2018 Renewable Resources Assessment

PacifiCorp

2018 Renewable Resources Assessment
Project No. 109571

Revision 3
October 2018

2018 Renewable Resources Assessment

prepared for

PacifiCorp
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Salt Lake City, Utah

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prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

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1.0 INTRODUCTION

PacifiCorp (Owner) retained Burns & McDonnell Engineering Company (BMcD) to evaluate various renewable energy resources in support of the development of the Owner's 2019 Integrated Resource Plan (IRP) and associated resource acquisition portfolios and/or products. The 2018 Renewable Resources Assessment (Assessment) is screening-level in nature and includes a comparison of technical capabilities, capital costs, and O&M costs that are representative of renewable energy and storage technologies listed below.

It is the understanding of BMcD that this Assessment will be used as preliminary information in support of the Owner's long-term power supply planning process. Any technologies of interest to the Owner should be followed by additional detailed studies to further investigate each technology and its direct application within the Owner's long-term plans.

1.1 Evaluated Technologies

- Single Axis Tracking Solar
- Onshore Wind
- Energy Storage
  - Pumped Hydro Energy Storage (PHES)
  - Compressed Air Energy Storage (CAES)
  - Lithium Ion Battery
  - Flow Battery
- Solar + Energy Storage
- Wind + Energy Storage

1.2 Assessment Approach

This report accompanies the Renewable Resources Assessment spreadsheet files (Summary Tables) provided by BMcD. The Summary Tables are broken out into three separate files for Solar, Wind, and Energy Storage options. The costs are expressed in mid-2018 dollars for a fixed price, turn-key resource implementation. Appendix A includes the Summary Tables.

This report compiles the assumptions and methodologies used by BMcD during the Assessment. Its purpose is to articulate that the delivered information is in alignment with PacifiCorp's intent to advance its resource planning initiatives.

1.3 Statement of Limitations

Estimates and projections prepared by BMcD relating to performance, construction costs, and operating and maintenance costs are based on experience, qualifications, and judgment as a professional consultant. BMcD has no control over weather, cost and availability of labor, material and equipment, labor productivity, construction contractor's procedures and methods, unavoidable delays, construction contractor's method of determining prices, economic conditions, government regulations and laws (including interpretation thereof), competitive bidding and market conditions or other factors affecting such estimates or projections. Actual rates, costs, performance ratings, schedules, etc., may vary from the data provided.

2.0 STUDY BASIS AND ASSUMPTIONS

2.1 Scope Basis

Scope and economic assumptions used in developing the Assessment are presented below. Key assumptions are listed as footnotes in the summary tables, but the following expands on those with greater detail for what is assumed for the various technologies.

2.2 General Assumptions

The assumptions below govern the overall approach of the Assessment:

- All estimates are screening-level in nature, do not reflect guaranteed costs, and are not intended for budgetary purposes. Estimates concentrate on differential values between options and not absolute information.
- All information is preliminary and should not be used for construction purposes.
- All capital cost and O&M estimates are stated in mid-2018 US dollars (USD). Escalation is excluded.
- Estimates assume an Engineer, Procure, Construct (EPC) fixed price contract for project execution.
- Unless stated otherwise, all wind and solar options are based on a generic site with no existing structures or underground utilities and with sufficient area to receive, assemble and temporarily store construction material. Battery options are assumed to be located on existing Owner land.
- Sites are assumed to be flat, with minimal rock and with soils suitable for spread footings.
- Wind and solar technologies were evaluated across five states within Owner's service areas: Washington, Oregon, Idaho, Utah, and Wyoming. The specific locations within each state for potential wind/solar sites were determined by Owner.
- All performance estimates assume new and clean equipment. Operating degradation is excluded.
- Electrical scope is assumed to end at the high side of the generator step up transformer (GSU) unless otherwise specified in the summary table (most notably for CAES and PHES).
- Demolition or removal of hazardous materials is not included.

2.3 EPC Project Indirect Costs

The following project indirect costs are included in capital cost estimates:

- Construction/startup technical service
- Engineering and construction management

- Freight
- Startup spare parts
- EPC fees & contingency

2.4 Owner Costs

Allowances for Owner's costs are included in the pricing estimates. The cost buckets for Owner's costs varies slightly by technology, but is broken out in the summary tables in Appendix A.

2.5 Cost Estimate Exclusions

The following costs are excluded from all estimates:

- Financing fees
- Interest during construction (IDC)
- Escalation
- Performance and payment bond
- Sales tax
- Property taxes and insurance
- Off-site infrastructure
- Utility demand costs
- Decommissioning costs
- Salvage values

2.6 Operating and Maintenance Assumptions

Operations and maintenance (O&M) estimates are based on the following assumptions:

- O&M costs are based on a greenfield facility with new and clean equipment.
- O&M costs are in mid-2018 USD.
- Property taxes allowance included for solar and onshore wind options.
- Land lease allowance included for PV and onshore wind options.
- Li-Ion battery O&M includes costs for additional cells to be added over time.

3.0 SOLAR PHOTOVOLTAIC

This Assessment includes 5 MW, 50 MW, and 200 MW single axis tracking photovoltaic (PV) options evaluated at five locations within the PacifiCorp services area.

3.1 PV General Description

The conversion of solar radiation to useful energy in the form of electricity is a mature concept with extensive commercial experience that is continually developing into a diverse mix of technological designs. PV cells consist of a base material (most commonly silicon), which is manufactured into thin slices and then layered with positively (i.e. Phosphorus) and negatively (i.e. Boron) charged materials. At the junction of these oppositely charged materials, a "depletion" layer forms. When sunlight strikes the cell, the separation of charged particles generates an electric field that forces current to flow from the negative material to the positive material. This flow of current is captured via wiring connected to an electrode array on one side of the cell and an aluminum back-plate on the other. Approximately 15% of the solar energy incident on the solar cell can be converted to electrical energy by a typical silicon solar cell. As the cell ages, the conversion efficiency degrades at a rate of approximately 2% in the first year and 0.5% per year thereafter. At the end of a typical 30-year period, the conversion efficiency of the cell will still be approximately 80% of its initial efficiency.

3.2 PV Performance

BMcD pulled Typical Meteorological Year (TMY) weather data for each site to determine expected hourly irradiance. BMcD then ran simulations of each PV option using PVSYST software. The resultant capacity factors for single axis tracking systems are shown in the Summary Tables. Inverter loading ratios (ILR) for each base plant nominal output at the point of electrical interconnect are indicated in Table 3-1.

Table 3-1: Inverter Loading Ratios in Assessment

Nominal Output	Single-Axis Tracking (SAT) DC/AC Ratio
5 MW	1.32
50 MW	1.46
200 MW	1.46

There are different panel technologies which may exhibit different performance characteristics depending on the site. This assessment assumes poly-crystalline panels. The alternative, thin film technologies, are typically cheaper per panel, but they are also less energy dense, so it’s likely that more panels would be required to achieve the same output. In addition, the two technologies respond differently to shaded conditions. The two technologies are also impacted differently by current solar tariffs which has also impacted availability of the two.

Appendix B shows the PVSYST model output for a 5 MW block with the input assumptions, losses, and output summary. Appendix C shows an additional output summary page unique for each solar option size and location. TMY data for each site as well as PVSYST 8760 outputs are provided to accompany this report outside of the formal report appendices.

3.3 PV Cost Estimates

Cost estimates were developed using in-house information based on BMcD project experience as an EPC contractor as well as an Owner's Engineer for EPC solar projects. Cost estimates assume an EPC project plus typical Owner's costs. A typical solar project cash flow is included in Appendix F.

PV cost estimates for the single axis tracking systems are included in the Summary Tables. Costs are based on the DC/AC ratios in Table 4-1 above, and $/kW costs, based on the nominal AC output, are shown in Appendix A. The project scope assumes a medium voltage interconnection for the 5 MW options, and a high voltage interconnection for the 50 and 200 MW options. Owner's costs include a switchyard allowance for the larger scale options, but no transmission upgrade costs or high voltage transmission interconnect line costs are included.

PV installed costs have steadily declined for years. The main drivers of cost decreases include substantial module price reductions, lower inverter prices, and higher module efficiency. However, recent US tariffs have had an impact on PV panels and steel imports. Pricing in the summary table is based on actual competitive EPC market quotes since these tariffs have been in place to take into account this impact. The panel tariffs only impact crystalline solar modules, however the availability of CdTe is limited for the next couple years, so it is prudent to assume similar cost increases for thin film panels until the impacts of the tariff are clearer.

The 2018 Assessment excludes land costs from capital and Owner costs. It is assumed that all PV projects will be on leased land with allowances provided in the O&M costs.

3.4 PV O&M Cost Estimate

O&M costs for the PV options are shown in the Summary Tables. O&M costs are derived from BMcD project experience and vendor information. The 2018 Assessment includes allowances for land lease and property tax costs.

The following assumptions and clarifications apply to PV O&M:

- O&M costs assume that the system is remotely operated and that all O&M activities are performed through a third-party contract. Therefore, all O&M costs are modeled as fixed costs, shown in terms of $MM per year.
- Land lease and property tax allowances are included based on in house data from previous projects.
- Equipment O&M costs are included to account for inverter maintenance and other routine equipment inspections.
- BOP costs are included to account for monitoring & security and site maintenance (vegetation, fencing, etc.).
- Panel cleaning and snow removal are not included in O&M costs.
- The capital replacement allowance is a sinking fund for inverter replacements, assuming they will be replaced once during the project life. It is a 15-year levelized cost based on the current inverter capital cost.

3.5 PV Plus Storage

The PV plus storage options combine the PV technology discussed in section 3.0 with the lithium ion batteries described in section 7.0. The battery storage size is set at approximately 25% of the total nominal output of the base solar options, with options for two, four, and eight hours of storage duration.

The storage system is assumed to be electrically coupled to the PV system on the AC side, meaning the PV and storage systems have separate inverters. However, there are use cases such as PV clipping that may be better served by a DC-DC connection. In a DC coupled system, the storage side would have a DC-DC voltage converter and connect to the PV system upstream of the DC-AC inverters. For a clipping application, a DC-DC connection allows the storage system to capture the DC output from the PV modules that may have otherwise been clipped by the inverters. Further study beyond the scope of this assessment would be required to determine the best electrical design for a particular application or site, but at this level of study, the capital costs provided are expected to be suitable for either AC or DC coupled systems.

Capital costs are show as add-on costs, broken out as project and owner's costs. These represent the additional capital above the PV base cost, intended to capture modest savings to account for shared system costs such as transformer(s) and switchgear. In addition, overlapping owner costs are eliminated or reduced. Finally, a line for O&M add-on costs is also included which can be added with the base PV O&M costs to determine overall facility O&M.

As with the Li-Ion battery options, the co-located storage option assumes an operation profile of one cycle per day, which is used for calculating the O&M costs.

4.0 ON-SHORE WIND

4.1 Wind Energy General Description

Wind turbines convert the kinetic energy of wind into mechanical energy, which can be used to generate electrical energy that is supplied to the grid. Wind turbine energy conversion is a mature technology and is generally grouped into two types of configurations:

- Vertical-axis wind turbines, with the axis of rotation perpendicular to the ground.
- Horizontal-axis wind turbines, with the axis of rotation parallel to the ground.

Over 95 percent of turbines over 100 kW are horizontal-axis. Subsystems for either configuration typically include the following: a blade/rotor assembly to convert the energy in the wind to rotational shaft energy; a drive train, usually including a gearbox and a generator; a tower that supports the rotor and drive train; and other equipment, including controls, electrical cables, ground support equipment and interconnection equipment.

Wind turbine capacity is directly related to wind speed and equipment size, particularly to the rotor/blade diameter. The power generated by a turbine is proportional to the cube of the prevailing wind, that is, if the wind speed doubles, the available power will increase by a factor of eight. Because of this relationship, proper siting of turbines at locations with the highest possible average wind speeds is vital.

Appendix D includes NREL wind resource maps for Idaho, Oregon, Utah, Washington, and Wyoming with the locations of interest marked as provided by Owner.

4.2 Wind Performance

This Assessment includes 200 MW onshore wind generating facilities in Idaho, Oregon, Utah, Washington, and Wyoming service areas. BMcD relied on publicly available data and proprietary computational programs to complete the net capacity factor characterization. Generic project locations were selected within the area specified by Owner.

The Vestas V136-3.6 and GE3.8-137 wind turbine models were assumed for this analysis. The respective nameplate capacity, rotor diameter, and a hub height are provided in the Table 4-1. The maximum tip height of this package is under 500 feet, which means there are less likely to be conflicts with the Federal Aviation Administration (FAA) altitudes available for general aircraft. A generic power curve at standard atmospheric conditions for each of the sites was assumed for the V136-3.6 and GE3.8-137. Note that this turbine is intended only to be representative of a typical International Electrotechnical Commission wind turbine. Because this analysis assumes generic site locations, the turbine selection is not optimized for a specific location or condition. Actual turbine selection requires further site-specific analysis.

Table 4-1: Summary of Wind Turbine Model Information

	Vestas V136-3.6	GE3.8-137
Name Plate Capacity, MW	3.6	3.6
Rotor Diameter, meters	136	137
Hub Height, meters	80	80

Using the NREL wind resource maps, the mean annual hub height wind speed at each potential project location was estimated and then extrapolated for the appropriate hub height to determine a representative wind speed. Using a Rayleigh distribution and power curve for the turbine technology described above, a gross annual capacity factor (GCF) was subsequently estimated for each site for both turbine types.

Annual losses for a wind energy facility were estimated at approximately 17 percent, which is a common assumption for screening level estimates in the wind industry. This loss factor was applied to the gross capacity factor estimates to derive a net annual capacity factor (NCF) for each potential site. Ideally, a utility-scale generation project should have an NCF of 30 percent or better. The NCF estimates for the PacifiCorp service areas are shown in the Summary Tables and represent an average of the two evaluated technologies.

4.3 Wind Cost Estimate

The wind energy cost estimate is shown in the Summary Tables. A typical cash flow for a wind project is included in Appendix F. Cost estimates assume an EPC project plus typical Owner's costs. Costs are based on a 200 MW plant with 3.6 MW turbines (56 total turbines) and 80-meter hub heights.

- Equipment and construction costs are broken down into subcategories per PacifiCorp's request. These breakouts represent the general scale of a 200 MW wind project but are not intended to indicate the expected scope for a specific site.
- The EPC scope includes a GSU transformer for interconnection at 230 kV.
- Land costs are excluded from the EPC and Owner's cost. For the 2018 Study, it is assumed that land is leased, and those costs are incorporated into the O&M estimate.

- Cost estimates also exclude escalation, interest during construction, financing fees, off-site infrastructure, and transmission.

4.4 Wind Energy O&M Estimates

O&M costs in the Summary Tables are derived from in-house information based on BMcD project experience and vendor information. Wind O&M costs are modeled as fixed O&M, including all typical operating expenses including:

- Labor costs
- Turbine O&M
- BOP O&M and other fixed costs (G&A, insurance, environmental costs, etc.)
- Property taxes
- Land lease payments

An allowance for capital replacement costs is not included within the annual O&M estimate in the Summary Table. A capital expenditures budget for a wind farm is generally a reserve that is funded over the life of the project that is dedicated to major component failures. An adequate capital expenditures budget is important for the long-term viability of the project, as major component failures are expected to occur, particularly as the facility ages.

If a capital replacement allowance is desired for planning purposes, Table 4-2 shows indicative budget expectations as a percentage of the total operating cost. As with operating expenses, however, these costs can vary with the type, size, or age of the facility, and project-specific considerations may justify deviations in the budgeted amounts.

Table 4-2: Summary of Indicative Capital Expenditures Budget by Year

Operational Years	Capital Expenditure Budget
0 – 2	None (warranty)
3 – 5	3% – 5%
6 – 10	5% – 10%
11 – 20	10% – 15%
21 – 30	15% – 20%
31 – 40	20% – 25%

4.5 Wind Energy Production Tax Credit

Tax credits such as the production tax credit (PTC) and investment tax credit (ITC) are not factored into the cost or O&M estimates in this Assessment, but an overview of the PTC is included below for reference.

To incentivize wind energy development, the PTC for wind was first included in the Energy Policy Act of 1992. It began as a $15/MWh production credit and has since been adjusted for inflation, currently worth approximately $24/MWh.

The PTC is awarded annually for the first 10 years of a wind facility's operation. Unlike the ITC that is common in the solar industry, there is no upfront incentive to offset capital costs. The PTC value is calculated by multiplying the $/MWh credit times the total energy sold during a given tax year. At the end of the tax year, the total value of the PTC is applied to reduce or eliminate taxes that the owners would normally owe. If the PTC value is greater than the annual tax bill, the excess credits can potentially go unused unless the owner has a suitable tax equity partner.

Since 1992, the changing PTC expiration/phaseout schedules have directly impacted market fluctuations, driving wind industry expansions and contractions. The PTC is currently available for projects that begin construction by the end of 2019, but with a phaseout schedule that began in 2017. Projects that started construction in 2015 and 2016 will receive the full value of the PTC, but those that start(ed) construction in later years will receive reduced credits:

- 2017: 80% of the full PTC value
- 2018: 60% of the full PTC value
- 2019: 40% of the full PTC value
- 2020: PTC Expires

To avoid receiving a reduction in the PTC, a "Safe Harbor" clause allowed for developers to avoid the reduction through an upfront investment in wind turbines by the end of 2016. The Safe Harbor clause allowed for wind projects to be considered as having begun construction by the end of the year if a minimum of 5% of the project's total capital cost was incurred before January 1st, 2017.

Many wind farms were planned for construction and operation when it was assumed they would receive 100% of the PTC. However, with the reduction in the PTC, some of these projects are no longer financially viable for developers to operate. This may result in renegotiated or canceled PPAs, or transfers to utilities for operation.

4.6 Wind Plus Storage

The wind plus storage options combine the wind technology discussed in section 4.0 with the lithium ion batteries described in section 7.0. The battery storage size is set at approximately 25% of the total nominal output of the base solar options, with options for two, four, and eight hours of storage duration. The storage system is assumed to be electrically coupled to the wind system on the AC side, meaning the storage system has its own inverter.

Capital costs are shown as add-on costs, broken out as project and owner's costs. These represent the additional capital above the wind base cost, intended to capture modest savings to account for shared system costs such as transformer(s) and switchgear. In addition, overlapping owner costs are eliminated or reduced. Finally, a line for O&M add-on costs is also included which can be added to the base wind O&M costs to determine overall facility O&M. As with the Li-Ion battery options, the co-located storage option assumes an operation profile of one cycle per day, which is used for calculating the O&M costs.

5.0 PUMPED HYDRO ENERGY STORAGE

5.1 General Description

Pumped-hydro Energy Storage (PHES) offers a way of storing off peak generation that can be dispatched during peak demand hours. This is accomplished using a reversable pump-turbine generator-motor where water is pumped from a lower reservoir to an upper reservoir using surplus off-peak electrical power. Energy is then recaptured by releasing the water back through the turbine to the lower reservoir during peak demand. To utilize PHES, locations need to be identified that have suitable geography near high-voltage transmission lines.

PHES provides the ability to optimize the system for satisfying monthly or even seasonal energy needs and PHES can provide spinning reserve capacity with its rapid ramp-up capability. Energy stored off-peak and delivered on-peak can help reduce on-peak prices and is therefore beneficial to consumers. PHES is well suited for markets where there is a high spread in day-time and night-time energy costs, such that water can be pumped at a low cost and used to generate energy when costs are considerably higher.

PHES also has the ability to reduce cycling of existing generation plants. Additionally, PHES has a direct benefit to renewable resources as it is able to absorb excess energy that otherwise would need to be curtailed due to transmission constraints. This could increase the percentage of power generated by clean technologies and delivered during peak hours.

5.2 PHES Cost Estimate

The PHES cost estimate was based on information provided by developers with limited scope definition. We aligned the costs as closely as possible based on the information provided. The reason information from developers was used versus using a generic site for PHES is due to the significant importance of geographical location for this type of energy storage. The cost estimate is shown in the Summary Tables. PHES can see life cycle benefits as their high capital cost is offset by long lifespan of assets.

6.0 COMPRESSED AIR ENERGY STORAGE

6.1 General Description

Compressed air energy storage (CAES) offers a way of storing off peak generation that can be dispatched during peak demand hours. CAES is a proven, utility-scale energy storage technology that has been in operation globally for over 30 years. To utilize CAES, the project needs a suitable storage site, either above ground or below ground, and availability of transmission and fuel source. CAES facilities use off-peak electricity to power a compressor train that compresses air into an underground reservoir at approximately 850 psig. Energy is then recaptured by releasing the compressed air, heating it (typically) with natural gas firing, and generating power as the heated air travels through an expander.

