Glossary of Terms

Anchor Data Set (ADS). Intended to be a compilation of load, resource, and transmission topology information used by the Regional Planning Groups (RPG) in the Western Interconnection as part of their regional transmission plans. The ADS can be used by other stakeholders in various planning analyses. WECC is developing the ADS process in partnership with the Western Planning Regions (WPR) and International Planning Regions (IPR).

annual technology baseline (ATB). The NREL ATB provides a consistent set of technology cost and performance data for energy analysis. The ATB is a populated framework to identify technology-specific cost and performance parameters or other investment decision metrics across a range of fuel prices as well as site-specific conditions for electric generation technologies at present and with projections through 2050.

Balancing Authority (BA). The responsible entity that integrates resource plans ahead of time, maintains load-interchange-generation balance within a Balancing Authority Area, and supports interconnection frequency in real time.

battery energy storage system (BESS). An electrochemical device that charges (or collects energy) from the grid or a power plant, then discharges that energy later to provide electricity or other grid services when needed [1].

behind-the-meter (BTM). A system that provides power that can be used on-site without passing through a meter. With a few exceptions, behind-the-meter systems are maintained and controlled by the end-use owner of the system, and electricity service providers have little or no control over or visibility on how they are operated other than what the meter provides. Behind-the-meter systems are often installed and operated to provide backup power, to manage load demand as part of a demand rate with the electricity service provider, and to sell excess power back to the electricity service provider.

bulk power system (BPS). The transmission power system where bulk power is produced, transmitted, and consumed at high voltages, usually 69 kV and above.

bus node. In power system modeling, a bus node is where a transmission line or several transmission lines are connected and may also include several components such as loads, generators, transformers, and capacitor banks in a power system. Quantities that characterize each bus node include voltage magnitude, phase angle of voltage, active power, reactive power, and location marginal pricing.

According to Kirchhoff's laws, the active and reactive power flows into and out of a bus node from connected transmission lines and components must sum to zero. The terms bus, node, and bus node collectively are often used interchangeable to mean the same thing.

candidate resource. Represents a new resource modeled in the 2040 clean energy case available as a candidate for commitment and dispatch by the production cost model. If dispatched by the production cost model over the course of a simulation for a case, it is then considered part of the final resource portfolio mix.

capacity factor (CF). The ratio of actual electrical energy output to the maximum possible electrical energy output over a given period. Also, the average dispatch (in megawatts) of a generation resource over a period (usually a year) divided by the maximum capacity (in megawatts) of the resource. Capacity factor is used to measure energy production capability (e.g., wind) or use (e.g., gas turbine) of a resource relative to its maximum capacity. Capacity factors are also used in resource capital expansion model tools to estimate annual energy production for a resource.

carbon dioxide. Chemical formula CO_2, an acidic colorless gas with a molecular structure consisting of a carbon atom covalently double bonded to two oxygen atoms. Carbon dioxide makes up most of the greenhouse gas emissions from the electricity sector [2].

compound annual growth rate (CAGR). As used in the context of annual energy consumption over a specific period, it is the average rate at which energy consumption grows compounded annually.

compressed air energy storage (CAES). Energy stored using compressed air. As is the case with other utility-scale generation, energy generated during low load demand periods can be stored and later released during high load demand periods. While compressed air energy storage systems can store energy for longer periods than battery energy storage systems, thermodynamically, compressed air leads to unwanted high temperatures that reduce operational efficiency and can lead to equipment damage.

congestion. In relation to a bulk power system, congestion is caused by transmission constraints such as a lack of transmission line capacity to deliver electricity without exceeding thermal, voltage, and stability limits designed to ensure reliability. In a production cost model, congestion represents a binding constraint in which line flows are at their limits and generation redispatch or load shedding is used to prevent a violation of line limits.

curtailment. A condition in which generation dispatch on the bulk power system exceeds load demand, requiring generation to be limited. When curtailment occurs, location marginal prices will become negative. Excess curtailments lead to extremes in negative location marginal prices. Generation from wind and hydro are typically the first resources to be curtailed, since they are dispatched as price takers. Resources that are dispatched based on price signals will have already responded to negative curtailment prices by dispatching their generation down.

demand response. An operational strategy in which demand for power can be curtailed or shifted during periods when reliability of the bulk power system or distribution power system is at risk.

demand-side management (DSM). A strategy in which load demand is managed to provide a more uniform consumption of electrical energy. Load factors are often used as a measure to gauge the effectiveness of a demand-side management program. Larger energy users such as commercial and industrial customers are often offered rates for which they are charged on demand and on energy usage and are given a discount on their energy use if they use an effective demand-side management program to maintain a higher load factor. Many load-serving entities have demand-side management programs residential customers are offered monthly fixed discounts on their electric bills in exchange for allowing them to install switches on large appliances that the entities can activate remotely when system demand levels are high.

