZjk4NWQzM2YyMi00YjRmLTcxMjM2NDhmY2Uy&rID=NTYxMzkw&plD=NTYw&attchmnt=True&uSesDM=False&rlDx=MjIxMDM5&rCFU=>

⁹ http://aures2project.eu/wp-content/uploads/2019/12/AURES_II_case_study_Netherlands.pdf

HOW TO ADDRESS ADDITIONAL OBJECTIVES IN TECHNOLOGY-NEUTRAL AND MULTI-TECHNOLOGY AUCTIONS

While promoting the efficiency of auction results (i.e., minimizing generation costs), fully technology-neutral designs often are unable to deliver on certain objectives (see Table 1). Nonetheless, policymakers may want to address certain objectives in their auction design without having to rely on higher degrees of technology differentiation (e.g., technology-specific auctions), especially if they have to comply with regulation that demands technology neutrality.

Table 2 provides an overview of basic options to incorporate the benefits of technology differentiation in technology-neutral and multi-technology auctions. For each of the four identified benefits of technology differentiation, Table 3 presents design options for both types of discriminatory elements outlined above—qualification requirements and discriminatory instruments as part of the winner selection process.

TABLE 2. DESIGN OPTIONS TO ADDRESS ADDITIONAL OBJECTIVES IN TECHNOLOGY-NEUTRAL AND MULTI-TECHNOLOGY AUCTIONS

BENEFITS OF TECHNOLOGY DIFFERENTIATION	QUALIFICATION REQUIREMENTS RESTRICTING PARTICIPATION OF TECHNOLOGIES	DIFFERENTIATION OF TECHNOLOGIES AS PART OF THE WINNER SELECTION PROCESS
Preselection of RE technologies to minimize total system costs	<p>Impose technical qualification requirements on bidders for providing firm energy and/or supplying during certain times of the day and/or year. For example, bidders may be subjected to a certain capacity utilization factor that encourages system-friendly installations, such as physical hybrids and RE + storage installations, that are able to provide a firmer power supply.</p> <p>Require bidders to supply electricity during certain times of the year and/or day (i.e., supply commitments). For example, generators may be required to provide electricity during certain times of the day which incentivizes technologies such as hydro, dispatchable concentrated solar power, and solar PV + storage.</p> <p>Introduce locational restrictions on sites. Generators may be required to place their installations in certain regions or connect to certain substations to reduce transmission constraints.</p>	<p>Implement non-price selection criteria accounting for the system value of a certain technology. This could include time-of-day and time-of-year price adjustment factors applied to the price paid to the producer, which incentivize/disincentivize electricity generation supplied at specific times of the day/year.</p> <p>Implement quotas or bonuses for system-friendly technologies accounting for system value and/or geographic location. For example, designers can implement a bonus/penalty for bids located in areas with available/insufficient grid capacities or capacity quotas at the regional level or grid connection point. Such quotas may impact the selection of technologies in the case of regional resource differences. For instance, deployment of onshore wind plants in an area with high wind resources could be restricted in favor of solar PV projects in less grid-constrained regions.</p>
Reduction of windfall profits for cheaper technologies	<p>Implement different technology bands to avoid significant cost differences between technologies competing in one auction. For example, a country could decide to establish a band for less mature technologies and a band for immature technologies.</p>	<p>Impose technology-specific ceiling prices for the cheaper technology to cap potential windfall profits. For example, if a bidder for a low-cost technology project is able to bid above its true costs of 5 cents/kilowatt-hour (kWh) at a bid price of 8 cents/kWh, a ceiling price of 6 cents/kWh could effectively reduce the potential windfall profits of this bidder.</p>