This method of operation takes advantage of less expensive, off-peak power to charge the system to later be used for generation during periods of higher demand. CAES provides the ability to optimize the system for satisfying monthly, or even seasonal, energy needs and CAES can provide spinning reserve capacity with its rapid ramp-up capability. Energy stored off-peak and delivered on-peak can help reduce on-peak prices and is therefore beneficial to consumers. Additionally, CAES has a direct benefit to renewable resources as it is able to absorb excess energy that otherwise would need to be curtailed due to transmission constraints. This could increase the percentage of power generated by clean technologies and delivered during peak hours.

There have been two commercial CAES plants built and operated in the world. The first plant began commercial operations in 1978 and was installed near Huntorf, Germany. This 290 MW facility included major equipment by Brown, Boveri, and Company (BBC). The second is located near McIntosh, Alabama and is currently owned and operated by PowerSouth (originally by Alabama Electric Cooperative). This 110 MW facility began commercial operations in 1991 and employs Dresser Rand (DR) equipment. BMcD served as the Owner's engineer for this project.

"Second generation" CAES designs have recently been developed, but do not have commercial operating experience. The compression-expansion portion of these designs is similar to "first generation" CAES designs. The designs differ in that a simple cycle gas turbine plant operates in parallel to the compression-expansion train and the exhaust is used in a recuperator instead of utilizing a combustor to preheat the stored air.

CAES is well suited for markets where there is a high spread in day-time and night-time energy costs, such that air can be compressed at a low cost and used to generate energy when costs are considerably higher.

6.2 CAES Cost Estimate

The CAES cost estimate is shown in the Summary Tables. It was developed using generic Siemens information that includes the power island, balance of plant and reservoir. Cost estimates assume an EPC project plus typical Owner's costs.

6.3 CAES Emissions Control

A Selective Catalytic Reduction (SCR) system is utilized in the CAES design along with demineralized water injection in the combustor to achieve NOx emissions of 2 parts per million, volumetric dry (ppmvd). A carbon monoxide (CO) catalyst is also used to control CO emissions to 2 ppmvd at the exit of the stack.

The use of an SCR and a CO catalyst requires additional site infrastructure. An SCR system injects ammonia into the exhaust gas to absorb and react with the exhaust gas to strip out NOx. This requires onsite ammonia storage and provisions for ammonia unloading and transfer.

7.0 BATTERY STORAGE TECHNOLOGY

This Assessment includes standalone battery options for both lithium ion (Li-Ion) and flow battery technologies. Li-Ion options included 1 MW output with 15-minute, 2-hour, 4-hour, and 8-hour storage capacities as well as a 15 MW option with 4-hours of storage. A 1 MW, 6-hour flow cell battery option was also included. Additionally, the solar and wind summary tables include optional costs for adding Li-Ion battery capacity of 25% of the nominal renewable output to the site with 2, 4, or 8-hours of storage.

7.1 General Description

Electrochemical energy storage systems utilize chemical reactions within a battery cell to facilitate electron flow, converting electrical energy to chemical energy when charging and generating an electric current when discharged. Electrochemical technology is continually developing as one of the leading energy storage and load following technologies due to its modularity, ease of installation and operation, and relative design maturity. Development of electrochemical batteries has shifted into three categories, commonly termed “flow,” “conventional,” and “high temperature” battery designs. Each battery type has unique features yielding specific advantages compared to one another.

7.1.1 Flow Batteries

Flow batteries utilize an electrode cell stack with externally stored electrolyte material. The flow battery is comprised of positive and negative electrode cell stacks separated by a selectively permeable ion exchange membrane, in which the charge-inducing chemical reaction occurs, and liquid electrolyte storage tanks, which hold the stored energy until discharge is required. Various control and pumped circulation systems complete the flow battery system in which the cells can be stacked in series to achieve the desired voltage difference.

The battery is charged as the liquid electrolytes are pumped through the electrode cell stacks, which serve only as a catalyst and transport medium to the ion-inducing chemical reaction. The excess positive ions at the anode are allowed through the ion-selective membrane to maintain electroneutrality at the cathode, which experiences a buildup of negative ions. The charged electrolyte solution is circulated back to storage tanks until the process is allowed to repeat in reverse for discharge as necessary.

In addition to external electrolyte storage, flow batteries differ from traditional batteries in that energy conversion occurs as a direct result of the reduction-oxidation reactions occurring in the electrolyte solution itself. The electrode is not a component of the electrochemical fuel and does not participate in the chemical reaction. Therefore, the electrodes are not subject to the same deterioration that depletes electrical performance of traditional batteries, resulting in high cycling life of the flow battery. Flow batteries are also scalable such that energy storage capacity is determined by the size of the electrolyte storage tanks, allowing the system to approach its theoretical energy density. Flow batteries are typically less capital intensive than some conventional batteries but require additional installation and operation costs associated with balance of plant equipment.

7.1.2 Conventional Batteries

A conventional battery contains a cathodic and an anodic electrode and an electrolyte sealed within a cell container that can be connected in series to increase overall facility storage and output. During charging, the electrolyte is ionized such that when discharged, a reduction-oxidation reaction occurs, which forces electrons to migrate from the anode to the cathode thereby generating electric current. Batteries are designated by the electrochemicals utilized within the cell; the most popular conventional batteries are lead acid and Li-Ion type batteries.

Lead acid batteries are the most mature and commercially accessible battery technology, as their design has undergone considerable development since conceptualized in the late 1800s. The Department of Energy (DOE) estimates there is approximately 110 MW of lead acid battery storage currently installed worldwide. Although lead acid batteries require relatively low capital cost, this technology also has inherently high maintenance costs and handling issues associated with toxicity, as well as low energy density (yields higher land and civil work requirements). Lead acid batteries also have a relatively short life cycle at 5 to 10 years, especially when used in high cycling applications.

Li-Ion batteries contain graphite and metal-oxide electrodes and lithium ions dissolved within an organic electrolyte. The movement of lithium ions during cell charge and discharge generates current. Li-Ion technology has seen a resurgence of development in recent years due to its high energy density, low self-discharge, and cycling tolerance. Many Li-Ion manufacturers currently offer 15-year warranties or performance guarantees. Consequently, Li- Ion has gained traction in several markets including the utility and automotive industries.

Li-Ion battery prices are trending downward, and continued development and investment by manufacturers are expected to further reduce production costs. While there is still a wide range of project cost expectations due to market uncertainty, Li-Ion batteries are anticipated to expand their reach in the utility market sector.

7.1.3 High Temperature Batteries

High temperature batteries operate similarly to conventional batteries, but they utilize molten salt electrodes and carry the added advantage that high temperature operation can yield heat for other applications simultaneously. The technology is considered mature with ongoing commercial development at the grid level. The most popular and technically developed high temperature option is the Sodium Sulfur (NaS) battery. Japan-based NGK Insulators, the largest NaS battery manufacturer, installed a 4 MW system in Presidio, Texas in 2010 following operation of systems totaling more than 160 MW since the project's inception in the 1980s.

The NaS battery is typically a hermetically sealed cell that consists of a molten sulfur electrolyte at the cathode and molten sodium electrolyte at the anode, separated by a Beta-alumina ceramic membrane and enclosed in an aluminum casing. The membrane is selectively permeable only to positive sodium ions, which are created from the oxidation of sodium metal and pass through to combine with sulfur resulting in the formation of sodium polysulfides. As power is supplied to the battery in charging, the sodium ions are dissociated from the polysulfides and forced back through the membrane to re-form elemental sodium. The melting points of sodium and sulfur are approximately 98ºC and 113ºC, respectively. To maintain the electrolytes in liquid form and for optimal performance, the NaS battery systems are typically operated and stored at around 300ºC, which results in a higher self-discharge rate of 14 percent to 18 percent. For this reason, these systems are usually designed for use in high-cycling applications and longer discharge durations.

NaS systems are expected to have an operable life of around 15 years and are one of the most developed chemical energy storage technologies. However, unlike other battery types, costs of NaS systems have historically held, making other options more commercially viable at present.

7.2 Battery Emissions Controls

No emission controls are currently required for battery storage facilities. However, Li-Ion batteries can release large amounts of gas during a fire event. While not currently an issue, there is potential for increased scrutiny as more battery systems are placed into service.

7.3 Battery Storage Performance

This assessment includes performance for multiple Li-Ion options as well as one flow battery option. Li-Ion systems can respond in seconds and exhibit excellent ramp rates and round-trip cycle efficiencies. Because the technology is rapidly advancing, there is uncertainty regarding estimates for cycle life, and these estimates vary greatly depending on the application and depth of discharge. The systems in this Assessment are assumed to perform one full cycle per day, and capacity factors are based on the duration of full discharge for 365 days. OEMs typically have battery products that are designed to suit different use-cases such as high power or high energy applications. The power to energy ratio is commonly shown as a C-ratio (for example, a 1MW / 4 MWh system would use a 0.25C battery product). However, the 8-hour battery option is based on a 0.25C system that is sized for twice the power and discharged for eight hours instead of four. While the technology continues to advance, commercially available, high energy batteries for utility scale applications are generally 0.25C and above.

Flow batteries are a maturing technology that is well suited for longer discharge durations (>4 hours, for example). Flow batteries can provide multiple use cases from the same system and they are not expected to exhibit performance degradation like lithium ion technologies. However, they typically have lower round trip efficiency than Li-Ion batteries. Storage durations are currently limited to commercial offerings from select vendors but are expected to broaden over the next several years. Performance guarantees of 20 years are expected with successful commercialization, but there is not necessarily a technical reason that original equipment manufacturer (OEM) and/or balance of plant (BOP) designs could not accommodate 30+ year life.

7.4 Regulatory Trends

Two (2) Federal Energy Regulatory Commission (FERC) Orders released in 2018 are expected to provide clarity on the role of storage in wholesale markets, and potentially drive continued growth. FERC Order 841 requires RTOs and ISOs to develop clear rules regulating the participation of energy storage systems in wholesale energy, capacity, and ancillary services markets. Prior to the final release of FERC 841, the California Public Utilities Commission introduced 11 rules to determine how multi-use storage products participate in California Independent System Operator (CAISO). FERC Order 842 addresses requirements for some generating facilities to provide frequency response, including accommodations for storage technologies. In addition, the Internal Revenue Service (IRS) is considering new guidance for the ITC that will impact projects combining storage with renewables.

7.5 Battery Storage Cost Estimate

The estimated costs of the Li-Ion and flow battery systems are included in the Summary Tables, based on BMcD experience and vendor correspondence. The key cost elements of a Li-Ion battery system are the inverter, the battery cells, the interconnection, and the installation. The capital costs reflect recent trends for overbuild capacity to account for short term degradation. The battery enclosures include space for future augmentation, but the costs associated with augmentation are covered in the O&M costs. It is assumed that land is available at an existing PacifiCorp facility and is therefore excluded from the cost estimate. These options assume the battery interconnects at medium voltage.

Flow battery estimates for the 1 MW option are based on zinc-bromine technology with a 6-hour storage duration. This is a modular design in which the OEM scope includes the stack, electrolyte storage, and associated pumps and controls in a factory assembled package. The EPC scope includes the inverters, switchgear, MV transformer, and installation.

7.6 Battery Storage O&M Cost Estimate

O&M estimates for the Li-Ion and flow battery systems are shown in the Summary Tables, based on BMcD experience and recent market trends. The battery storage system is assumed to be operated remotely.

The technical life of a Li-Ion battery project is expected to be 15 years, but battery performance degrades over time, and this degradation is considered in the system design. Systems can be "overbuilt" by including additional capacity in the initial installation, and they can also be designed for future augmentation. Augmentation means that designs account for the addition of future capacity to maintain guaranteed performance.

Overbuild and augmentation philosophies can vary between projects. Because battery costs are expected to continue falling, many installers/integrators are aiming for lower initial overbuild percentages to reduce initial capital costs, which means guarantees and service contracts will require more future augmentation to maintain capacity. Because costs should be lower in the future, the project economics may favor this approach. This assessment assumes minimal overbuild beyond system efficiency losses, and the O&M estimates include allowances for augmentation.

Battery storage O&M costs are modeled to represent the fixed and variable portions of performance guarantees and augmentation from recent BMcD project experience. The fixed O&M cost for the Li-Ion systems include a nominal fixed cost to administer and maintain the O&M contract with an OEM/integrator, plus an allowance for calendar degradation fees. Calendar degradation represents performance degradation and subsequent augmentation expected to occur regardless of the system's operation profile, even if the batteries sit unused. Because calendar degradation is not tied to system operation or output, it is modeled as part of the fixed O&M.

Variable O&M estimates for Li-ion options account for cycling degradation fees. Cycling the batteries increases performance degradation, so the performance guarantees provided by the OEM and/or integrator are commonly modeled to account for augmentation based on the expected operating profile. The variable O&M estimates in this assessment are based on an operation profile of one charge/discharge cycle per day and may not be valid for increased cycling.

Flow battery O&M costs are modeled around an annual service contract from the OEM or a factory trained third party. Costs are based on correspondence with manufacturers and are subject to change as the technology achieves greater commercialization and utilization in the utility sector. Unlike Li-Ion technologies, flow batteries generally do not exhibit calendar or cycle degradation, so there is not a variable O&M component per cycle. There is mechanical equipment that requires service based on an OEM recommended schedule, which is modeled as a levelized annual cost for the life of the system.

8.0 CONCLUSIONS

This Renewable Energy Resource Technology Assessment provides information to support PacifiCorp's power supply planning efforts. Information provided in this Assessment is screening level in nature and is intended to highlight indicative, differential costs associated with each technology. BMcD recommends that PacifiCorp use this information to update production cost models for comparison of renewable resource alternatives and their applicability to future resource plans. PacifiCorp should pursue additional engineering studies to define project scope, budget, and timeline for technologies of interest.

Renewable options include PV and wind systems. PV is a proven technology for daytime peaking power and a viable option to pursue renewable goals. PV capital costs have steadily declined for years, but recent import tariffs on PV panels and foreign steel may impact market trends. Wind energy generation is a proven technology and turbine costs dropped considerably over the past few years.

Utility-scale battery storage systems are being installed in varied applications from frequency response to arbitrage, and recent cost reduction trends are expected to continue. Li-Ion technology is achieving the greatest market penetration, aided in large part by its dominance in the automotive industry, but other technologies like flow batteries should be monitored, as well.

PacifiCorp's region has several geological sites that can support large scale storage options including PHES and CAES. This gives PacifiCorp flexibility in terms of energy storage. Smaller applications will be much better suited for battery technologies, but if a larger need is identified PHES or CAES could provide excellent larger scale alternatives. Both of these technologies benefit from economies of scale in regard to their total kWh of storage, allowing them to decrease the overall $/kWh project costs.

APPENDIX A – SUMMARY TABLES

PACIFICORP RENEWABLE TECHNOLOGY ASSESSMENT SUMMARY TABLE
ENERGY STORAGE

PROJECT TYPE	**Pumped Hydro**						**Li-Ion Battery**					**Flow Battery**
BASE PLANT DESCRIPTION	**Swan Lake**	**Goldendale**	**Seminoe**	**Flat Canyon**	**Idaho PS 1**							
Nominal Output	400 MW 3,800 MWh	1200 MW 16,800 MWh	700 MW 7,000 MWh	300 MW 1,800 MWh	360 MW 2,880 MWh	320 MW 15,360 MWh	1 MW 0.25 MWh	1 MW 2 MWh	1 MW 4 MWh	1 MW 8 MWh	15 MW 60 MWH	1 MW 6 MWh
Capacity Factor (%)	17%	17%	17%	17%	17%	20%	2%	8%	17%	33%	17%	25%
Startup Time (Cold Start), minutes	1.5	1.5	1.5	1.5	1.5	10	N/A	N/A	N/A	N/A	N/A	N/A
Full Pumping to Full Gen, minutes	4	4	4	4	4	7	N/A	N/A	N/A	N/A	N/A	N/A
Transition Time from Charging to Discharging, minutes (note 10)	6	6	6	6	6	3	<1 sec in active mode	<1 sec in active mode	<1 sec in active mode	<1 sec in active mode	<1 sec in active mode	<1 sec in active mode
Availability Factor, %	90%	90%	90%	90%	90%	96%	97%	97%	97%	97%	97%	95%
Technology Rating	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Commercial
Life Cycle, yrs	60	60	60	60	60	30+	15	15	15	15	15	20
Permitting & Construction Schedule, year (note 1)	6	10	8	6	12	3	1	1	1	1	1	2
ESTIMATED PERFORMANCE												
Base Load Performance @ (Annual Average)												
Net Plant Output, kW	393,300	1,200,000	700,000	300,000	360,000	320,000	1,000	1,000	1,000	1,000	15,000	1,000
Total Plant Storage, kWh (note 4)	3,736,350	16,800,000	7,000,000	1,800,000	2,880,000	15,360,000	250	2,000	4,000	8,000	60,000	6,000
Time for Full Discharge, hours	9.5	14	10	6	8	48	0.25	2	4	8	4	6
Time for Full Charge, hrs	9.5	14	12	7.5	8	192	0.3	2.3	4.6	9.2	4.6	8
Heat Rate (HHV), Btu/kWh	N/A	N/A	N/A	N/A	N/A	4,230	N/A	N/A	N/A	N/A	N/A	N/A
Round-Trip Efficiency (%) (note 5)	79%	79%	79%	79%	79%	55%	88%	88%	88%	88%	88%	65%
ESTIMATED CAPITAL AND O&M COSTS (Note 11)												
EPC Project Capital Costs, 2018 MM$ (w/o Owner's Costs)	**$814**	**$2,146**	**$1,352**	**$545**	**$635**	**$384**	**$1.0**	**$1.8**	**$2.5**	**$3.8**	**$21.8**	**$2.8**
Owner's Costs, 2018 MM$	**$163**	**$429**	**$270**	**$109**	**$127**	**$77**	**$0.4**	**$0.6**	**$0.6**	**$0.8**	**$2.1**	**$0.7**
Owner's Project Development	Included	Included	Included	Included	Included	Included	$0.1	$0.1	$0.1	$0.1	$0.2	$0.1
Owner's Engineer	Included	Included	Included	Included	Included	Included	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
Owner's Project Management	Included	Included	Included	Included	Included	Included	$0.1	$0.1	$0.1	$0.1	$0.2	$0.1
Owner's Legal Costs	Included	Included	Included	Included	Included	Included	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
Permitting and Licensing Fees	Included	Included	Included	Included	Included	Included	$0.1	$0.1	$0.1	$0.1	$0.2	$0.1
Generation Switchyard (note 6)	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	N/A	N/A	N/A	N/A	N/A	N/A
Transmission to Interconnection Point	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	N/A	N/A	N/A	N/A	N/A	N/A
Training/Testing	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
Land	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	Assumes Co-located	Assumes Co-located	Assumes Co-located	Assumes Co-located	Assumes Co-located	Assumes Co-located
Builders Risk Insurance (0.45% of Project Cost)	Included	Included	Included	Included	Included	Included	$0.00	$0.01	$0.01	$0.02	$0.1	$0.01
Owner's Contingency	Included	Included	Included	Included	Included	Included	$0.1	$0.1	$0.1	$0.2	$1.1	$0.2
Total Screening Level Project Costs, 2018 MM$	**$977**	**$2,575**	**$1,622**	**$654**	**$762**	**$461**	**$1.4**	**$2.4**	**$3.1**	**$4.7**	**$24.0**	**$3.5**
EPC Project Costs, 2018 $/kW	**$2,070**	**$1,790**	**$1,930**	**$1,820**	**$1,760**	**$1,200**	**$990**	**$1,780**	**$2,470**	**$3,850**	**$1,450**	**$2,790**
EPC Project Costs, 2018 $/kWh	**$220**	**$130**	**$190**	**$300**	**$220**	**$30**	**$3,940**	**$890**	**$620**	**$480**	**$360**	**$460**
Total Screening Level Project Costs, 2018 $/kW	**$2,480**	**$2,150**	**$2,320**	**$2,180**	**$2,120**	**$1,440**	**$1,420**	**$2,380**	**$3,110**	**$4,670**	**$1,600**	**$3,520**
Total Screening Level Project Costs, 2018 $/kWh	**$260**	**$150**	**$230**	**$360**	**$260**	**$30**	**$5,670**	**$1,190**	**$780**	**$580**	**$400**	**$590**
O&M Cost, 2018 MM$/yr	$7	$15	$12	$5	$6	$2	$0.009	$0.035	$0.056	$0.094	$0.489	$0.032
Fixed O&M Cost, 2018 MM$/yr							$0.008	$0.024	$0.035	$0.052	$0.172	$0.032
Variable O&M Cost, 2018 MM$/yr							$0.001	$0.011	$0.021	$0.042	$0.317	Incl. in FOM

Notes

Note 1. Permitting & Construction Schedule is based on earliest COD date for some of the pumped hydro options
Note 2. Swan Lake Capital Cost and Fixed O&M Cost is middle of range given by Rye Development and National Grid Ventures
Note 3. Owner's cost is assumed to be 20% of capital costs for pumped hydro and CAES options. Based on information provided by developers and includes items listed above.
Note 4. CAES storage is based on full charge. Typical operation is to not fully discharge, but rather to discharge only a portion of the capacity to maintain cavern pressure.
Note 5. Round trip efficiency for CAES is based on the electric energy input to compress air plus the energy in the gas input compared to the electrical output.
Note 6. Battery options (Li-Ion and Flow) assumes interconnection at distribution voltage and therefore excludes GSU and switchyard.
Note 7. Battery O&M assumes the site is remotely controlled. Capital costs assume the system is slightly oversized initially to accommodate normal degradation at the start of the project life, and then degradation supplement cost throughout the project life. O&M accounts for the parasitic power draw of the system, including HVAC and efficiency losses.