distribution factor. A ratio representing a quantity share that a component part has to an aggregate quantity of parts in which the sum of distribution factors for the aggregates parts is equal to one. Context examples are Balancing Authority component share of generation to a state-level aggregate of generation or a bus node share of load to a Balancing Authority aggregate load.

distributed energy resource (DER). Also called distributed generation, distributed energy, on-site generation, or district/decentralized energy, is electrical generation and storage performed by a variety of small, distribution-system-connected devices. They can be directly connected to the distribution power system (e.g., utility operated) or connected behind the meter (e.g., end-user operated).

distribution power system (DPS). The distribution power system in which power from the bulk power system is transformed to lower voltages, usually 38 kV and below, and distributed to end-use consumers.

demand curve. A graph that shows the timing imbalance between hourly demand with and without offset dispatch adjustment from variable renewable energy dispatches (usually solar and, in some cases, with the inclusion of wind and battery dispatch and charging).

effective load carrying capability (ELCC). A metric to assess capacity credit, not only for wind generation plants, but for any power plant. This translates into an ELCC value that is typically a large percentage of the conventional plant rated capacity.

electric vehicle. A vehicle that uses an electric motor for propulsion. They can be road and rail vehicles, surface and underwater vessels, etc. Most road electric vehicles are powered by batteries. Most rail electric vehicles are powered directly from a distribution power system source.

electrification. Widespread application of electrical infrastructure in all U.S. economic sectors including residential, commercial, industrial, and transportation.

Electrification Futures Study (EFS). A study in which NREL explored the effects of widespread electrification in all U.S. economic sectors.

emerging clean and flexible resource (emerging clean flex). A generation technology type representing a possible emerging clean and flexible resource type with the same performance and flexibility characteristic of gas-fired generation that was introduced into the modeling of the sensitivity cases to overcome the challenges of variable renewable energy saturation at 90% clean and above. There are many emerging technologies that could play a significant role in achieving clean energy levels above 80%. Advances are being made in the areas of demand response, storage, hydrogen, and nuclear that have the potential to provide resource flexibility [3].

energy shifting. The process of storing energy when its production is high and load demand is low, then dispatching the stored energy when energy production is low and load demand is high.

Federal Energy Regulatory Commission (FERC). FERC is the U.S. federal agency that regulates the interstate transmission of natural gas, oil, and electricity. FERC also regulates natural gas and hydropower projects.

generation commitment. A decision, usually made day-ahead or longer, whether to make a generating unit available for dispatch. Generation commitment must be made least a day ahead because of the need to schedule gas (for gas-fired generation), minimum up and down times, and anticipated market prices. In the context of a production cost model—commitment generally refers to a day-ahead optimization. Commitment differs from dispatch in that dispatch is a decision on *how much* energy will be generated for a given hour, if the unit is available to do so (committed). An example of an exception to the day-ahead rule are units that are able to be called on for dispatch without explicitly being committed day-ahead, such as peaking units with their own fuel supplies.

generation dispatch. The amount of power (in megawatts) that a resource provides to the bulk power system. In the hourly context, it is the amount of energy (in megawatt hours) that a resource supplies to the bulk power system. In the context of a production cost model, dispatch is understood to be energy. In the context of power flow, dispatch is understood to be power. Dispatch differs from commitment in that the decision whether to dispatch is usually made hourly rather than a day ahead.

hourly resource. A production cost model resource type for which the dispatch for an hourly resource is modeled by a fixed hourly shape. An hourly resource is often described as "not dispatchable" since the dispatch for an hourly resource is fixed —not available to the production cost model to be optimized. The exception to this fixed-shape treatment of hourly resources is when generation exceeds load demand, then the generation from an hourly resource can be curtailed.

inverter-based resource (IBR). A resource such as wind, solar, or a battery energy storage system that is asynchronously connected to the bulk power system and dependent on power electronics (inverters)

to convert direct current (DC) power to alternating current (AC) power at the operating frequency of the bulk power system and in phase.