TABLE 2. DESIGN OPTIONS TO ADDRESS ADDITIONAL OBJECTIVES IN TECHNOLOGY-NEUTRAL AND MULTI-TECHNOLOGY AUCTIONS

BENEFITS OF TECHNOLOGY DIFFERENTIATION	QUALIFICATION REQUIREMENTS RESTRICTING PARTICIPATION OF TECHNOLOGIES	DIFFERENTIATION OF TECHNOLOGIES AS PART OF THE WINNER SELECTION PROCESS
Compliance with RPS, emission reduction targets and/or deployment goals for specific RE technologies	<p>Implement simultaneous multi-technology groups auctioning the specific technologies required to achieve specific RE targets. For example, in the UK, RE technologies are divided into different groups (Table 4). The first group targets established technologies such as onshore wind and solar PV, while the second group auctions capacities from less established technologies such as offshore wind and geothermal.</p>	<p>Introduce technology quotas. For example, if a country intends to award at least 50 megawatts (MW) of onshore wind in a technology-neutral auction, it can implement a minimum/maximum quota for this technology to ensure such projects are awarded. A bonus for the desired technology could also be implemented.</p> <p>Multi-criteria auctions with an additional CO₂-footprint selection criterion could help align technology-neutral auctions (both RE and conventional technologies) with emission reduction targets. Quotas for RE technologies may be another option.</p>
Promotion of secondary policy objectives (e.g., local industrial development)	<p>Impose technical qualification requirements in line with the specific policy goal to be followed. For example, a country may require that a certain percentage of equipment be sourced by local suppliers. This requirement favors technologies for which domestic supply chains exist.</p>	<p>Multi-criteria auctions with selection criteria other than bid price can help address secondary policy objectives. Similarly, bids complying with a desired policy objective could receive bonus payments.</p>

CASE STUDIES: CHILE AND THE UNITED KINGDOM

TABLE 3. TECHNOLOGY-NEUTRAL AUCTIONS BETWEEN RENEWABLE ENERGY AND CONVENTIONAL SOURCES IN CHILE SINCE 2014¹⁰

OBJECTIVE	Reduction of electricity tariffs, encouragement of market competition, reduction of electricity outages, facilitation of RE system integration, reduction of greenhouse gas (GHG) emissions, meeting long-term supply contracts in the context of growing demand.
DESCRIPTION OF DISCRIMINATORY DESIGN ELEMENTS	<p>Qualification requirements: Both RE and conventional technologies may compete for the provision of electricity (gigawatt-hours (GWh)) in hourly or seasonal supply blocks. The supply blocks consist of three intra-day (12–8 a.m. + 11 p.m.–12 a.m.; 8 a.m.–6 p.m.; 6–11 p.m.), and four, three-month seasonal blocks. Each of the blocks has a base (annual energy requirement) and a variable component (10 percent of base component). Hourly supply blocks allow RE producers to concentrate their contractual commitments to the times of day when they effectively generate electricity. The objective of the hourly blocks is to achieve the overall lowest price for every 24-hour period since each RE technology can optimize its feed-in potential and guarantee supply to distribution companies in line with its specific production profile. Production deviations from the supply commitment are settled by generators at spot market prices, thereby shifting generation risks to RE producers.</p>
EXPERIENCES	<p>Three auctions have been carried out under auction law 20805. The most recent auction was held in 2017, auctioning a volume of 2,200 GWh, which corresponded to roughly 600 megawatts (MW) of capacity. In this round, only RE projects won, with the majority of awarded bids going to wind and solar. The average bid price was \$3.25 cents/kilowatt-hour (kWh), and the lowest bid (for a solar plant) was \$2.15 cent/kWh,¹¹ which was also the lowest price ever recorded in the country. These low bid prices can be attributed to strong competition in the auction round, with the submitted bids reaching a volume nine times higher than the auction volume.¹² Overall, this points to high efficiency (<i>i.e.</i> the minimization of generation costs).</p> <p>While the participation of technologies is not restricted, hourly and seasonal supply blocks are designed in a way to favor certain RE technologies in the winner selection process. While quarterly blocks mainly favor wind and hydro, the hourly blocks benefit solar PV, since the latter—in line with its generation profile—can only bid in these blocks. Historically, tenders for electricity supply to regulated customers in Chile disadvantaged solar over other technologies as they had to commit to flat blocks of electricity for a whole year. This created significant short-term risk for solar generators, particularly during nighttime hours, when solar generators would need to purchase electricity on the wholesale market for amounts not delivered.</p>

¹⁰ Based on http://aures2project.eu/wp-content/uploads/2019/12/AURES_II_case_study_Chile.pdf

¹¹ <https://www.pv-magazine.com/2017/11/03/chiles-auction-concludes-with-average-price-of-32-5mwh/>