Note 8. Pumped Hydro O&M excludes major maintenance cost items, like generator rewinds, that are viewed as end of life repairs to extend the intended life of the asset.
Note 9. Battery capacity factor and annual O&M is based on one full cycle per day.
Note 10. CAES storage supports simultaneous operation of compression and expansion.
Note 11. EPC and Owner's Cost estimates exclude AFUDC, Sales Tax, Insurance and Property Tax During Construction

PACIFICORP RENEWABLE TECHNOLOGY ASSESSMENT SUMMARY TABLE
SOLAR GENERATION

PROJECT TYPE	Solar Photovoltaic - Single Axis Tracking														
PROJECT LOCATION	Idaho Falls, ID			Lakeview, OR			Milford, UT			Rock Springs, WY			Yakima, WA		
BASE PLANT DESCRIPTION	**5 MW**	**50 MW**	**200 MW**	**5 MW**	**50 MW**	**200 MW**	**5 MW**	**50 MW**	**200 MW**	**5 MW**	**50 MW**	**200 MW**	**5 MW**	**50 MW**	**200 MW**
Nominal Output, MW	5	50	200	5	50	200	5	50	200	5	50	200	5	50	200
Annualized Energy Production, MWh (Yr 1)	11,597	122,929	491,714	12,292	130,139	520,556	13,451	142,375	569,501	12,355	131,702	526,808	10,609	114,065	456,258
AC Capacity Factor at POI (%) (Note 1)	26.5%	28.1%	28.1%	28.1%	29.7%	29.7%	30.7%	32.5%	32.5%	28.2%	30.1%	30.1%	24.2%	26.0%	26.0%
Availability Factor, % (Note 2)	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
Assumed Land Use, Acres	40	400	1600	40	400	1600	40	400	1600	40	400	1600	40	400	1600
PV Inverter Loading Ratio (DC/AC)	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
PV POI Ratio (DC/AC)	1.32	1.46	1.46	1.32	1.46	1.46	1.32	1.46	1.46	1.32	1.46	1.46	1.32	1.46	1.46
PV Degradation, %/yr (Note 3)	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year	1st year: 2% After 1st Year: 0.5% per year
Technology Rating	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature
Permitting & Construction Schedule, year	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
ESTIMATED PERFORMANCE															
Base Load Performance @ (Annual Average)															
Net Plant Output, kW	5,000	50,000	200,000	5,000	50,000	200,000	5,000	50,000	200,000	5,000	50,000	200,000	5,000	50,000	200,000
ESTIMATED CAPITAL AND O&M COSTS (Note 7)															
EPC Project Capital Costs, 2018 MM$ (w/o Owner's Costs)	**$7**	**$71**	**$277**	**$8**	**$76**	**$297**	**$7**	**$71**	**$276**	**$7**	**$70**	**$275**	**$8**	**$76**	**$296**
Modules	$2	$27	$107	$2	$27	$107	$2	$27	$107	$2	$27	$107	$2	$27	$107
Racking w/ Piles	$1	$9	$35	$1	$9	$35	$1	$9	$35	$1	$9	$35	$1	$9	$35
Inverter & MV Transformer	$0	$3	$13	$0	$3	$13	$0	$3	$13	$0	$3	$13	$0	$3	$13
Labor, Materials, and BOP Equiment	$2	$25	$102	$3	$30	$121	$2	$25	$101	$2	$25	$100	$3	$30	$120
Project Indirects, Fee, and Contingency	$1	$7	$20	$1	$7	$21	$1	$7	$20	$1	$7	$20	$1	$7	$21
Owner's Costs, 2018 MM$	**$1**	**$54**	**$67**	**$2**	**$54**	**$68**	**$1**	**$54**	**$67**	**$1**	**$54**	**$67**	**$2**	**$54**	**$68**
Owner's Project Development	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3
Owner's Project Management	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
Owner's Legal Costs	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3
Permitting and Licensing Fees	$0.4	$0.5	$0.6	$0.4	$0.5	$0.6	$0.4	$0.5	$0.6	$0.4	$0.5	$0.6	$0.4	$0.5	$0.6
Generation Switchyard (Note 5)	$0.0	$2.0	$2.0	$0.0	$2.0	$2.0	$0.0	$2.0	$2.0	$0.0	$2.0	$2.0	$0.0	$2.0	$2.0
Transmission Interconnection (Note 8)	$0.0	$34.5	$34.5	$0.0	$34.5	$34.5	$0.0	$34.5	$34.5	$0.0	$34.5	$34.5	$0.0	$34.5	$34.5
Transmission Interconnection Application and Upgrades (Note 9)	$0.0	$9.8	$9.8	$0.0	$9.8	$9.8	$0.0	$9.8	$9.8	$0.0	$9.8	$9.8	$0.0	$9.8	$9.8
Land (Note 4)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Operating Spare Parts	$0.0	$0.4	$1.6	$0.0	$0.4	$1.6	$0.0	$0.4	$1.6	$0.0	$0.4	$1.6	$0.0	$0.4	$1.6
Builders Risk Insurance (0.45% of Project Cost)	$0.0	$0.3	$1.2	$0.0	$0.3	$1.3	$0.0	$0.3	$1.2	$0.0	$0.3	$1.2	$0.0	$0.3	$1.3
Owner's Contingency	$0.4	$5.9	$16.4	$0.4	$6.2	$17.4	$0.4	$5.9	$16.3	$0.4	$5.9	$16.3	$0.4	$6.2	$17.3
Total Screening Level Project Costs, 2018 MM$	**$9**	**$125**	**$343**	**$9**	**$130**	**$365**	**$9**	**$125**	**$343**	**$9**	**$124**	**$342**	**$9**	**$130**	**$364**
EPC Project Costs, 2018 $/kW	**$1,430**	**$1,420**	**$1,380**	**$1,520**	**$1,520**	**$1,490**	**$1,420**	**$1,410**	**$1,380**	**$1,420**	**$1,410**	**$1,380**	**$1,510**	**$1,510**	**$1,480**
Total Screening Level Project Costs, 2018 $/kW	**$1,720**	**$2,500**	**$1,720**	**$1,820**	**$2,600**	**$1,820**	**$1,720**	**$2,490**	**$1,710**	**$1,710**	**$2,490**	**$1,710**	**$1,810**	**$2,600**	**$1,820**
O&M Cost, 2018 MM$/yr	$0.2	$2.0	$8.1	$0.2	$2.0	$8.1	$0.2	$2.0	$8.1	$0.2	$2.0	$8.1	$0.2	$2.0	$8.1
O&M Cost, 2018 $/kW-yr	$42.20	$40.40	$40.40	$42.20	$40.40	$40.40	$42.20	$40.40	$40.40	$42.20	$40.40	$40.40	$42.20	$40.40	$40.40
Co-Located Energy Storage - 2 hr Capacity	1 MW | 2 MWh	10 MW | 20 MWh	50 MW | 100 MWh	1 MW | 2 MWh	10 MW | 20 MWh	50 MW | 100 MWh	1 MW | 2 MWh	10 MW | 20 MWh	50 MW | 100 MWh	1 MW | 2 MWh	10 MW | 20 MWh	50 MW | 100 MWh	1 MW | 2 MWh	10 MW | 20 MWh	50 MW | 100 MWh
Add-On Costs															
Capital Costs, 2018 MM$	$1.7	$10.8	$33.7	$1.9	$11.6	$36.3	$1.7	$10.8	$33.7	$1.7	$10.8	$33.7	$1.9	$11.6	$36.3
Owner's Costs, 2018 MM$	$0.5	$1.2	$2.7	$0.5	$1.3	$2.8	$0.5	$1.2	$2.7	$0.5	$1.2	$2.7	$0.5	$1.3	$2.8
Incremental O&M Cost, 2018 MM$/Yr	$0.03	$0.19	$0.77	$0.03	$0.19	$0.77	$0.03	$0.19	$0.77	$0.0	$0.19	$0.77	$0.03	$0.19	$0.77
Co-Located Energy Storage - 4 hr Capacity	1 MW | 4 MWh	10 MW | 40 MWh	50 MW | 200 MWh	1 MW | 4 MWh	10 MW | 40 MWh	50 MW | 200 MWh	1 MW | 4 MWh	10 MW | 40 MWh	50 MW | 200 MWh	1 MW | 4 MWh	10 MW | 40 MWh	50 MW | 200 MWh	1 MW | 4 MWh	10 MW | 40 MWh	50 MW | 200 MWh
Add-On Costs															
Capital Costs, 2018 MM$	$2.4	$16.3	$58.7	$2.6	$17.6	$63.3	$2.4	$16.3	$58.7	$2.4	$16.3	$58.7	$2.6	$17.6	$63.3
Owner's Costs, 2018 MM$	$0.6	$1.5	$4.0	$0.6	$1.6	$4.28	$0.4	$1.5	$4.0	$0.4	$1.5	$4.0	$0.4	$1.6	$4.3
Incremental O&M Cost, 2018 MM$/Yr	$0.06	$0.35	$1.43	$0.06	$0.35	$1.43	$0.06	$0.35	$1.43	$0.0	$0.35	$1.43	$0.06	$0.35	$1.43
Co-Located Energy Storage - 8 hr Capacity	1 MW | 8 MWh	10 MW | 80 MWh	50 MW | 400 MWh	1 MW | 8 MWh	10 MW | 80 MWh	50 MW | 400 MWh	1 MW | 8 MWh	10 MW | 80 MWh	50 MW | 400 MWh	1 MW | 8 MWh	10 MW | 80 MWh	50 MW | 400 MWh	1 MW | 8 MWh	10 MW | 80 MWh	50 MW | 400 MWh
Add-On Costs															
Capital Costs, 2018 MM$	$3.8	$26.6	$107.8	$4.1	$28.6	$116.2	$3.8	$26.6	$107.8	$3.8	$26.6	$107.8	$4.1	$28.7	$116.2
Owner's Costs, 2018 MM$	$0.6	$2.1	$6.7	$0.7	$2.2	$7.2	$0.8	$2.1	$6.7	$0.8	$2.1	$6.7	$0.8	$2.2	$7.2
Incremental O&M Cost, 2018 MM$/Yr	$0.09	$0.63	$2.72	$0.09	$0.63	$2.72	$0.09	$0.63	$2.72	$0.0	$0.63	$2.72	$0.09	$0.63	$2.72

Notes

Note 1. Solar capacity factor accounts for typical losses. 50 and 200 MW options have AC capacity overbuilt for high voltage losses. Additional inverters and economic efficiencies for overbuilding for larger sizes results in the capacity factor different between the two larger sizes and the 5 MW installation.
Note 2. Availability estimates are based on vendor correspondence and industry publications.
Note 3. PV degradation based on typical warranty information for polycrystalline products. Assuming factory recommended maintenance is performed, PV performance is estimated to degrade ~2% in the first year and 0.5% each following year. The first year 2% degradation is accounted for in the PVSyst model output for year 1.
Note 4. PV projects assume that land is leased and therefore land costs are included in O&M, not capital costs. Assumes eight acres per MW for tracking.
Note 5. 5 MW options assume interconnection at medium voltage. 50 & 200 MW options assume high voltage connection with switchyard.
Note 6. Oregon and Washington cost estimates assume union labor.
Note 7. EPC and Owner's Cost estimates exclude AFUDC, Sales Tax, Insurance and Property Tax During Construction
Note 8. Transmission interconnect allowance assumes 15 miles of transmission line at high voltage for 50 & 200 MW options. Land costs are excluded.
Note 9. Transmission interconnect application costs and upgrade costs are representative only. These costs can vary greatly depending on the site location and existing infrastructure.

PACIFICORP RENEWABLE TECHNOLOGY ASSESSMENT SUMMARY TABLE
WIND GENERATION

PROJECT TYPE	**Onshore Wind**				
PROJECT LOCATION	**Pocatello, ID**	**Arlington, OR**	**Monticello, UT**	**Medicine Bow, WY**	**Goldendale, WA**
BASE PLANT DESCRIPTION	**200 MW**	**200 MW**	**200 MW**	**200 MW**	**200 MW**
Nominal Output, MW	200	200	200	200	200
Number of Turbines	56 x 3.6 MW	56 x 3.6 MW	56 x 3.6 MW	56 x 3.6 MW	56 x 3.6 MW
Capacity Factor (Note 1)	37.1%	37.1%	29.5%	43.6%	37.1%
Availability Factor, % (Note 2)	95%	95%	95%	95%	95%
Assumed Land Use, Acres	56	56	56	56	56
Technology Rating	Mature	Mature	Mature	Mature	Mature
Permitting & Construction Schedule, year	2.5	2.5	2.5	2.5	2.5
ESTIMATED PERFORMANCE					
Base Load Performance @ (Annual Average)					
Net Plant Output, kW	200,000	200,000	200,000	200,000	200,000
ESTIMATED CAPITAL AND O&M COSTS (Note 6)					
Project Capital Costs, 2018 MM$ (w/o Owner's Costs)	**$228**	**$229**	**$228**	**$228**	**$228**
Wind Turbine Generators	$160	$160	$160	$160	$161
Roads	$5	$5	$5	$5	$5
O&M Building	$2	$2	$2	$2	$2
Collection System	$8	$8	$8	$8	$8
Other BOP, Materials, Labor, Indirects	$53	$54	$53	$53	$53
Owner's Costs, 2018 MM$	**$103**	**$103**	**$103**	**$103**	**$103**
Project Development (Note 3)	$22.8	$22.8	$22.8	$22.8	$22.8
Wind Resource Assessment	$1.0	$1.0	$1.0	$1.0	$1.0
Land Control	$2.4	$2.4	$2.4	$2.4	$2.4
Permitting and Licensing Fees	$3.2	$3.2	$3.2	$3.2	$3.2
Generation Switchyard	$2.0	$2.0	$2.0	$2.0	$2.0
Transmission Interconnection (Note 7)	$34.5	$34.5	$34.5	$34.5	$34.5
Transmission Interconnection Application and Upgrades (Note 8)	$9.8	$9.8	$9.8	$9.8	$9.8
Land (Note 4)	$0.0	$0.0	$0.0	$0.0	$0.0
Operating Spare Parts	Included in O&M	Included in O&M	Included in O&M	Included in O&M	Included in O&M
Temporary facilities and Construction Utilities	$12.0	$12.0	$12.0	$12.0	$12.0
Builders Risk Insurance (0.45% of Project Cost)	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs	Included in Project Costs
Owner's Contingency	$15.8	$15.8	$15.8	$15.8	$15.8
Total Screening Level Project Costs, 2018 MM$	**$332**	**$333**	**$332**	**$332**	**$332**
EPC Project Costs, 2018 $/kW	**$1,140**	**$1,150**	**$1,140**	**$1,140**	**$1,140**
Total Screening Level Project Costs, 2018 $/kW	**$1,660**	**$1,660**	**$1,660**	**$1,660**	**$1,660**
O&M Cost, 2018 MM$/yr	$10.2	$10.2	$9.8	$9.2	$9.8
O&M Cost, 2018 $/kW-yr	$51.0	$51.0	$49.0	$46.0	$49.0
Co-Located Energy Storage - 2 hr Capacity	50 MW | 100 MWh	50 MW | 100 MWh	50 MW | 100 MWh	50 MW | 100 MWh	50 MW | 100 MWh
Add-On Costs					
Capital Costs, 2018 MM$	$33.7	$35.9	$33.7	$33.7	$35.8
Owner's Costs, 2018 MM$	$2.7	$2.8	$2.7	$2.7	$2.8
Incremental O&M Cost, 2018 MM$/Yr	$0.77	$0.77	$0.77	$0.77	$0.77
Co-Located Energy Storage - 4 hr Capacity	50 MW | 200 MWh	50 MW | 200 MWh	50 MW | 200 MWh	50 MW | 200 MWh	50 MW | 200 MWh
Add-On Costs					
Capital Costs, 2018 MM$	$58.7	$62.6	$58.7	$58.7	$62.5
Owner's Costs, 2018 MM$	$4.0	$4.3	$4.0	$4.0	$4.3
Incremental O&M Cost, 2018 MM$/Yr	$1.4	$1.4	$1.4	$1.4	$1.4
Co-Located Energy Storage - 8 hr Capacity	50 MW | 400 MWh	50 MW | 400 MWh	50 MW | 400 MWh	50 MW | 400 MWh	50 MW | 400 MWh
Add-On Costs					
Capital Costs, 2018 MM$	$107.8	$114.9	$107.8	$107.8	$114.8
Owner's Costs, 2018 MM$	$6.7	$7.2	$6.7	$6.7	$7.2
Incremental O&M Cost, 2018 MM$/Yr	$2.7	$2.7	$2.7	$2.7	$2.7

Notes

Note 1. Wind capacity factor based on NREL 80 meter wind speed maps.
Note 2. Availability estimates are based on vendor correspondence and industry publications.
Note 3. Development costs include legal costs, developer costs prior to COD, Owner project management, engineering, and interconnect studies.
Note 4. Wind projects assume that land is leased and therefore land costs are included in O&M, not capital costs. Assumes one acre per turbine.
Note 5. Oregon and Washington cost estimates assume union labor.
Note 6. EPC and Owner's Cost estimates exclude AFUDC, Sales Tax, Insurance and Property Tax During Construction
Note 7. Transmission interconnect allowance assumes 15 miles of transmission line at high voltage. Land costs are excluded.
Note 8. Transmission interconnect application and upgrade costs are representative only. These costs can vary greatly depending on the site location and existing infrastructure.