Kirchhoff's laws. Two equalities that deal with the current and voltage difference in a lumped element model of electrical circuits. Kirchhoff's first law stipulates that the algebraic sum of currents in a network of conductors meeting at a point (node) is zero. Kirchhoff's second law stipulates that the directed sum of the potential differences (voltages) around any closed loop is zero.

load factor. The ratio of average electrical load demand to peak load demand over a given period. Load factors close to 1.0 represent uniform and efficient electrical energy consumption patterns. Lower load factors are undesirable because they represent highly variable and inefficient energy consumption patterns. Higher load factors are desirable in the operation of a bulk power system because they represent electrical energy consumption patterns that do not fluctuate much and are easier to schedule and dispatch power around.

location marginal price (LMP). The price for electric energy (in dollars per megawatt hour) at different locations, accounting for the patterns of load, generation, and the physical limits of the transmission system. Location marginal prices are made up of three cost components: 1) energy—the price for electric energy at the "reference node," which is the load-weighted average of the system node prices; 2) congestion—the marginal cost of congestion at a given node relative to the reference node price; and 3) loss—the marginal cost of losses at a given node relative to the reference node price.

look-ahead. In the context of production cost model tools there are two types of optimizations that take place. 1) commitment of resources day-ahead, 2) hourly security constrained economic dispatch of resources. Where look-ahead logic is designed within a production cost model before a final look-ahead/day-ahead commitment is adopted, cursory non-look-ahead commitments and dispatches two or more days forward are performed. Prescient knowledge of possible outcomes from these cursory commitments and dispatches are then fed back to the final look-ahead/day-ahead logic before a final day-ahead commitment solution is made.

National Renewable Energy Laboratory (NREL). NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy LLC. NREL's focus is to find creative answers to today's energy challenges from breakthroughs in fundamental science to new clean technologies and integrated energy systems.

node. In the context of power system analysis, a node (or bus) is a point on the bulk power system where one or more transmission branch lines terminate, where the distribution power system loads may be represented, and where generators or other equipment may be located.

Operating and Maintenance cost (O&M). The functions, duties, and labor associated with daily operations. The goal is to preserve an asset so that it continues to provide reliable service throughout its expected lifetime. There are two forms of O&M costs associated with generation resources: 1) *fixed*

O&M (FOM)—costs that are incurred regardless of the energy produced by a process and are entered per unit of capacity over a fixed period (e.g., $/MW/month or $/MW/year), for instance, regular maintenance; 2) *variable O&M (VOM)*—costs that vary as a function of energy production (e.g., $/MWh) for example, the cost of water usage and treatment for cooling or boilers.

phase lock loop (PLL). A control system that generates an output signal whose phase is related to the phase of an input signal. Also called *phase-locked loop*. In the context of inverter-based resources, the purpose of a PLL system is to match the frequency and phase of power injected into the bulk power system at the same frequency and phase angle as detected at the terminal bus to which it is connected.

price taker. A term used in wholesale electrical energy markets to describe a resource that is bid upon and committed into energy markets irrespective of price. Variable renewable energy resources such as wind and solar are examples of price taking resources because they have no fuel costs and low O&M costs. In production cost model tools, price taking resources are modelled as hourly resources where their dispatch is fixed and not available to the production cost model for dispatch optimization.

probabilistic analysis. Analysis focused on the likelihood of the occurrence of outcomes based on historical patterns and trends.

production cost model (PCM). A tool that decreases production costs in the simulation of day-ahead commitments and hourly dispatches of generation resources to load on a bulk power system while enforcing operating (e.g., ramping) and security constraints (e.g., branch limits).

pumped storage hydro (PSH). A type of hydroelectric energy storage. It is a configuration of two water reservoirs at different elevations that can generate power as water moves down from one to the other (discharge), passing through a turbine. The system also requires power as it pumps water back into the upper reservoir (recharge). Pumped storage hydro acts like a battery in that it can store power then release it when needed [4].

qualified capacity. The amount of a resources generation capacity that can be depended upon during specific times of need (usually at peak demand). For instance, while a wind generation farm may have a maximum capacity of 100 MW, its probabilistic capacity at peak demand may only be 40 MW, in which case, its qualified capacity may be determined to be 40 MW rather than 100 MW.

ramping. The rate at which a generating resource is able to change its dispatch of power to balance with load demand.

resource capital expansion model (RCEM). A tool that minimizes investment costs to get optimal resource expansions (e.g., portfolio mixes) based on underlying desired assumptions, goals, and constraints.

resource flexibility. How assets in a power system can be operated to ensure that generation supply is balanced with load demand. There are many factors in the operation of a power system that pertain to

resource flexibility, including regulating generation to balance with load demand, responding to sudden shifts in demand or variable resources (e.g., ramping), and responding to contingencies (e.g., inertia).