¹² *Ibid.*

TABLE 4. MULTI-TECHNOLOGY RENEWABLE ENERGY AUCTIONS: CONTRACTS FOR DIFFERENCE (CFD) IN THE UNITED KINGDOM¹³

OBJECTIVE	Introduction of competition within technology groups in order to limit producer surplus and reduce costs for consumers. More recently, the auction system has been more aligned with UK’s Industrial Strategy, ¹⁴ particularly in terms of the emphasis given to offshore wind as a key sector.
DESCRIPTION OF DISCRIMINATORY DESIGN ELEMENTS	<p>Qualification requirements: RE technologies are divided into different groups. The first group for established technologies includes onshore wind, solar, waste energy with combined heat and power (CHP), hydro (5–50 megawatts (MW)), landfill gas, and sewage gas. The second group for less established technologies includes offshore wind, biomass CHP, wave, tidal stream, advanced conversion technologies, anaerobic digestion, geothermal, and remote island onshore wind (only in the third auction round).</p> <p>Differentiation as part of the winner selection process: Technology-specific ceiling prices apply based on technology and finance cost estimates. In addition, minimum and maximum quotas for specific technologies may be set (in terms of MW or budget). For example, the first auction round in 2014–2015 implemented a minimum of ten MW for wave and tidal technologies. The second auction round set a cap of 150 MW for fueled technologies (biomass, advanced conversion technologies).</p>
EXPERIENCES	The average contract prices achieved in the first and second auction round seemed to be competitive when compared with administratively set ceiling prices and cost estimates. For the first auction round, the budget reserved for immature technologies in the second group was almost three times as high as the budget for the mature technology group, which resulted in more than half of the awarded bids going to offshore wind. The 150 megawatt (MW) capacity cap on fueled technologies in the second round (only group two) created a situation where larger fueled projects were rejected in favor of smaller, more expensive plants. This increased the clearing price, resulting in windfall profits for larger offshore wind projects. However, prices were still below the ceiling price due to previous changes in how the capacity cap operated.

¹³ Based on http://aures2project.eu/wp-content/uploads/2019/10/AURES_II_UK_case_study.pdf

¹⁴ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf

KEY TAKEAWAYS FOR POLICYMAKERS

TECHNOLOGY-NEUTRAL AND TECHNOLOGY-DIFFERENTIATED AUCTIONS MAY BE IMPLEMENTED TO PROMOTE DIFFERENT OBJECTIVES. Technology-neutral designs tend to promote the efficiency of auction results (i.e., the minimization of generation costs), allow for compliance with regulations requiring technology neutrality, and limit opportunities for regulatory capture of the technology selection. Technology-differentiated designs are better suited to account for RE system integration considerations, avoid windfall profits for cheaper technologies, and promote secondary policy objectives.

DESIGNING TECHNOLOGY-NEUTRAL AUCTIONS IS COMPLEX. Policymakers face a trade-off between creating a level playing field for technologies that may require certain discriminatory design elements and disregarding differences between technologies, leading to implicit disadvantages for some technologies.

RESTRICTING PARTICIPATION TO CERTAIN TECHNOLOGIES is the most obvious choice at the policymakers' disposal to implement technology differentiation (e.g., to a set of RE technologies or a single technology) in line with certain objectives.

CHOOSE DESIGN OPTIONS TO ADDRESS ADDITIONAL OBJECTIVES IN TECHNOLOGY-NEUTRAL AND MULTI-TECHNOLOGY AUCTIONS. One way to address additional objectives is to implement qualification requirements that restrict participation based on certain characteristics, such as technology maturity level or generation profile. Alternatively, elements such as technology-specific quotas, bonus payments, or ceiling prices may be implemented in the winner selection process to promote a desired technology mix. However, for the benefits of more differentiated designs to materialize, the responsible power system planner needs to have extensive knowledge and capacity to determine the desired long-term technology mix in the power system.

THE EFFECT OF TECHNOLOGY-NEUTRAL AUCTIONS DEPENDS ON THE ENERGY SECTOR CONTEXT. Market design, such as the existence of wholesale markets or balancing markets, can create price signals or additional revenue streams for some technologies, increasing their competitiveness. Similarly, the regulatory environment outside the auction design, such as grid-connection costs or priority dispatch, affects the competitiveness of technologies in the auction when such costs are reflected in the bid prices of project developers.

WITH TECHNOLOGY-NEUTRAL AUCTIONS, INTEGRATED RESOURCE PLANS NEED TO CHANGE from defining technology generation volumes to defining generation characteristics. Currently, many developing countries devise integrated resource plans that include technology-specific capacity additions. With technology-neutral auctions, governments should instead focus on the power characteristics (dispatchability, location, feed-in times) they wish to procure if they do not already have power markets sending the appropriate price signals.