APPENDIX B – SOLAR PVSYST MODEL OUTPUT (5MW)

Grid-Connected System: Simulation parameters

Project :	**PC18-Grid-IdahoFallsID-SAT**			
Geographical Site	**Idaho Falls Fanning Field**		Country	**USA**
Situation	Latitude	43.5°N	Longitude	112.1°W
Time defined as	Legal Time	Time zone UT-7	Altitude	1441 m
	Albedo	0.20		
Meteo data:	**Idaho Falls Fanning Field**	TMY - NREL: TMY3 hourly DB (1991-2005)		

Simulation variant :	**PC18_IdahoFalls_Rev3**			
	Simulation date	31/08/18 13h50		

Simulation parameters

Tracking plane, tilted Axis	Axis Tilt	0°	Axis Azimuth	0°
Rotation Limitations	Minimum Phi	-60°	Maximum Phi	60°
Backtracking strategy	Tracker Spacing	5.50 m	Collector width	1.98 m
Inactive band	Left	0.20 m	Right	0.20 m
Models used	Transposition	Perez	Diffuse	Imported
Horizon	Free Horizon			
Near Shadings	Linear shadings			

PV Array Characteristics

PV module Si-poly	Model	**CS3U-340P 1500V**		
	Manufacturer	Canadian Solar Inc.		
	Orientation	#1	Tilt/Azimuth	30°/0°
Number of PV modules	In series	26 modules	In parallel	738 strings
Total number of PV modules	Nb. modules	19188	Unit Nom. Power	340 Wp
Array global power	Nominal (STC)	**6524 kWp**	At operating cond.	5890 kWp (50°C)
Array operating characteristics (50°C)	U mpp	895 V	I mpp	6580 A
Total area	Module area	**38069 m²**	Cell area	33931 m²
Inverter	Model	**SMA SC2500 EV Prelim!**		
	Manufacturer	SMA		
Characteristics	Operating Voltage	850-1425 V	Unit Nom. Power	2500 kWac
Inverter pack	Nb. of inverters	2 units	Total Power	5000 kWac

PV Array loss factors

Array Soiling Losses

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2.5%	2.5%	2.5%	2.5%	2.0%	2.0%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%

Thermal Loss factor	Uc (const)	25.0 W/m²K	Uv (wind)	1.2 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	2.3 mOhm	Loss Fraction	1.5 % at STC
LID - Light Induced Degradation			Loss Fraction	2.0 %
Module Quality Loss			Loss Fraction	-0.4 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP

Grid-Connected System: Simulation parameters (continued)

Incidence effect, user defined profile

10°	20°	30°	40°	50°	60°	70°	80°	90°
1.00	1.00	1.00	0.99	0.99	0.97	0.92	0.76	0.00

System loss factors
Wiring Ohmic Loss   Wires 0 m 3x0.0 mm²   Loss Fraction 0.0 % at STC

User's needs : Unlimited load (grid)

Grid-Connected System: Main results

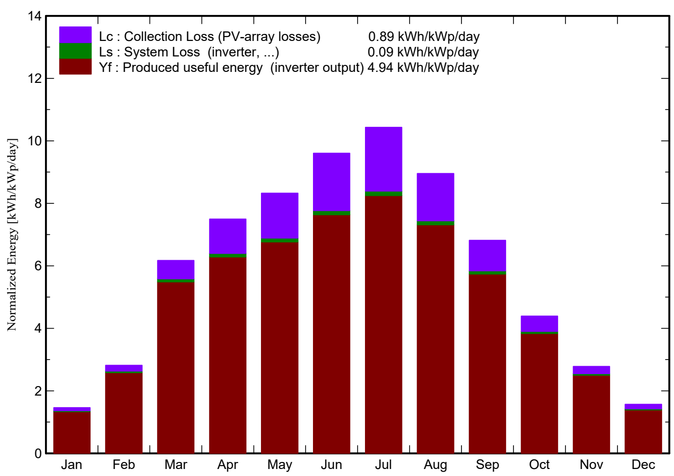
Project : **PC18-Grid-IdahoFallsID-SAT**

Simulation variant : **PC18_IdahoFalls_Rev3**

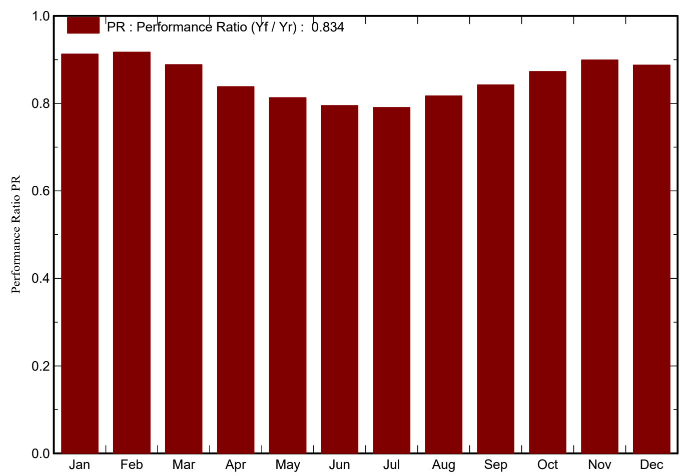
Main system parameters	System type	**Grid-Connected**		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**11763 MWh/year**	Specific prod.	1803 kWh/kWp/year
	Performance Ratio PR	83.4 %		

Normalized productions (per installed kWp): Nominal power 6524 kWp



Performance Ratio PR



PC18_IdahoFalls_Rev3

Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	34.6	-7.63	45.3	41.6	276	270	16.00	15.64
February	62.3	-6.02	78.9	73.2	481	472	16.02	15.72
March	138.9	1.52	191.4	180.6	1129	1109	15.50	15.23
April	170.8	8.07	225.0	212.6	1252	1230	14.62	14.36
May	200.8	12.25	258.1	244.9	1393	1369	14.18	13.93
June	219.3	16.42	288.2	274.8	1521	1495	13.86	13.62
July	241.0	20.60	323.5	307.7	1698	1669	13.78	13.55
August	203.6	19.01	277.6	263.8	1505	1479	14.24	14.00
September	149.5	13.70	204.5	193.1	1143	1123	14.69	14.43
October	98.8	6.88	136.2	127.8	790	775	15.23	14.96
November	59.9	0.19	83.5	77.6	499	490	15.70	15.41
December	38.7	-2.59	48.6	44.5	288	282	15.56	15.21
Year	1618.2	6.94	2160.8	2042.0	11975	11763	14.56	14.30

Legends:				
	GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
	GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

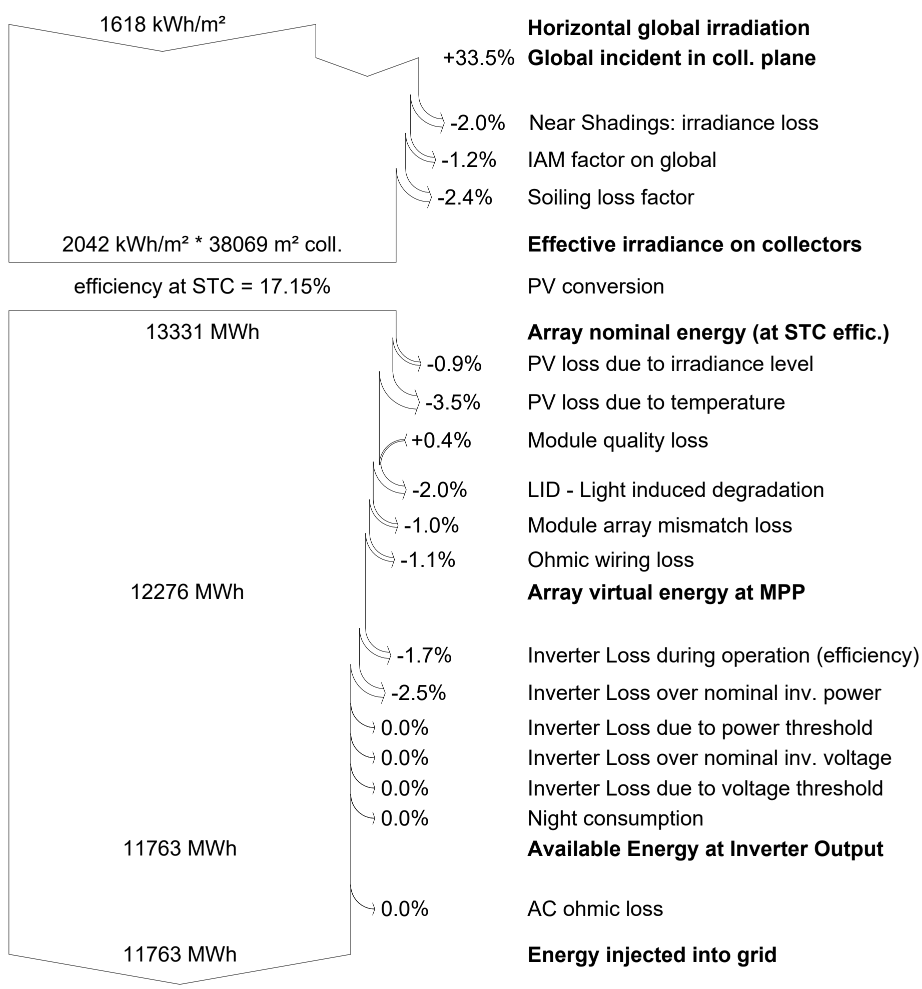
Grid-Connected System: Loss diagram

Project : **PC18-Grid-IdahoFallsID-SAT**

Simulation variant : **PC18_IdahoFalls_Rev3**

Main system parameters	System type	**Grid-Connected**		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



Grid-Connected System: Simulation parameters

Project : **PC18-LakeviewOR**

Geographical Site	**Lakeview**		Country	**United States**
Situation	Latitude	42.2°N	Longitude	120.4°W
Time defined as	Legal Time	Time zone UT-8	Altitude	1441 m
	Albedo	0.20		
Meteo data:	**Lakeview**	TMY - NREL: TMY3 hourly DB (1991-2005)		

Simulation variant : **PC18-LakeviewOR_Rev2**

Simulation date 31/08/18 14h20

Simulation parameters

Tracking plane, tilted Axis	Axis Tilt	0°	Axis Azimuth	0°
Rotation Limitations	Minimum Phi	-60°	Maximum Phi	60°
Backtracking strategy	Tracker Spacing	5.50 m	Collector width	1.98 m
Inactive band	Left	0.20 m	Right	0.20 m
Models used	Transposition	Perez	Diffuse	Imported
Horizon	Average Height	2.4°		
Near Shadings	Linear shadings			

PV Array Characteristics

PV module Si-poly	Model	**CS3U-340P 1500V**		
	Manufacturer	Canadian Solar Inc.		
	Orientation	#1	Tilt/Azimuth	30°/0°
Number of PV modules	In series	26 modules	In parallel	738 strings
Total number of PV modules	Nb. modules	19188	Unit Nom. Power	340 Wp
Array global power	Nominal (STC)	**6524 kWp**	At operating cond.	5890 kWp (50°C)
Array operating characteristics (50°C)	U mpp	895 V	I mpp	6580 A
Total area	Module area	**38069 m²**	Cell area	33931 m²
Inverter	Model	**SMA SC2500 EV Prelim!**		
	Manufacturer	SMA		
Characteristics	Operating Voltage	850-1425 V	Unit Nom. Power	2500 kWac
Inverter pack	Nb. of inverters	2 units	Total Power	5000 kWac

PV Array loss factors

Array Soiling Losses

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.5%	2.5%	2.5%	2.0%	2.0%	2.0%

Thermal Loss factor	Uc (const)	25.0 W/m²K	Uv (wind)	1.2 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	2.5 mOhm	Loss Fraction	1.6 % at STC
LID - Light Induced Degradation			Loss Fraction	2.0 %
Module Quality Loss			Loss Fraction	-0.4 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP

Grid-Connected System: Simulation parameters (continued)

Incidence effect, user defined profile

10°	20°	30°	40°	50°	60°	70°	80°	90°
1.00	1.00	1.00	0.99	0.99	0.97	0.92	0.76	0.00

System loss factors
Wiring Ohmic Loss   Wires 0 m 3x0.0 mm²   Loss Fraction 0.0 % at STC

User's needs : Unlimited load (grid)

Grid-Connected System: Horizon definition

Project : **PC18-LakeviewOR**

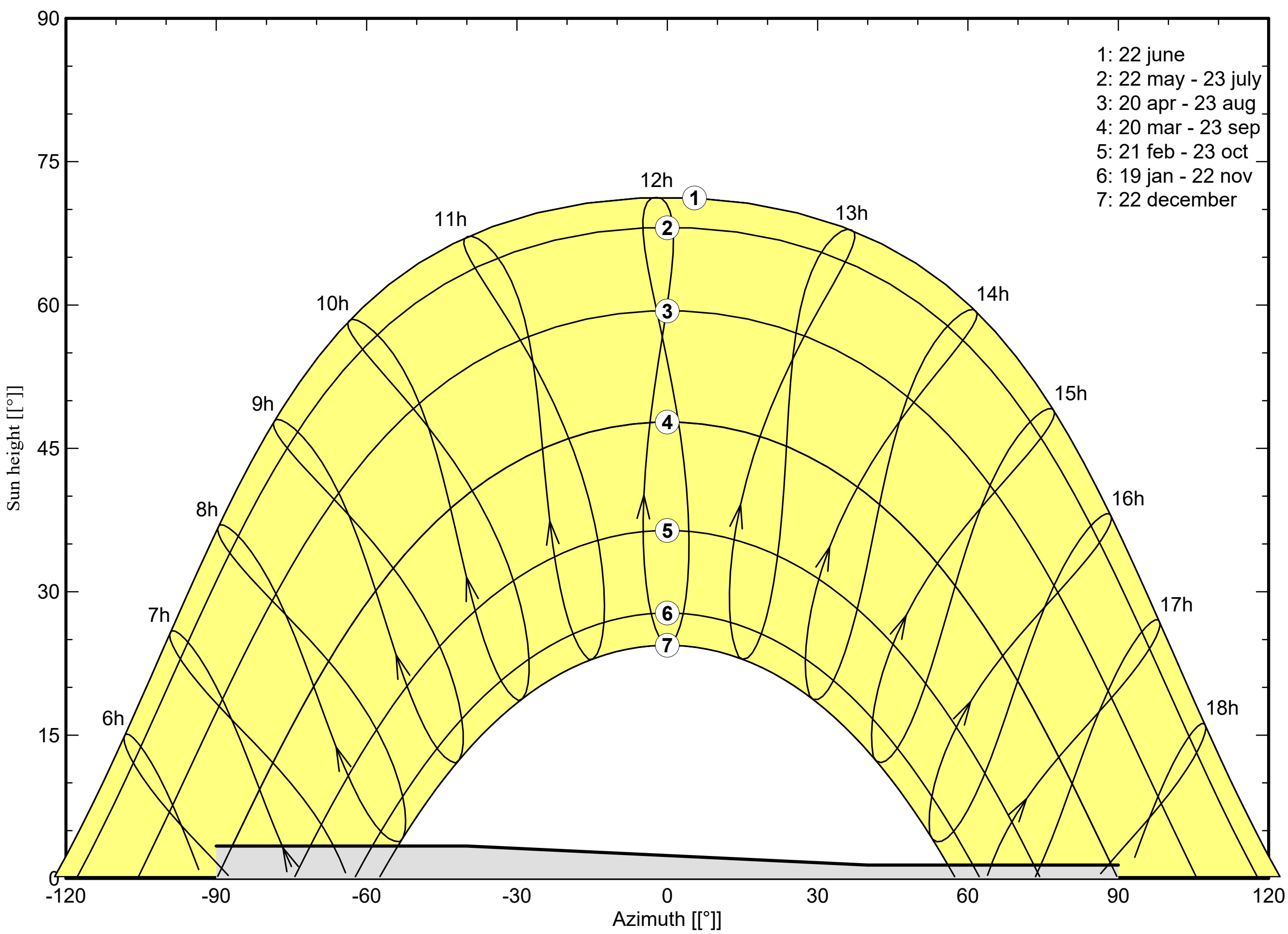
Simulation variant : **PC18-LakeviewOR_Rev2**

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	2.4°		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Horizon	Average Height	2.4°	Diffuse Factor	0.99
	Albedo Factor	100 %	Albedo Fraction	0.96

Height [°]	3.4	3.4	1.4	1.4
Azimuth [°]	-90	-40	40	90

Horizon



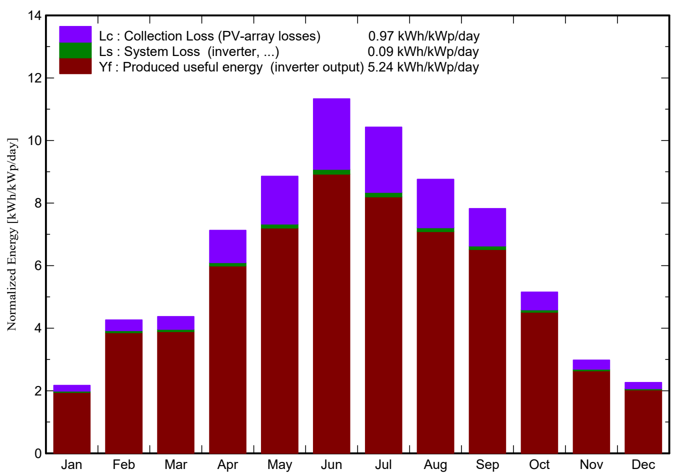
Grid-Connected System: Main results

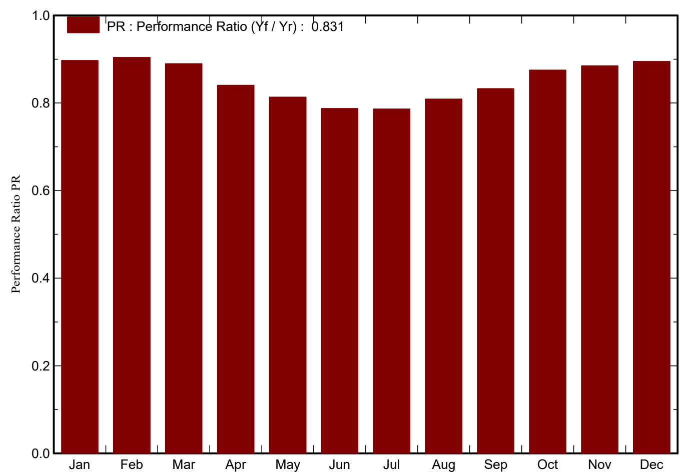
Project : **PC18-LakeviewOR**

Simulation variant : **PC18-LakeviewOR_Rev2**

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	2.4°		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**12468 MWh/year**	Specific prod.	1911 kWh/kWp/year
	Performance Ratio PR	83.1 %		





PC18-LakeviewOR_Rev2

Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	52.8	-1.22	67.4	62.3	402	394	15.68	15.37
February	85.1	-0.46	119.4	112.0	717	704	15.77	15.49
March	106.7	2.86	135.6	127.4	802	787	15.53	15.24
April	163.1	5.42	213.8	202.5	1193	1172	14.66	14.40
May	209.3	9.94	274.6	261.2	1482	1457	14.18	13.94
June	251.2	16.42	340.1	325.4	1777	1747	13.72	13.49
July	242.7	20.83	323.3	307.4	1687	1659	13.71	13.48
August	198.5	17.73	271.7	258.0	1459	1434	14.11	13.86
September	167.3	14.61	234.7	222.3	1297	1275	14.52	14.27
October	114.2	6.91	159.8	150.6	928	912	15.26	14.99
November	63.8	1.73	89.5	83.4	527	517	15.45	15.16
December	49.6	-0.87	70.3	65.0	418	410	15.63	15.33
Year	1704.3	7.87	2300.2	2177.6	12690	12468	14.49	14.24

Legends:

GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
T Amb	Ambient Temperature	E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

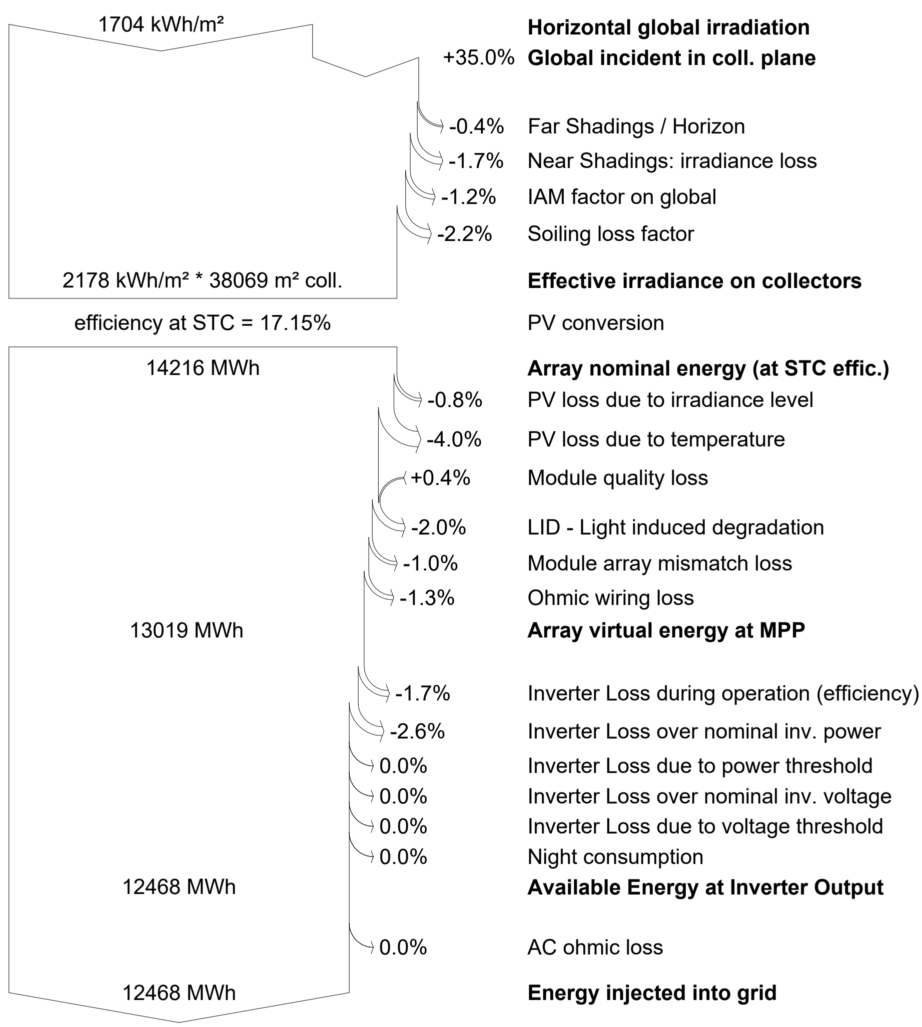
Grid-Connected System: Loss diagram

Project : **PC18-LakeviewOR**

Simulation variant : **PC18-LakeviewOR_Rev2**

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	2.4°		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



Grid-Connected System: Simulation parameters

Project :	**PC18-Grid-MildfordUT-SAT**			
Geographical Site	**MilfordUT_S1**		Country	**United States**
Situation	Latitude	38.4°N	Longitude	113.0°W
Time defined as	Legal Time	Time zone UT-7	Altitude	1563 m
	Albedo	0.20		
Meteo data:	**MilfordUT_NSRDB**	TMY - NREL: TMY3 hourly DB (1991-2005)		