Renewable Portfolio Standard (RPS). A regulatory mandate to increase production of energy from renewable sources such as wind, solar, biomass, and other alternatives to fossil-fueled and nuclear electric generation. Also known as a Renewable Electricity Standard [5].

resource adequacy. The concept of having enough energy production capability to serve energy consumption requirements in a given period.

resource stack. Sometimes referred to as supply stack, a collection of resources available for commitment and dispatch. In the context of energy production it is all resources that have produced energy in a given period. In the context of capacity it is resources that are available to meet capacity requirements. In the context of commitment and dispatch it is resources ordered by operating cost available for commitment or dispatch. Resources at the bottom of the stack are chosen first to meeting a commitment or dispatch need. There are usually several commitment and dispatch rules for which only resources with certain characteristics qualify, in which case specific resource stacks will be generated dynamically for each rule before the most economic resource is selected to satisfy a given rule.

security-constrained economic dispatch (SCED). A method of dispatch in which generation is balanced with load demand while minimizing overall generation dispatch subject to security constraints (e.g., transmission line ratings).

security constraints. Physical constraints on the bulk power system.

Scenarios Work Group (SWG). A WECC stakeholder work group. Through a scenario planning process, the work group describes plausible futures in which potential reliability risks could arise by identifying drivers of change, patterns of change, and the underlying systemic structures inducing these changes. Through scenario planning, the work group sets the context for WECC's reliability assessment activities in the 10-to-20-year planning horizon by creating scenario narratives upon which study cases are constructed and studied.

shoulder hours. The hours in which hourly demand approaches peak demand and peak demand drops off. It is during these hours that ramping capability from flexible resources is most needed.

transmission capital expansion model (TCEM). Tools that that decrease investment costs to get optimal transmission expansions based on underlying desired assumptions, goals, and constraints.

variable renewable energy (VRE) resources. Resources whose energy production is dependent on external factors such as weather (e.g., wind and solar) and less predictable than more conventional resources.

Western Interconnection. There are six bulk power system regions in North America of which the Western Interconnection is the largest and most geographically diverse. The Western Interconnection extends from Canada to Mexico and comprises the provinces of Alberta and British Columbia, the northern portion of Baja California, and the 11 Western states between.

Abbreviations

AC	alternating current
ADS	Anchor Data Set (WECC)
ATB	Annual Technology Baseline (NERC)
BA	Balancing Authority
BESS	battery energy storage system
BPS	bulk power system
CAES	compressed air energy storage
CAGR	compound annual growth rate
CapEx	capital expansion
CCS	carbon capture sequestration
CF	capacity factor
CO_2	carbon dioxide
CSP	concentrated solar power
DC	direct current
DER	distributed energy resource
DG	distributed generation
DPS	distribution power system
DSIRE	Database of State Incentives for Renewables and Efficiency
DSM	demand-side management
ECF	emerging clean and flexible
EFS	Electrification Futures Study (NREL)
ELCC	effective load carrying capability
EV	electric vehicle
FERC	Federal Energy Regulatory Commission
GHG	greenhouse gas
GW	gigawatt
GWh	gigawatt hour
IBR	inverter-based resource
JHSMINE	johns hopkins stochastic multi-stage integrated network expansion
LF	load factor
LIB	lithium-ion battery
LMP	locational marginal price

MW	megawatt
MWh	megawatt hour
NERC	North American Electric Reliability Corporation
NREL	national renewable energy laboratory
O&M	operating and maintenance
PCM	production cost model
PLL	phase lock loop
PSH	pumped storage hydro
PV	photovoltaic
RA	resource adequacy
RCEM	resource capital expansion model
RPS	renewable portfolio standard
SMR	small modular reactor
SWG	scenarios work group (wecc)
TCEM	transmission capital expansion model
TW	terawatt
TWh	terawatt hour
VRE	variable renewable energy
WECC	Western Electricity Coordinating Council
West	Western Interconnection

References

[1] National Renewable Energy Laboratory (NREL), "Grid-Scale Battery Storage—Frequently Asked Questions," 2019. [Online]. Available: https://www.nrel.gov/docs/fy19osti/74426.pdf. [Accessed 2021].

[2] United States Environmental Protection Agency, "Sources of Greenhouse Gas Emissions," 2021. [Online]. Available: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

[3] K. Highstreet and P. Rudnicki, "WECC Schultz Fellowship Final Report," 2021. [Online]. Available: https://www.wecc.org/Administrative/Shultz%20Fellows%20Final%20Report.docx.

[4] Office of Energy Efficiency & renewable Energy—Water Power Technologies Office, "Pumped Storage Hydropower," 2021. [Online]. Available: https://www.energy.gov/eere/water/pumped-storage-hydropower.

[5] NC Clean Energy Technology Center, "Database of State Incentives for Renewables & Efficiency (DSIRE)," 2021. [Online]. Available: https://www.dsireusa.org/.