Simulation variant :	**PC18-MilfordUT_Rev0**			
	Simulation date	31/08/18 14h47		

Simulation parameters

Tracking plane, tilted Axis	Axis Tilt	0°	Axis Azimuth	0°
Rotation Limitations	Minimum Phi	-60°	Maximum Phi	60°
Backtracking strategy	Tracker Spacing	5.50 m	Collector width	1.98 m
Inactive band	Left	0.20 m	Right	0.20 m
Models used	Transposition	Perez	Diffuse	Imported
Horizon	Average Height	3.0°		
Near Shadings	Linear shadings			

PV Array Characteristics

PV module Si-poly	Model	**CS3U-340P 1500V**		
	Manufacturer	Canadian Solar Inc.		
	Orientation	#1	Tilt/Azimuth	30°/0°
Number of PV modules	In series	26 modules	In parallel	738 strings
Total number of PV modules	Nb. modules	19188	Unit Nom. Power	340 Wp
Array global power	Nominal (STC)	**6524 kWp**	At operating cond.	5890 kWp (50°C)
Array operating characteristics (50°C)	U mpp	895 V	I mpp	6580 A
Total area	Module area	**38069 m²**	Cell area	33931 m²
Inverter	Model	**SMA SC2500 EV Prelim!**		
	Manufacturer	SMA		
Characteristics	Operating Voltage	850-1425 V	Unit Nom. Power	2500 kWac
Inverter pack	Nb. of inverters	2 units	Total Power	5000 kWac

PV Array loss factors

Array Soiling Losses

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2.5%	2.5%	2.0%	2.0%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%

Thermal Loss factor	Uc (const)	25.0 W/m²K	Uv (wind)	1.2 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	2.3 mOhm	Loss Fraction	1.5 % at STC
LID - Light Induced Degradation			Loss Fraction	2.0 %
Module Quality Loss			Loss Fraction	-0.4 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP

Grid-Connected System: Simulation parameters (continued)

Incidence effect, user defined profile

10°	20°	30°	40°	50°	60°	70°	80°	90°
1.00	1.00	1.00	0.99	0.99	0.97	0.92	0.76	0.00

System loss factors

Wiring Ohmic Loss   Wires 0 m 3x5000.0 mm²   Loss Fraction 0.0 % at STC

User's needs :   Unlimited load (grid)

Grid-Connected System: Horizon definition

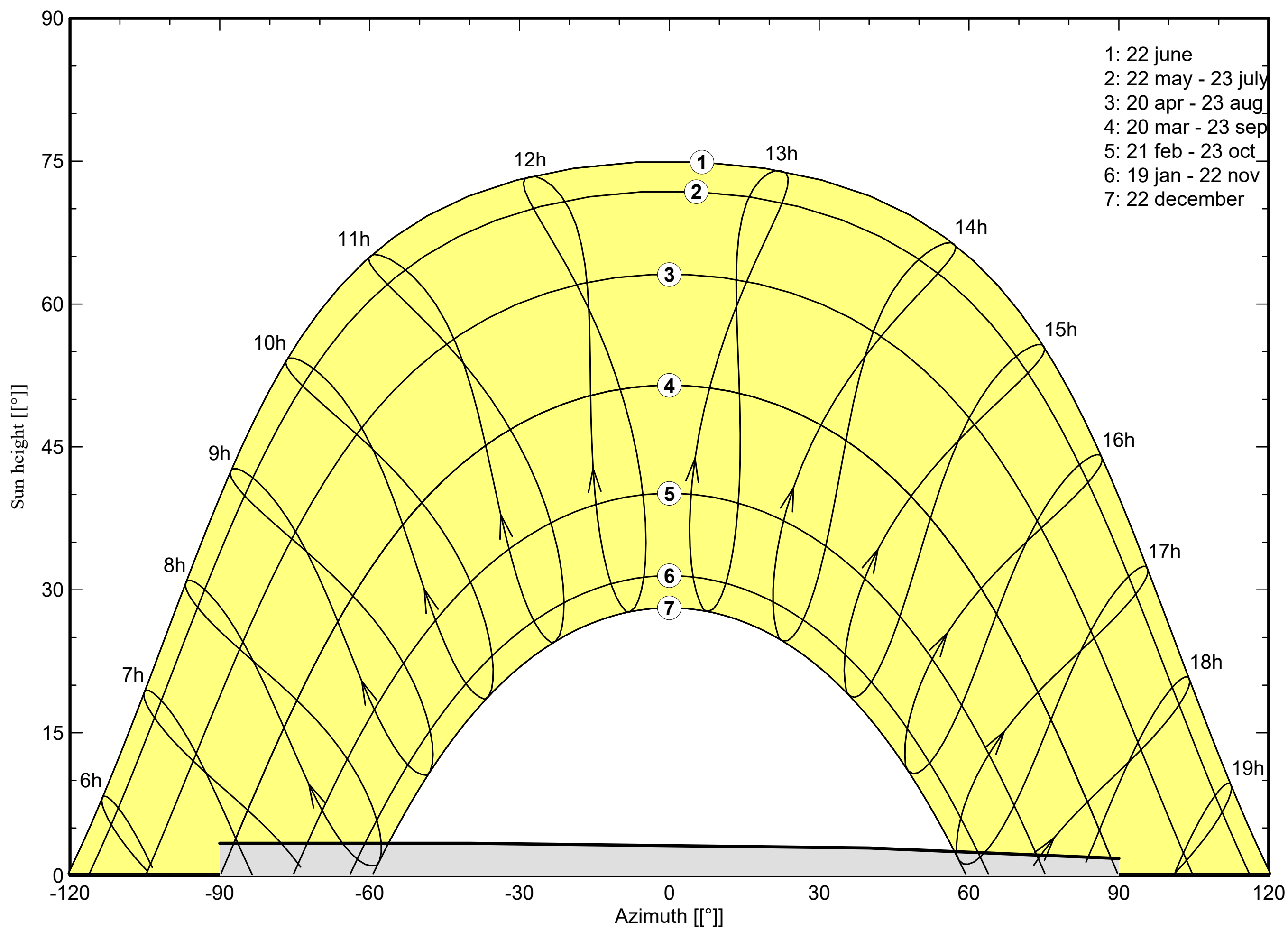
Project : **PC18-Grid-MildfordUT-SAT**

Simulation variant : **PC18-MilfordUT_Rev0**

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	3.0°		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Horizon	Average Height	3.0°	Diffuse Factor	0.98
	Albedo Factor	100 %	Albedo Fraction	0.94

Height [°]	3.4	3.4	2.9	1.8
Azimuth [°]	-90	-40	40	90



Grid-Connected System: Main results

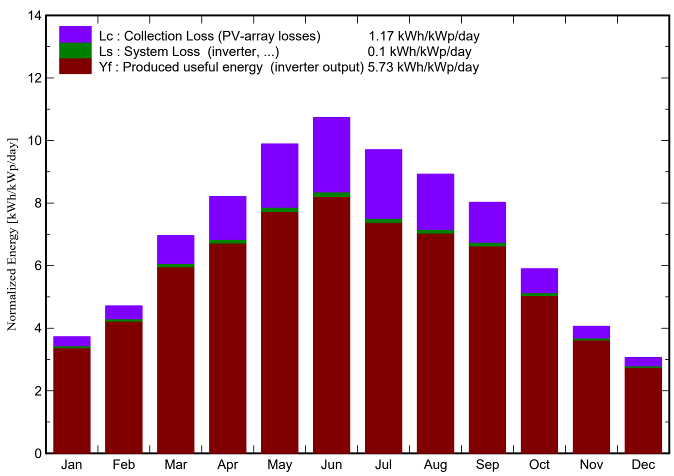
Project : **PC18-Grid-MildfordUT-SAT**

Simulation variant : **PC18-MilfordUT_Rev0**

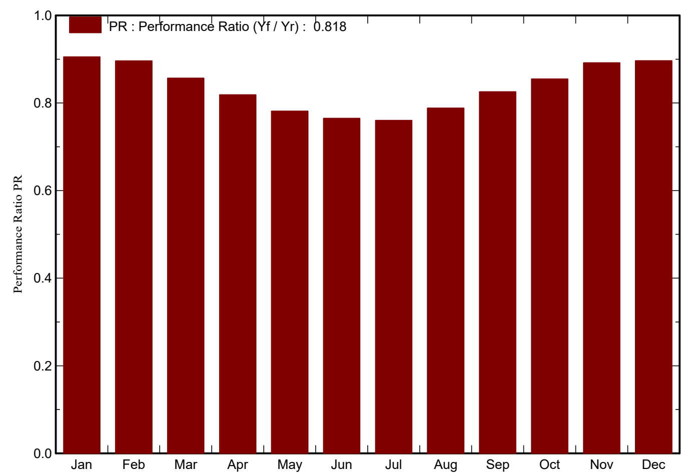
Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	3.0°		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**13645 MWh/year**	Specific prod.	2092 kWh/kWp/year
	Performance Ratio PR	81.8 %		

Normalized productions (per installed kWp): Nominal power 6524 kWp



Performance Ratio PR



PC18-MilfordUT_Rev0

Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	EffArrR	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	MWh	MWh	%	%
January	83.0	-1.63	115.6	107.5	695	683	15.80	15.52
February	97.2	0.96	132.0	123.7	786	772	15.63	15.36
March	158.1	2.97	215.8	204.6	1227	1206	14.94	14.68
April	188.5	7.14	246.3	234.0	1339	1315	14.28	14.03
May	233.1	15.67	306.7	290.9	1591	1563	13.63	13.39
June	243.9	19.11	322.0	306.2	1635	1607	13.34	13.11
July	230.2	23.97	301.0	285.9	1519	1493	13.26	13.03
August	207.6	23.16	276.7	262.8	1448	1423	13.75	13.51
September	175.2	15.35	240.8	228.6	1320	1297	14.40	14.15
October	132.0	11.70	182.9	172.2	1038	1020	14.91	14.65
November	86.8	1.58	121.9	113.8	722	709	15.56	15.28
December	67.8	-1.75	94.9	87.6	566	555	15.66	15.37
Year	1903.4	9.92	2556.6	2417.9	13887	13645	14.27	14.02

Legends:				
	GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
	GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

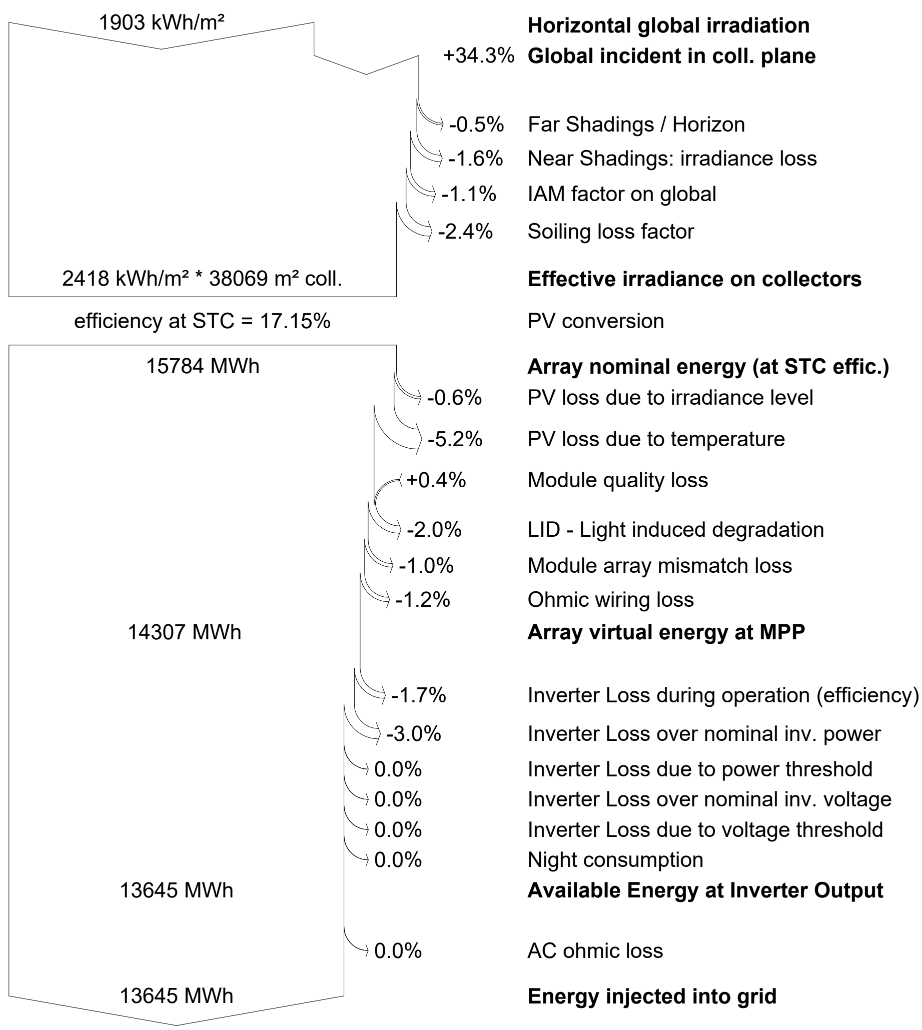
Grid-Connected System: Loss diagram

Project : **PC18-Grid-MildfordUT-SAT**

Simulation variant : **PC18-MilfordUT_Rev0**

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	3.0°		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



Grid-Connected System: Simulation parameters

Project : **PC18-Grid-RockSpringsWY-SAT**

Geographical Site	**Rock Springs Arpt**		Country	**United States**
Situation	Latitude	41.5°N	Longitude	109.4°W
Time defined as	Legal Time	Time zone UT-7	Altitude	1000 m
	Albedo	0.20		
Meteo data:	**Rock Springs Arpt**	TMY - NREL: TMY3 hourly DB (1991-2005)		

Simulation variant : **PC18-RockSpringsWY_Rev2**

Simulation date 31/08/18 15h16

Simulation parameters

Tracking plane, tilted Axis	Axis Tilt	0°	Axis Azimuth	0°
Rotation Limitations	Minimum Phi	-60°	Maximum Phi	60°
Backtracking strategy	Tracker Spacing	5.50 m	Collector width	1.98 m
Inactive band	Left	0.20 m	Right	0.20 m
Models used	Transposition	Perez	Diffuse	Imported
Horizon	Average Height	4.2°		
Near Shadings	Linear shadings			

PV Array Characteristics

PV module Si-poly	Model	**CS3U-340P 1500V**		
	Manufacturer	Canadian Solar Inc.		
	Orientation	#1	Tilt/Azimuth	30°/0°
Number of PV modules	In series	26 modules	In parallel	738 strings
Total number of PV modules	Nb. modules	19188	Unit Nom. Power	340 Wp
Array global power	Nominal (STC)	**6524 kWp**	At operating cond.	5890 kWp (50°C)
Array operating characteristics (50°C)	U mpp	895 V	I mpp	6580 A
Total area	Module area	**38069 m²**	Cell area	33931 m²
Inverter	Model	**SMA SC2500 EV Prelim!**		
	Manufacturer	SMA		
Characteristics	Operating Voltage	850-1425 V	Unit Nom. Power	2500 kWac
Inverter pack	Nb. of inverters	2 units	Total Power	5000 kWac

PV Array loss factors

Array Soiling Losses

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2.5%	2.5%	2.5%	2.5%	2.0%	2.0%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%

Thermal Loss factor	Uc (const)	25.0 W/m²K	Uv (wind)	1.2 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	2.3 mOhm	Loss Fraction	1.5 % at STC
LID - Light Induced Degradation			Loss Fraction	2.0 %
Module Quality Loss			Loss Fraction	-0.4 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP

Grid-Connected System: Simulation parameters (continued)

Incidence effect, user defined profile

10°	20°	30°	40°	50°	60°	70°	80°	90°
1.00	1.00	1.00	0.99	0.99	0.97	0.92	0.76	0.00

System loss factors

Wiring Ohmic Loss   Wires   0 m 3x5000.0 mm²   Loss Fraction   0.0 % at STC

User's needs :   Unlimited load (grid)

Grid-Connected System: Horizon definition

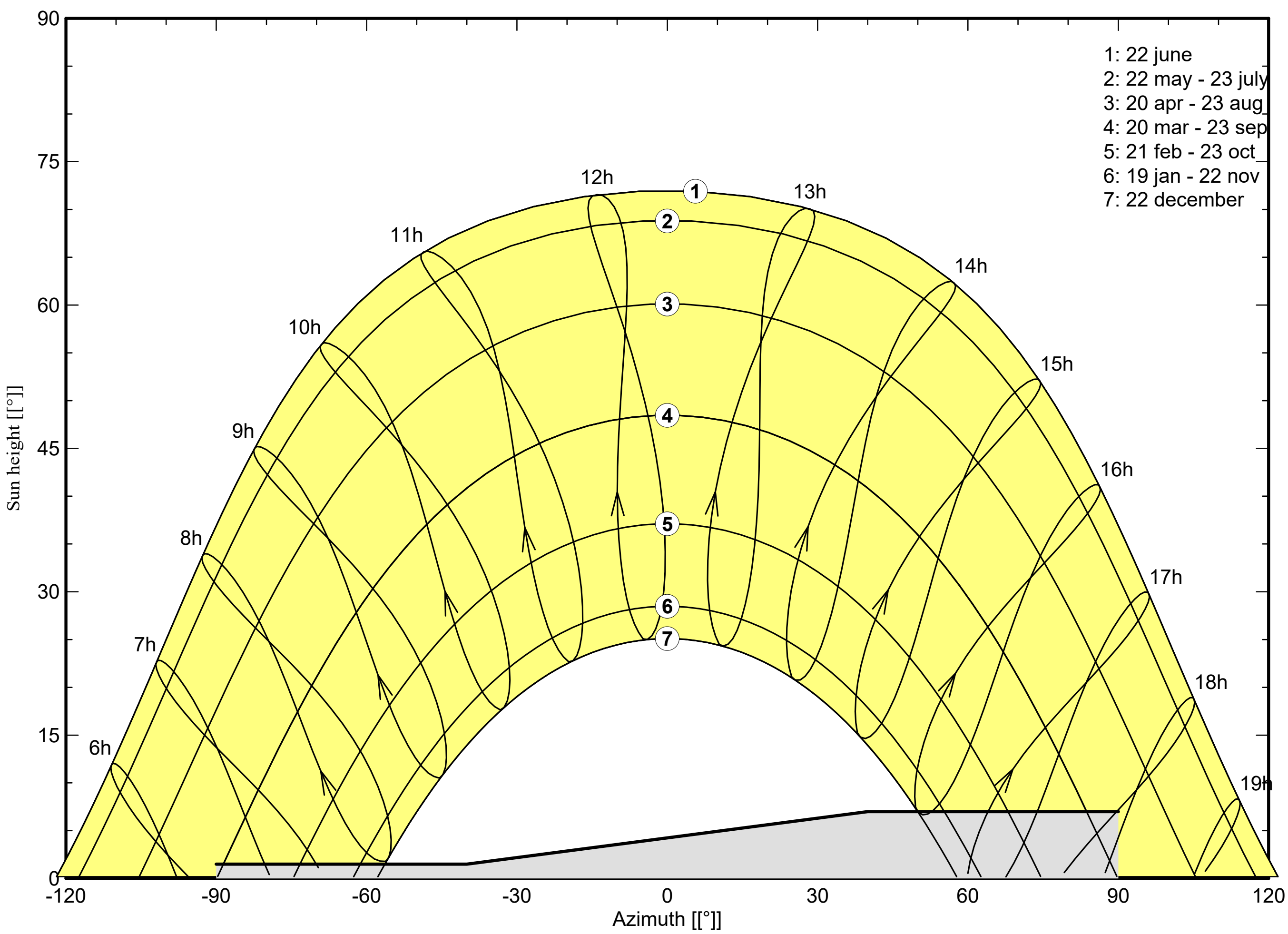
Project : **PC18-Grid-RockSpringsWY-SAT**

Simulation variant : **PC18-RockSpringsWY_Rev2**

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	4.2°		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Horizon	Average Height	4.2°	Diffuse Factor	0.96
	Albedo Factor	100 %	Albedo Fraction	0.83

Height [°]	1.5	1.5	7.0	7.0
Azimuth [°]	-90	-40	40	90



Grid-Connected System: Main results

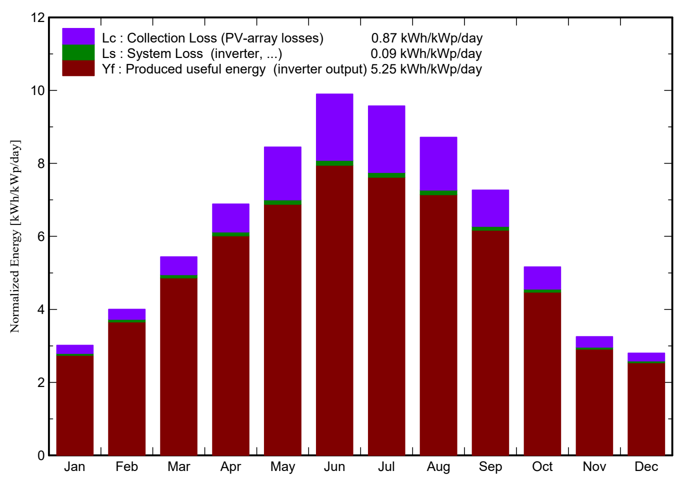
Project : **PC18-Grid-RockSpringsWY-SAT**

Simulation variant : **PC18-RockSpringsWY_Rev2**

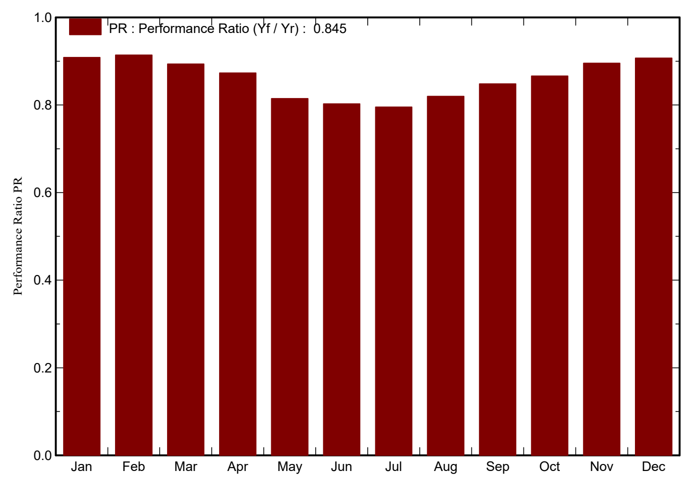
Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	4.2°		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**12510 MWh/year**	Specific prod.	1918 kWh/kWp/year
	Performance Ratio PR	84.5 %		

Normalized productions (per installed kWp): Nominal power 6524 kWp



Performance Ratio PR



PC18-RockSpringsWY_Rev2

Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	EffArrR	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	MWh	MWh	%	%
January	68.3	-4.70	93.6	85.6	565	555	15.86	15.57
February	84.1	-3.58	112.0	103.5	681	668	15.96	15.67
March	127.1	0.22	168.6	157.3	1001	983	15.59	15.32
April	156.6	4.99	206.7	194.1	1198	1177	15.23	14.96
May	200.6	10.16	261.8	248.2	1416	1392	14.21	13.96
June	224.4	17.24	297.0	282.8	1582	1555	14.00	13.76
July	223.3	19.89	296.9	281.4	1568	1541	13.87	13.63
August	202.1	18.73	270.2	255.6	1470	1445	14.29	14.05
September	158.0	12.84	218.1	204.9	1228	1207	14.79	14.54
October	116.0	7.61	160.1	149.2	921	905	15.11	14.84
November	72.1	-0.85	97.5	89.7	580	570	15.63	15.34
December	60.8	-5.39	86.8	79.4	523	514	15.84	15.54
Year	1693.5	6.49	2269.3	2131.7	12734	12510	14.74	14.48

Legends:				
	GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
	GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

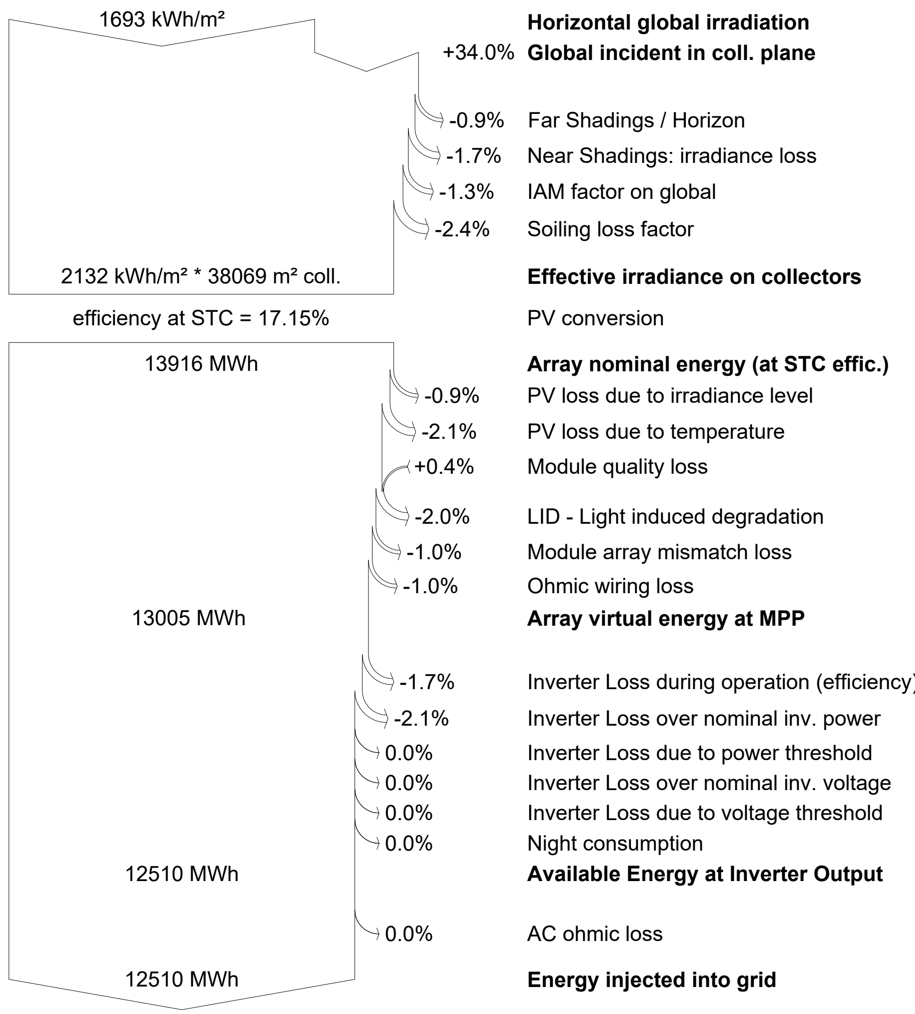
Grid-Connected System: Loss diagram

Project : **PC18-Grid-RockSpringsWY-SAT**

Simulation variant : **PC18-RockSpringsWY_Rev2**

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	4.2°		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



Grid-Connected System: Simulation parameters

Project : **PC18-Grid-YakimaWA-SAT**

Geographical Site		**Yakima**	Country	**United States**
Situation	Latitude	46.6°N	Longitude	120.5°W
Time defined as	Legal Time	Time zone UT-8	Altitude	320 m
	Albedo	0.20		
Meteo data:	**Yakima Air Terminal**	TMY - NREL: TMY3 hourly DB (1991-2005)		

Simulation variant : **YakimaWA_5MW-SAT_Report**

Simulation date 31/08/18 15h29

Simulation parameters

Tracking plane, tilted Axis	Axis Tilt	0°	Axis Azimuth	0°
Rotation Limitations	Minimum Phi	-60°	Maximum Phi	60°
Backtracking strategy	Tracker Spacing	5.50 m	Collector width	1.98 m
Inactive band	Left	0.20 m	Right	0.20 m
Models used	Transposition	Perez	Diffuse	Imported
Horizon	Free Horizon			
Near Shadings	Linear shadings			

PV Array Characteristics

PV module Si-poly	Model	**CS3U-340P 1500V**		
	Manufacturer	Canadian Solar Inc.		
	Orientation	#1	Tilt/Azimuth	30°/0°
Number of PV modules	In series	26 modules	In parallel	738 strings
Total number of PV modules	Nb. modules	19188	Unit Nom. Power	340 Wp
Array global power	Nominal (STC)	**6524 kWp**	At operating cond.	5890 kWp (50°C)
Array operating characteristics (50°C)	U mpp	895 V	I mpp	6580 A
Total area	Module area	**38069 m²**	Cell area	33931 m²

Inverter	Model	**SMA SC2500 EV Prelim!**		
	Manufacturer	SMA		
Characteristics	Operating Voltage	850-1425 V	Unit Nom. Power	2500 kWac
Inverter pack	Nb. of inverters	2 units	Total Power	5000 kWac

PV Array loss factors

Array Soiling Losses

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%

Thermal Loss factor	Uc (const)	25.0 W/m²K	Uv (wind)	1.2 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	2.5 mOhm	Loss Fraction	1.6 % at STC
LID - Light Induced Degradation			Loss Fraction	2.0 %
Module Quality Loss			Loss Fraction	-0.4 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP

Grid-Connected System: Simulation parameters (continued)

Incidence effect, user defined profile

10°	20°	30°	40°	50°	60°	70°	80°	90°
1.00	1.00	1.00	0.99	0.99	0.97	0.92	0.76	0.00

System loss factors

Wiring Ohmic Loss   Wires 0 m 3x0.0 mm²   Loss Fraction 0.0 % at STC

User's needs : Unlimited load (grid)

Grid-Connected System: Main results

Project : **PC18-Grid-YakimaWA-SAT**

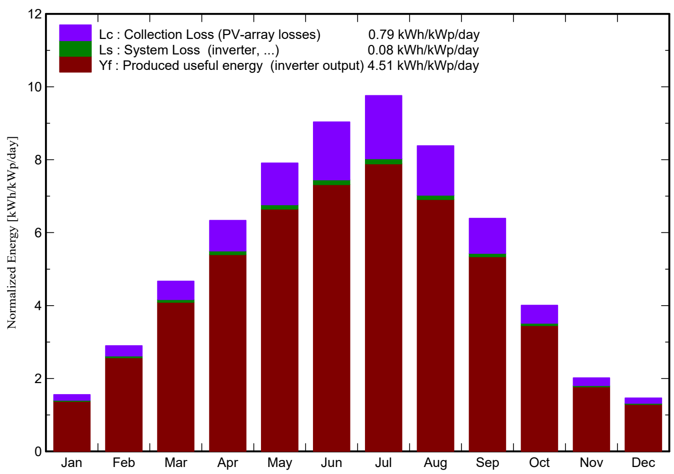
Simulation variant : **YakimaWA_5MW-SAT_Report**

Main system parameters System type **Grid-Connected**

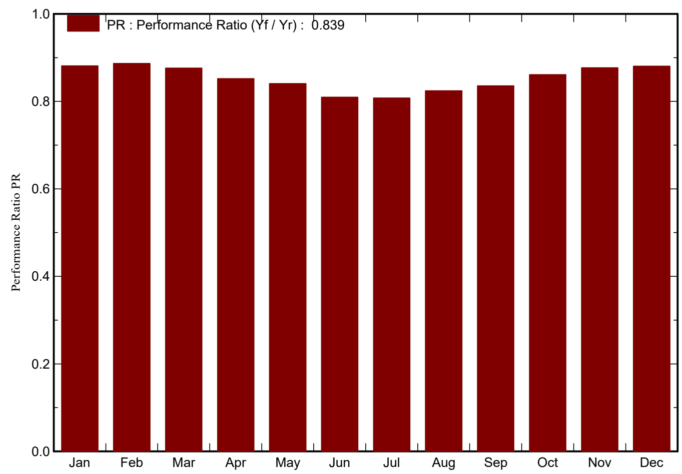
Near Shadings Linear shadings
PV Field Orientation tracking, tilted axis, Axis Tilt 0° Axis Azimuth 0°
PV modules Model CS3U-340P 1500V Pnom 340 Wp
PV Array Nb. of modules 19188 Pnom total **6524 kWp**
Inverter Model SMA SC2500 EV Prelim! Pnom 2500 kW ac
Inverter pack Nb. of units 2.0 Pnom total **5000 kW ac**
User's needs Unlimited load (grid)

Main simulation results
System Production **Produced Energy** **10749 MWh/year** Specific prod. 1648 kWh/kWp/year
Performance Ratio PR 83.9 %

Normalized productions (per installed kWp): Nominal power 6524 kWp



Performance Ratio PR



YakimaWA_5MW-SAT_Report
Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	EffArrR	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	MWh	MWh	%	%
January	41.1	-1.43	48.3	43.9	284	278	15.45	15.10
February	62.8	2.53	81.1	75.2	478	469	15.50	15.20
March	108.9	5.93	144.8	135.8	842	827	15.29	15.01
April	146.2	11.57	190.1	178.8	1076	1056	14.86	14.60
May	188.4	14.18	245.1	231.0	1368	1344	14.66	14.40
June	208.6	19.24	271.1	256.3	1458	1432	14.12	13.87
July	225.0	22.28	302.6	287.1	1623	1595	14.09	13.84
August	190.6	19.68	259.9	246.3	1422	1397	14.37	14.12
September	140.7	15.67	191.7	180.6	1064	1045	14.57	14.32
October	91.2	9.06	124.3	116.2	711	698	15.03	14.76
November	47.3	2.49	60.6	55.6	354	346	15.35	15.02
December	36.2	-2.00	45.4	41.2	267	261	15.43	15.09
Year	1486.8	9.97	1964.9	1847.9	10946	10749	14.63	14.37

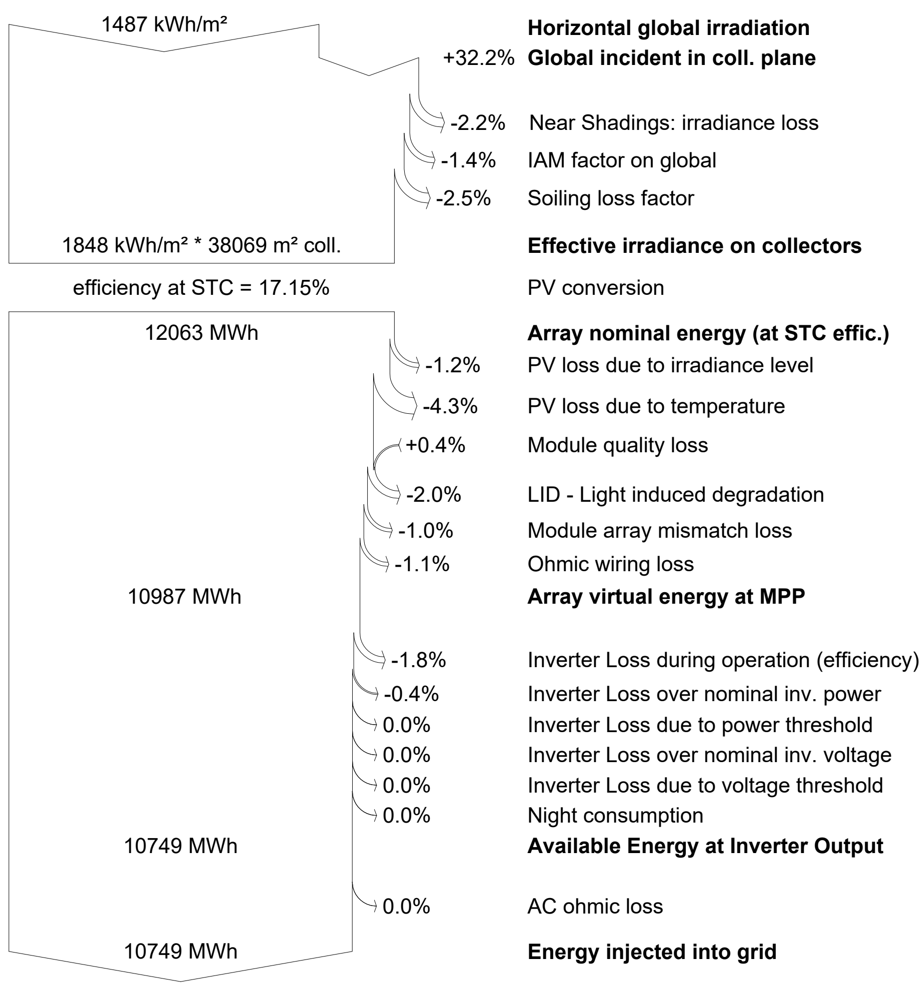
Legends:
- GlobHor: Horizontal global irradiation
- T Amb: Ambient Temperature
- GlobInc: Global incident in coll. plane
- GlobEff: Effective Global, corr. for IAM and shadings
- EArray: Effective energy at the output of the array
- E_Grid: Energy injected into grid
- EffArrR: Effic. Eout array / rough area
- EffSysR: Effic. Eout system / rough area

Grid-Connected System: Loss diagram

Project :	**PC18-Grid-YakimaWA-SAT**
Simulation variant :	**YakimaWA_5MW-SAT_Report**

Main system parameters	System type	**Grid-Connected**		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	CS3U-340P 1500V	Pnom	340 Wp
PV Array	Nb. of modules	19188	Pnom total	**6524 kWp**
Inverter	Model	SMA SC2500 EV Prelim!	Pnom	2500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**5000 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



APPENDIX C – SOLAR OUTPUT SUMMARY

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: Pacificorp 2018 Renewables Technology Assessment

Variant: VC3 Date: 31-Aug-18

Site Information	
City / State:	Idaho Falls, Idaho
Latitude (N):	43.5 °
Longitude (W):	-112 °
Altitude	1441 m
ASHRAE Cooling DB Temp.	32 °C
ASHRAE Extreme Mean Min. Temp.	-25 °C

Estimated Annual Energy Production	
P50 net production (yr-1)	11597.3 MWh
AC capacity factor - Inv Rating	26.48%
AC capacity factor - POI Rating	26.48%
DC capacity factor	20.00%
Specific Production	1752 kWh/kWp/yr
Performance Ratio PR	81.08%
Night time losses	-21.1 MWh
Plant Output Limitations	0.00%

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	N/A %/yr

Facility Level Information	
Nameplate Capacity	**6.62 MWDC**
Number of modules	19188
Nameplate Capacity	**5.00 MWAC**
Number of arrays	1
Interconnection Limit	**5.00 MWAC**
Inteconnection Voltage	34.5 kV
DC/AC ratio - POI Rating	1.324

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

Weather	
Source	TMY3
GHI	1618.2 kWh/m2
DHI	kWh/m2
Global POA	2160.8 kWh/m2
Average Temp.	6.94 °C
Average Temp. (Generation)	11.48 °C
Average Wind	3.84 m/s
Average Wind (Generation)	4.53 m/s

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.4 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	0.70%
HV transformer no-load losses	0.00%
HV transformer full load losses	0.00%
HV line	0.00%
Auxiliary	0.01%

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: **Pacificorp 2018 Renewables Technology Assessment**

Variant: VC3 Date: 28-Aug-18

Site Information	
City / State:	Idaho Falls, Idaho
Latitude (N):	43.5 °
Longitude (W):	-112 °
Altitude	1441 m
ASHRAE Cooling DB Temp.	32 °C
ASHRAE Extreme Mean Min. Temp.	-25 °C

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	N/A %/yr

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.4 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

Estimated Annual Energy Production	
P50 net production (yr-1)	122928.5 MWh
AC capacity factor - Inv Rating	25.51%
AC capacity factor - POI Rating	28.07%
DC capacity factor	19.27%
Specific Production	1688 kWh/kWp/yr
Performance Ratio PR	78.13%
Night time losses	-408.8 MWh
Plant Output Limitations	2.63%

Facility Level Information	
Nameplate Capacity	**72.82 MWDC**
Number of modules	211068
Nameplate Capacity	**55.00 MWAC**
Number of arrays	11
Interconnection Limit	**50.00 MWAC**
Inteconnection Voltage	115 kV
DC/AC ratio - POI Rating	1.456

Weather	
Source	TMY3
GHI	1618.2 kWh/m2
DHI	kWh/m2
Global POA	2160.8 kWh/m2
Average Temp.	6.94 °C
Average Temp. (Generation)	11.48 °C
Average Wind	3.84 m/s
Average Wind (Generation)	4.53 m/s

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	1.30%
HV transformer no-load losses	0.07%
HV transformer full load losses	0.48%
HV line	0.05%
Auxiliary	0.01%

BURNS & McDONNELL

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: Pacificorp 2018 Renewables Technology Assessment

Variant: VC3 Date: 31-Aug-18

Site Information	
City / State:	Idaho Falls, Idaho
Latitude (N):	43.5 °
Longitude (W):	-112 °
Altitude	1441 m
ASHRAE Cooling DB Temp.	32 °C
ASHRAE Extreme Mean Min. Temp.	-25 °C

Estimated Annual Energy Production	
P50 net production (yr-1)	491714.0 MWh
AC capacity factor - Inv Rating	25.51%
AC capacity factor - POI Rating	28.07%
DC capacity factor	19.27%
Specific Production	1688 kWh/kWp/yr
Performance Ratio PR	78.13%
Night time losses	-1635.2 MWh
Plant Output Limitations	2.63%

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	N/A %/yr

Facility Level Information	
Nameplate Capacity	**291.27 MWDC**
Number of modules	844272
Nameplate Capacity	**220.00 MWAC**
Number of arrays	44
Interconnection Limit	**200.00 MWAC**
Inteconnection Voltage	230 kV
DC/AC ratio - POI Rating	1.456

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

Weather	
Source	TMY3
GHI	1618.2 kWh/m2
DHI	kWh/m2
Global POA	2160.8 kWh/m2
Average Temp.	6.94 °C
Average Temp. (Generation)	11.48 °C
Average Wind	3.84 m/s
Average Wind (Generation)	4.53 m/s

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.4 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	1.30%
HV transformer no-load losses	0.07%
HV transformer full load losses	0.48%
HV line	0.05%
Auxiliary	0.01%

BURNS & McDONNELL

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: Pacificorp 2018 Renewables Technology Assessment

Variant: VC2

Date: 31-Aug-18

Site Information	
City / State:	Lakeview, OR
Latitude (N):	42.2 °
Longitude (W):	-120 °
Altitude	1441 m
ASHRAE Cooling DB Temp.	31 °C
ASHRAE Extreme Mean Min. Temp.	-22 °C

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.2 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

Estimated Annual Energy Production	
P50 net production (yr-1)	12291.9 MWh
AC capacity factor - Inv Rating	28.06%
AC capacity factor - POI Rating	28.06%
DC capacity factor	21.20%
Specific Production	1857 kWh/kWp/yr
Performance Ratio PR	80.72%
Night time losses	-21.2 MWh
Plant Output Limitations	0.00%

Facility Level Information	
Nameplate Capacity	**6.62 MWDC**
Number of modules	19188
Nameplate Capacity	**5.00 MWAC**
Number of arrays	1
Interconnection Limit	**5.00 MWAC**
Inteconnection Voltage	34.5 kV
DC/AC ratio - POI Rating	1.324

Weather	
Source	TMY3
GHI	1704.3 kWh/m2
DHI	kWh/m2
Global POA	2300.2 kWh/m2
Average Temp.	7.87 °C
Average Temp. (Generation)	12.57 °C
Average Wind	3.33 m/s
Average Wind (Generation)	3.63 m/s

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	0.70%
HV transformer no-load losses	0.00%
HV transformer full load losses	0.00%
HV line	0.00%
Auxiliary	0.01%

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: Pacificorp 2018 Renewables Technology Assessment

Variant: VC2 Date: 31-Aug-18

Site Information	
City / State:	Lakeview, OR
Latitude (N):	42.2 °
Longitude (W):	-120 °
Altitude	1441 m
ASHRAE Cooling DB Temp.	31 °C
ASHRAE Extreme Mean Min. Temp.	-22 °C

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.2 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

Estimated Annual Energy Production	
P50 net production (yr-1)	130139.1 MWh
AC capacity factor - Inv Rating	27.01%
AC capacity factor - POI Rating	29.71%
DC capacity factor	20.40%
Specific Production	1787 kWh/kWp/yr
Performance Ratio PR	77.70%
Night time losses	-411.2 MWh
Plant Output Limitations	2.75%

Facility Level Information	
Nameplate Capacity	**72.82 MWDC**
Number of modules	211068
Nameplate Capacity	**55.00 MWAC**
Number of arrays	11
Interconnection Limit	**50.00 MWAC**
Inteconnection Voltage	115 kV
DC/AC ratio - POI Rating	1.456

Weather	
Source	TMY3
GHI	1704.3 kWh/m2
DHI	kWh/m2
Global POA	2300.2 kWh/m2
Average Temp.	7.87 °C
Average Temp. (Generation)	12.57 °C
Average Wind	3.33 m/s
Average Wind (Generation)	3.63 m/s

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	1.30%
HV transformer no-load losses	0.07%
HV transformer full load losses	0.48%
HV line	0.05%
Auxiliary	0.01%

BURNS & McDONNELL

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: Pacificorp 2018 Renewables Technology Assessment

Variant: VC2 Date: 31-Aug-18

Site Information	
City / State:	Lakeview, OR
Latitude (N):	42.2 °
Longitude (W):	-120 °
Altitude	1441 m
ASHRAE Cooling DB Temp.	31 °C
ASHRAE Extreme Mean Min. Temp.	-22 °C

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.2 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

Estimated Annual Energy Production	
P50 net production (yr-1)	520556.4 MWh
AC capacity factor - Inv Rating	27.01%
AC capacity factor - POI Rating	29.71%
DC capacity factor	20.40%
Specific Production	1787 kWh/kWp/yr
Performance Ratio PR	77.70%
Night time losses	-1644.8 MWh
Plant Output Limitations	2.75%

Facility Level Information	
Nameplate Capacity	**291.27 MWDC**
Number of modules	844272
Nameplate Capacity	**220.00 MWAC**
Number of arrays	44
Interconnection Limit	**200.00 MWAC**
Inteconnection Voltage	230 kV
DC/AC ratio - POI Rating	1.456

Weather	
Source	TMY3
GHI	1704.3 kWh/m2
DHI	kWh/m2
Global POA	2300.2 kWh/m2
Average Temp.	7.87 °C
Average Temp. (Generation)	12.57 °C
Average Wind	3.33 m/s
Average Wind (Generation)	3.63 m/s

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	1.30%
HV transformer no-load losses	0.07%
HV transformer full load losses	0.48%
HV line	0.05%
Auxiliary	0.01%

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: **Pacificorp 2018 Renewables Technology Assessment**

Variant: VC2 Date: 31-Aug-18

Site Information	
City / State:	Milford, UT
Latitude (N):	38.4 °
Longitude (W):	-113 °
Altitude	1534 m
ASHRAE Cooling DB Temp.	34.9 °C
ASHRAE Extreme Mean Min. Temp.	-23.1 °C

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.2 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

Estimated Annual Energy Production	
P50 net production (yr-1)	13450.8 MWh
AC capacity factor - Inv Rating	30.71%
AC capacity factor - POI Rating	30.71%
DC capacity factor	23.20%
Specific Production	2032 kWh/kWp/yr
Performance Ratio PR	79.48%
Night time losses	-20.8 MWh
Plant Output Limitations	0.00%

Facility Level Information	
Nameplate Capacity	**6.62 MWDC**
Number of modules	19188
Nameplate Capacity	**5.00 MWAC**
Number of arrays	1
Interconnection Limit	**5.00 MWAC**
Inteconnection Voltage	34.5 kV
DC/AC ratio - POI Rating	1.324

Weather	
Source	NSRDB PSMv3
GHI	1903.4 kWh/m2
DHI	kWh/m2
Global POA	2556.6 kWh/m2
Average Temp.	9.92 °C
Average Temp. (Generation)	14.91 °C
Average Wind	2.11 m/s
Average Wind (Generation)	2.82 m/s

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	0.70%
HV transformer no-load losses	0.00%
HV transformer full load losses	0.00%
HV line	0.00%
Auxiliary	0.01%

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: **Pacificorp 2018 Renewables Technology Assessment**

Variant: VC2 Date: 31-Aug-18

Site Information	
City / State:	Milford, UT
Latitude (N):	38.4 °
Longitude (W):	-113 °
Altitude	1534 m
ASHRAE Cooling DB Temp.	34.9 °C
ASHRAE Extreme Mean Min. Temp.	-23.1 °C

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.2 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

Estimated Annual Energy Production	
P50 net production (yr-1)	142375.3 MWh
AC capacity factor - Inv Rating	29.55%
AC capacity factor - POI Rating	32.51%
DC capacity factor	22.32%
Specific Production	1955 kWh/kWp/yr
Performance Ratio PR	76.48%
Night time losses	-401.9 MWh
Plant Output Limitations	2.76%

Facility Level Information	
Nameplate Capacity	**72.82 MWDC**
Number of modules	211068
Nameplate Capacity	**55.00 MWAC**
Number of arrays	11
Interconnection Limit	**50.00 MWAC**
Inteconnection Voltage	115 kV
DC/AC ratio - POI Rating	1.456

Weather	
Source	NSRDB PSMv3
GHI	1903.4 kWh/m2
DHI	kWh/m2
Global POA	2556.6 kWh/m2
Average Temp.	9.92 °C
Average Temp. (Generation)	14.91 °C
Average Wind	2.11 m/s
Average Wind (Generation)	2.82 m/s

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	1.30%
HV transformer no-load losses	0.07%
HV transformer full load losses	0.48%
HV line	0.05%
Auxiliary	0.01%

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: Pacificorp 2018 Renewables Technology Assessment

Variant: VC2 Date: 31-Aug-18

Site Information	
City / State:	Milford, UT
Latitude (N):	38.4 °
Longitude (W):	-113 °
Altitude	1534 m
ASHRAE Cooling DB Temp.	34.9 °C
ASHRAE Extreme Mean Min. Temp.	-23.1 °C

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.2 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

Estimated Annual Energy Production	
P50 net production (yr-1)	569501.1 MWh
AC capacity factor - Inv Rating	29.55%
AC capacity factor - POI Rating	32.51%
DC capacity factor	22.32%
Specific Production	1955 kWh/kWp/yr
Performance Ratio PR	76.48%
Night time losses	-1607.7 MWh
Plant Output Limitations	2.76%

Facility Level Information	
Nameplate Capacity	**291.27 MWDC**
Number of modules	844272
Nameplate Capacity	**220.00 MWAC**
Number of arrays	44
Interconnection Limit	**200.00 MWAC**
Inteconnection Voltage	230 kV
DC/AC ratio - POI Rating	1.456

Weather	
Source	NSRDB PSMv3
GHI	1903.4 kWh/m2
DHI	kWh/m2
Global POA	2556.6 kWh/m2
Average Temp.	9.92 °C
Average Temp. (Generation)	14.91 °C
Average Wind	2.11 m/s
Average Wind (Generation)	2.82 m/s

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	1.30%
HV transformer no-load losses	0.07%
HV transformer full load losses	0.48%
HV line	0.05%
Auxiliary	0.01%

BURNS & McDONNELL

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: **Pacificorp 2018 Renewables Technology Assessment**

Variant: VC2 Date: 31-Aug-18

Site Information	
City / State:	Rock Springs, Wyoming
Latitude (N):	41.6 °
Longitude (W):	-109 °
Altitude	2055 m
ASHRAE Cooling DB Temp.	29.8 °C
ASHRAE Extreme Mean Min. Temp.	-25.1 °C

Estimated Annual Energy Production	
P50 net production (yr-1)	12343.3 MWh
AC capacity factor - Inv Rating	28.18%
AC capacity factor - POI Rating	28.18%
DC capacity factor	21.29%
Specific Production	1865 kWh/kWp/yr
Performance Ratio PR	82.17%
Night time losses	-20.0 MWh
Plant Output Limitations	0.00%

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Facility Level Information	
Nameplate Capacity	**6.62 MWDC**
Number of modules	19188
Nameplate Capacity	**5.00 MWAC**
Number of arrays	1
Interconnection Limit	**5.00 MWAC**
Inteconnection Voltage	34.5 kV
DC/AC ratio - POI Rating	1.324

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

Weather	
Source	TMY3
GHI	1693.5 kWh/m2
DHI	kWh/m2
Global POA	2269.3 kWh/m2
Average Temp.	6.49 °C
Average Temp. (Generation)	10.35 °C
Average Wind	4.81 m/s
Average Wind (Generation)	5.32 m/s

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.2 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	0.70%
HV transformer no-load losses	0.00%
HV transformer full load losses	0.00%
HV line	0.00%
Auxiliary	0.01%

BURNS & McDONNELL

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: Pacificorp 2018 Renewables Technology Assessment

Variant: VC2 Date: 31-Aug-18

Site Information	
City / State:	Rock Springs, Wyoming
Latitude (N):	41.6 °
Longitude (W):	-109 °
Altitude	2055 m
ASHRAE Cooling DB Temp.	29.8 °C
ASHRAE Extreme Mean Min. Temp.	-25.1 °C

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.2 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

Estimated Annual Energy Production	
P50 net production (yr-1)	131702.0 MWh
AC capacity factor - Inv Rating	27.34%
AC capacity factor - POI Rating	30.07%
DC capacity factor	20.65%
Specific Production	1809 kWh/kWp/yr
Performance Ratio PR	79.70%
Night time losses	-387.3 MWh
Plant Output Limitations	2.04%

Facility Level Information	
Nameplate Capacity	**72.82 MWDC**
Number of modules	211068
Nameplate Capacity	**55.00 MWAC**
Number of arrays	11
Interconnection Limit	**50.00 MWAC**
Inteconnection Voltage	115 kV
DC/AC ratio - POI Rating	1.456

Weather	
Source	TMY3
GHI	1693.5 kWh/m2
DHI	kWh/m2
Global POA	2269.3 kWh/m2
Average Temp.	6.49 °C
Average Temp. (Generation)	10.35 °C
Average Wind	4.81 m/s
Average Wind (Generation)	5.32 m/s

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	1.30%
HV transformer no-load losses	0.07%
HV transformer full load losses	0.48%
HV line	0.05%
Auxiliary	0.01%

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: **Pacificorp 2018 Renewables Technology Assessment**

Variant: VC2 Date: 31-Aug-18

Site Information	
City / State:	Rock Springs, Wyoming
Latitude (N):	41.6 °
Longitude (W):	-109 °
Altitude	2055 m
ASHRAE Cooling DB Temp.	29.8 °C
ASHRAE Extreme Mean Min. Temp.	-25.1 °C

Estimated Annual Energy Production	
P50 net production (yr-1)	526808.1 MWh
AC capacity factor - Inv Rating	27.34%
AC capacity factor - POI Rating	30.07%
DC capacity factor	20.65%
Specific Production	1809 kWh/kWp/yr
Performance Ratio PR	79.70%
Night time losses	-1549.3 MWh
Plant Output Limitations	2.04%

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Facility Level Information	
Nameplate Capacity	**291.27 MWDC**
Number of modules	844272
Nameplate Capacity	**220.00 MWAC**
Number of arrays	44
Interconnection Limit	**200.00 MWAC**
Inteconnection Voltage	230 kV
DC/AC ratio - POI Rating	1.456

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

Weather	
Source	TMY3
GHI	1693.5 kWh/m2
DHI	kWh/m2
Global POA	2269.3 kWh/m2
Average Temp.	6.49 °C
Average Temp. (Generation)	10.35 °C
Average Wind	4.81 m/s
Average Wind (Generation)	5.32 m/s

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.2 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	1.30%
HV transformer no-load losses	0.07%
HV transformer full load losses	0.48%
HV line	0.05%
Auxiliary	0.01%

BURNS & McDONNELL

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: Pacificorp 2018 Renewables Technology Assessment

Variant: VC3 Date: 31-Aug-18

Site Information	
City / State:	Yakima, WA
Latitude (N):	46.6 °
Longitude (W):	-120.5 °
Altitude	324 m
ASHRAE Cooling DB Temp.	34.1 °C
ASHRAE Extreme Mean Min. Temp.	-17 °C

Estimated Annual Energy Production	
P50 net production (yr-1)	10609.2 MWh
AC capacity factor - Inv Rating	24.22%
AC capacity factor - POI Rating	24.22%
DC capacity factor	18.29%
Specific Production	1603 kWh/kWp/yr
Performance Ratio PR	81.56%
Night time losses	-20.1 MWh
Plant Output Limitations	0.00%

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Facility Level Information	
Nameplate Capacity	**6.62 MWDC**
Number of modules	19188
Nameplate Capacity	**5.00 MWAC**
Number of arrays	1
Interconnection Limit	**5.00 MWAC**
Inteconnection Voltage	34.5 kV
DC/AC ratio - POI Rating	1.324

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

Weather	
Source	TMY3
GHI	1486.8 kWh/m2
DHI	kWh/m2
Global POA	1964.9 kWh/m2
Average Temp.	9.97 °C
Average Temp. (Generation)	14.53 °C
Average Wind	3.17 m/s
Average Wind (Generation)	3.30 m/s

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.4 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	0.70%
HV transformer no-load losses	0.00%
HV transformer full load losses	0.00%
HV line	0.00%
Auxiliary	0.01%

BURNS & McDONNELL

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: **Pacificorp 2018 Renewables Technology Assessment**

Variant: VC3 Date: 31-Aug-18

Site Information	
City / State:	Yakima, WA
Latitude (N):	46.6 °
Longitude (W):	-120.5 °
Altitude	324 m
ASHRAE Cooling DB Temp.	34.1 °C
ASHRAE Extreme Mean Min. Temp.	-17 °C

Estimated Annual Energy Production	
P50 net production (yr-1)	114064.6 MWh
AC capacity factor - Inv Rating	23.67%
AC capacity factor - POI Rating	26.04%
DC capacity factor	17.88%
Specific Production	1566 kWh/kWp/yr
Performance Ratio PR	79.72%
Night time losses	-389.2 MWh
Plant Output Limitations	1.32%

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Facility Level Information	
Nameplate Capacity	**72.82 MWDC**
Number of modules	211068
Nameplate Capacity	**55.00 MWAC**
Number of arrays	11
Interconnection Limit	**50.00 MWAC**
Inteconnection Voltage	115 kV
DC/AC ratio - POI Rating	1.456

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

Weather	
Source	TMY3
GHI	1486.8 kWh/m2
DHI	kWh/m2
Global POA	1964.9 kWh/m2
Average Temp.	9.97 °C
Average Temp. (Generation)	14.53 °C
Average Wind	3.17 m/s
Average Wind (Generation)	3.30 m/s

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.4 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	1.30%
HV transformer no-load losses	0.07%
HV transformer full load losses	0.48%
HV line	0.05%
Auxiliary	0.01%

Energy Production Summary

Burns & McDonnell, Energy Division

Project Name: **Pacificorp 2018 Renewables Technology Assessment**

Variant: VC3 Date: 31-Aug-18

Site Information	
City / State:	Yakima, WA
Latitude (N):	46.6 °
Longitude (W):	-120.5 °
Altitude	324 m
ASHRAE Cooling DB Temp.	34.1 °C
ASHRAE Extreme Mean Min. Temp.	-17 °C

Design Parameters	
System DC Voltage	1500 VDC
GCR	36 %
Row spacing	5.5 m
Mounting	Tracker
Tilt angle or rotation limits	60 °
Azimuth	0 °
Tracking strategy	TRUE
Availability	100.0 %
Degradation	0.5 %/yr

Array Level Information	
Module rating	345 W
# Modules per string	26
Strings in parallel	738
Total number of modules	19188
DC capacity	6620 kW
Inverter rating	5000 kW
DC/AC ratio - Inv Rating	1.324

PVsyst Input Parameters	
Transposition model	Perez
Constant thermal loss factor (Uc)	25.0 W/m2-K
Wind loss factor (Uv)	1.2 W/m2-K/m/s
Soiling losses	2.4 %
Light induced degradation	2.0 %
DC wiring loss	1.5 %
Module quality loss	-0.4 %
Module mismatch loss	1.0 %
DC health loss	1.0 %

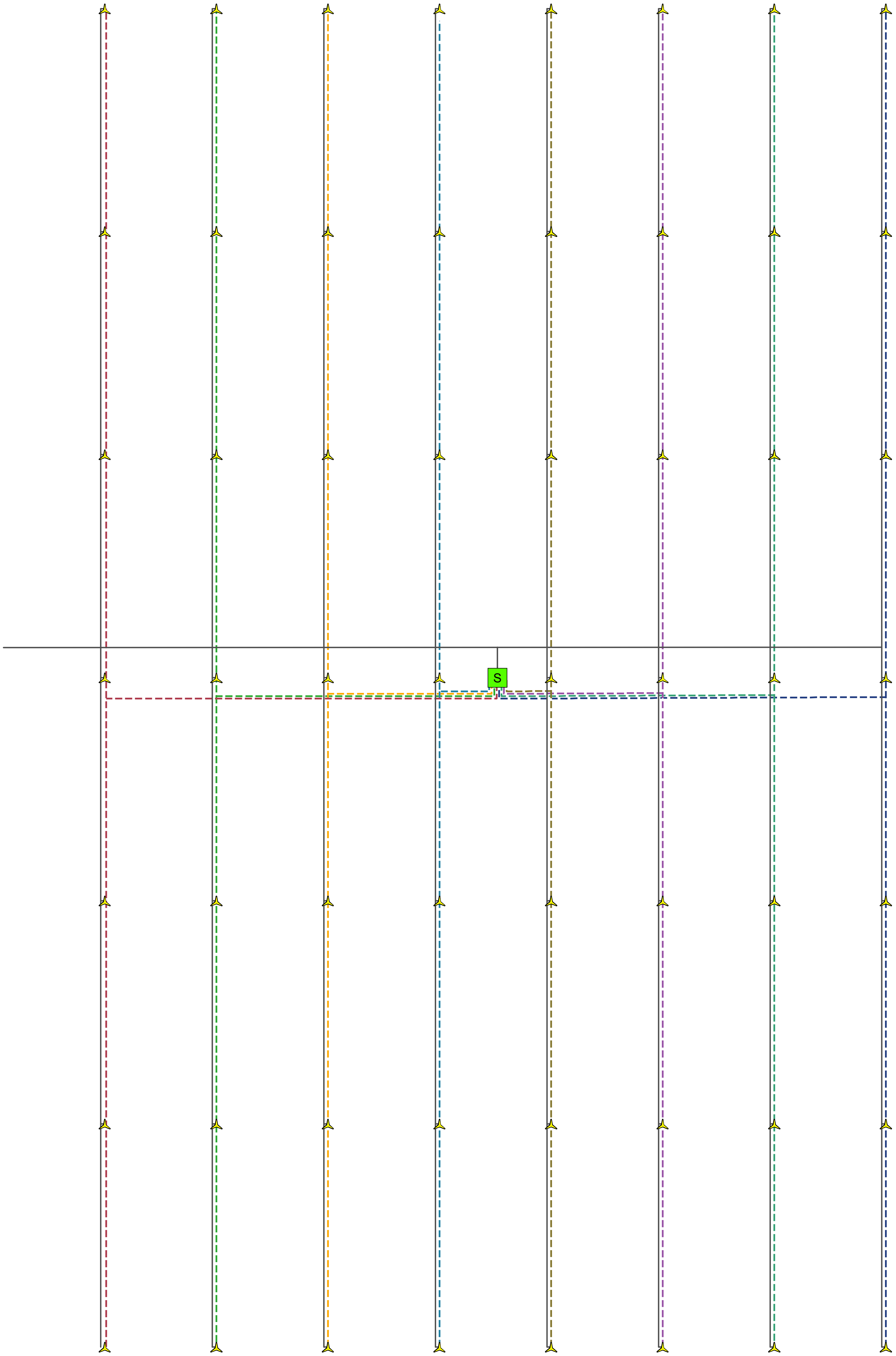
Estimated Annual Energy Production	
P50 net production (yr-1)	456258.5 MWh
AC capacity factor - Inv Rating	23.67%
AC capacity factor - POI Rating	26.04%
DC capacity factor	17.88%
Specific Production	1566 kWh/kWp/yr
Performance Ratio PR	79.72%
Night time losses	-1556.8 MWh
Plant Output Limitations	1.32%

Facility Level Information	
Nameplate Capacity	**291.27 MWDC**
Number of modules	844272
Nameplate Capacity	**220.00 MWAC**
Number of arrays	44
Interconnection Limit	**200.00 MWAC**
Inteconnection Voltage	230 kV
DC/AC ratio - POI Rating	1.456

Weather	
Source	TMY3
GHI	1486.8 kWh/m2
DHI	kWh/m2
Global POA	1964.9 kWh/m2
Average Temp.	9.97 °C
Average Temp. (Generation)	14.53 °C
Average Wind	3.17 m/s
Average Wind (Generation)	3.30 m/s

AC System Losses	
MV transformer no-load losses	0.07%
MV transformer full load losses	0.85%
MV collection system	1.30%
HV transformer no-load losses	0.07%
HV transformer full load losses	0.48%
HV line	0.05%
Auxiliary	0.01%

APPENDIX D – WIND PERFORMANCE INFORMATION



Drawing Notes:
1. Layout is intended to be generic / conceptual and not necessarily representative of a site that would be constructed. Layout based upon generic turbine model with approx. 414m by 828m gridded spacing. Final turbine model, project size, and site conditions will alter layout.

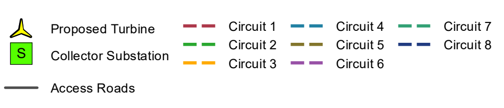
PRELIMINARY
NOT FOR CONSTRUCTION

GENERIC SITE LAYOUT
200 MW Wind Farm

LOCATION:	Generic
CLIENT:	Pacificorp
PROJ. NO.:	109571
CREATED:	09/06/2018

www.burnsmcd.com

LEGEND



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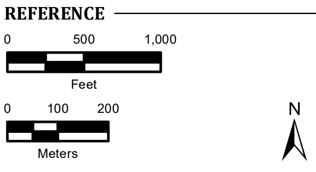
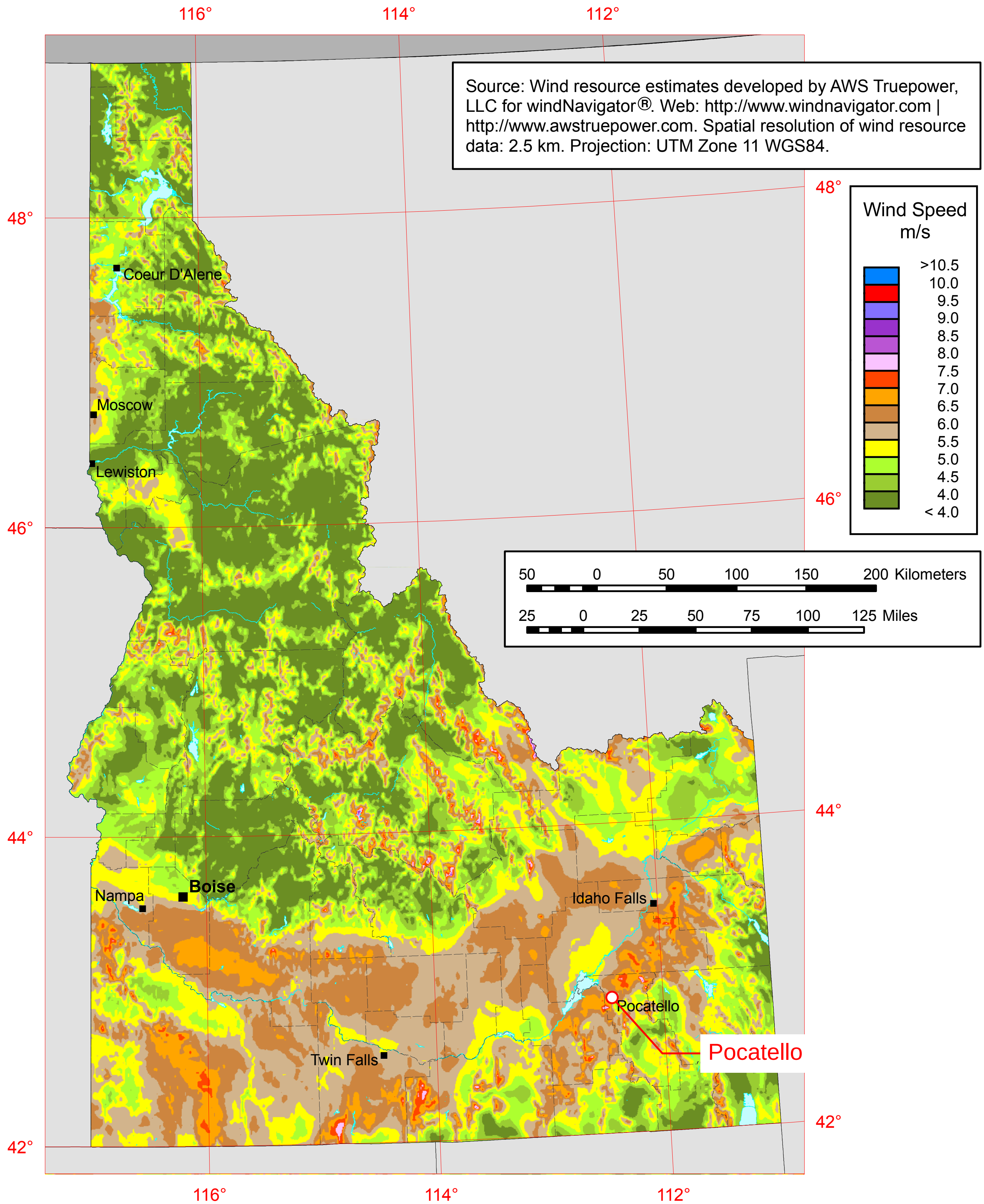


Idaho - Annual Average Wind Speed at 80 m



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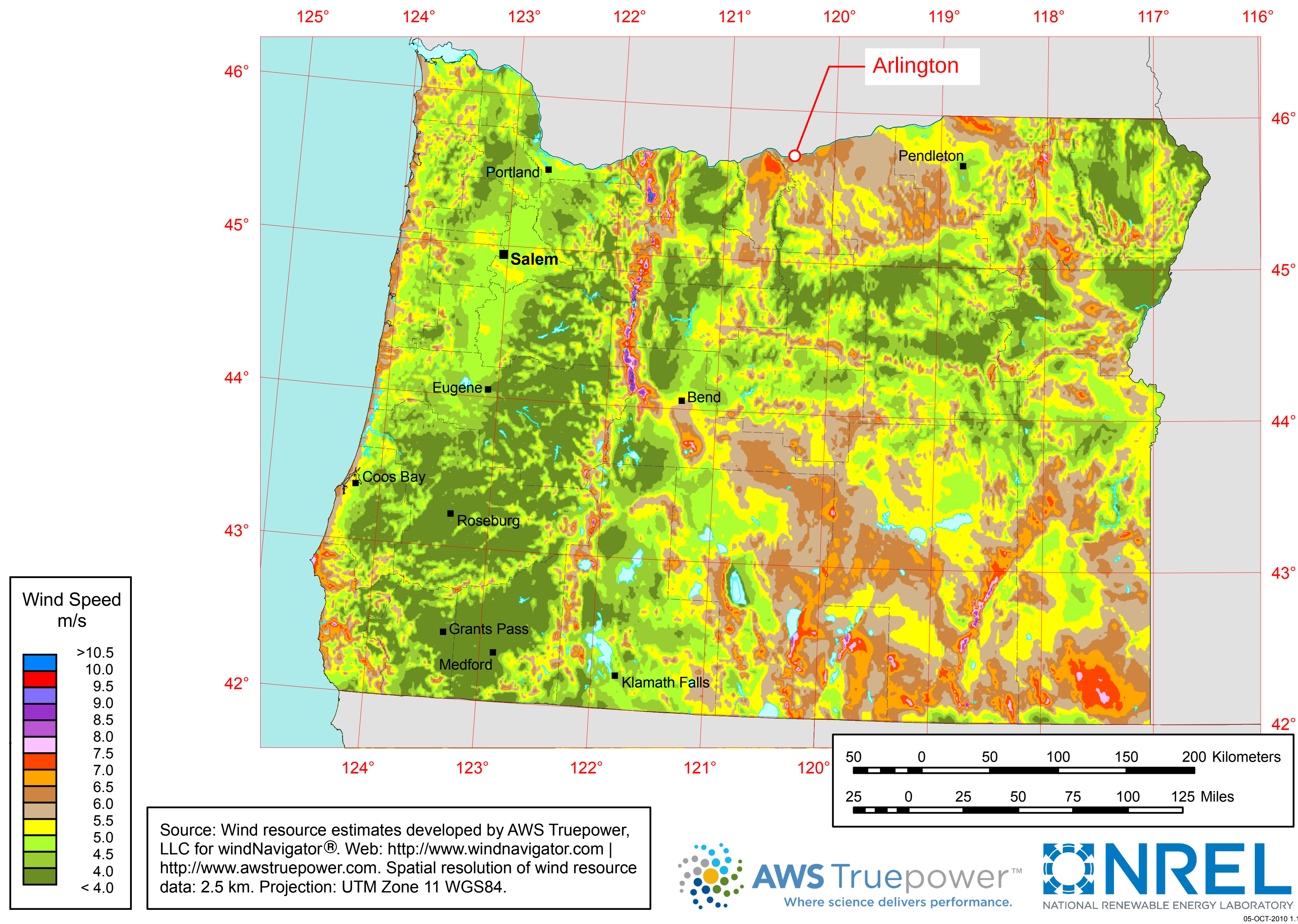
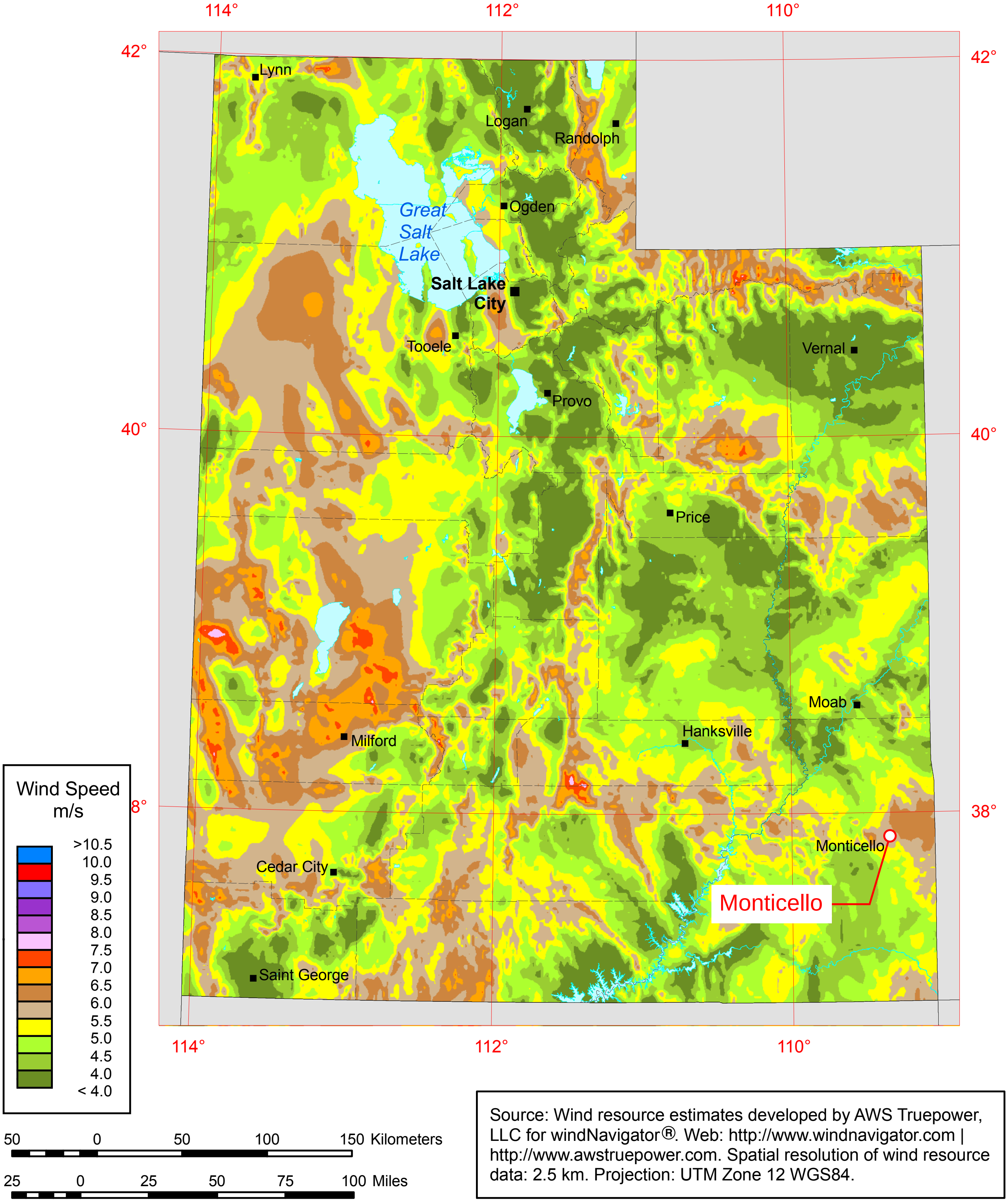
06-OCT-2010 1.1.1

Oregon - Annual Average Wind Speed at 80 m



Source: Wind resource estimates developed by AWS Truepower, LLC for windNavigator®. Web: http://www.windnavigator.com | http://www.awstruepower.com. Spatial resolution of wind resource data: 2.5 km. Projection: UTM Zone 11 WGS84.

Utah - Annual Average Wind Speed at 80 m



Source: Wind resource estimates developed by AWS Truepower, LLC for windNavigator®. Web: http://www.windnavigator.com | http://www.awstruepower.com. Spatial resolution of wind resource data: 2.5 km. Projection: UTM Zone 12 WGS84.

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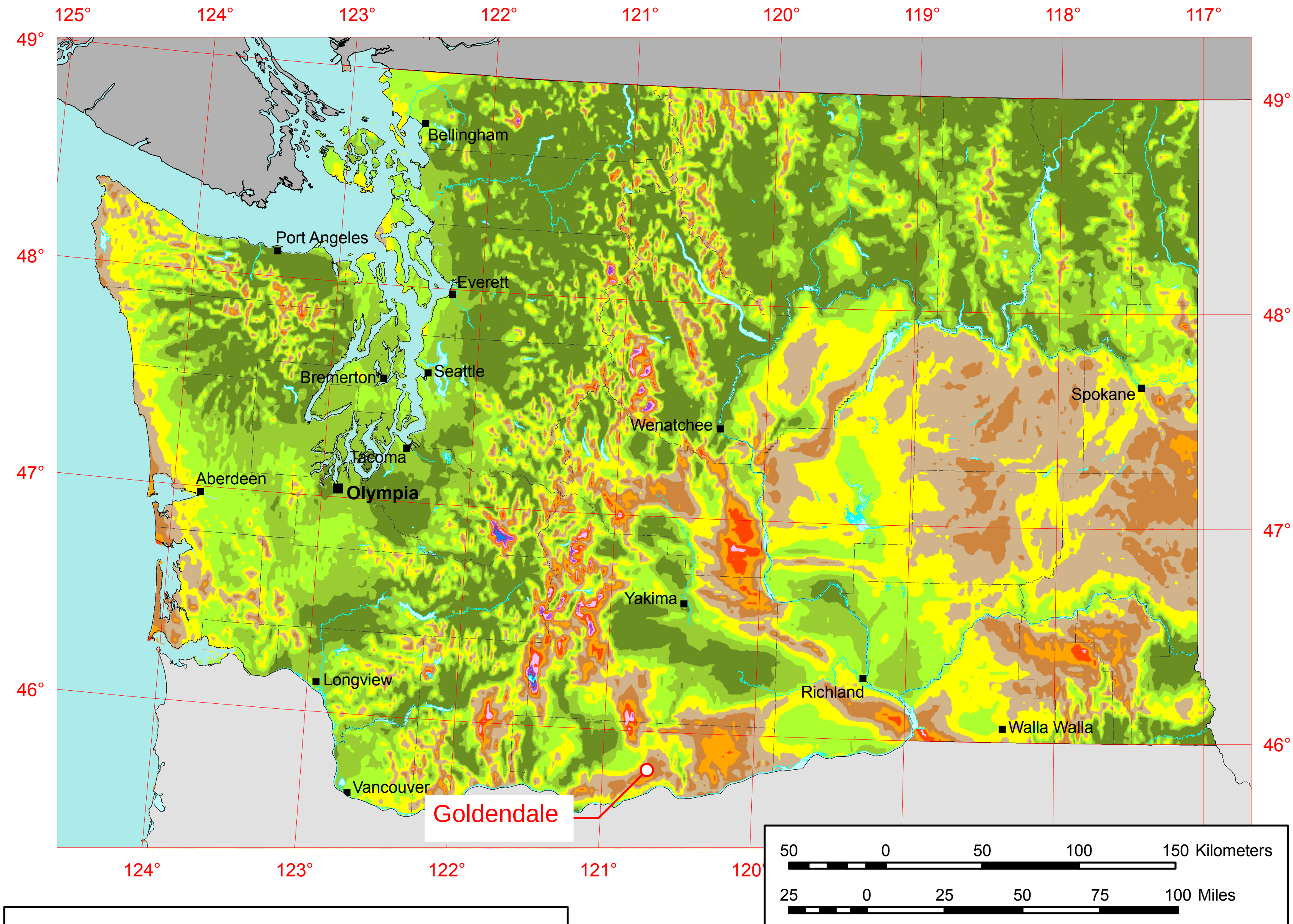
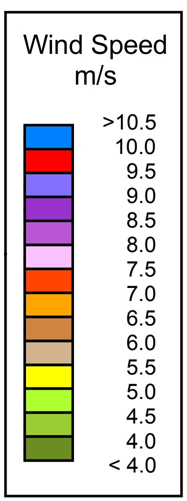
Washington - Annual Average Wind Speed at 80 m





Source: Wind resource estimates developed by AWS Truepower, LLC for windNavigator®. Web: http://www.windnavigator.com | http://www.awstruepower.com. Spatial resolution of wind resource data: 2.5 km. Projection: UTM Zone 11 WGS84.

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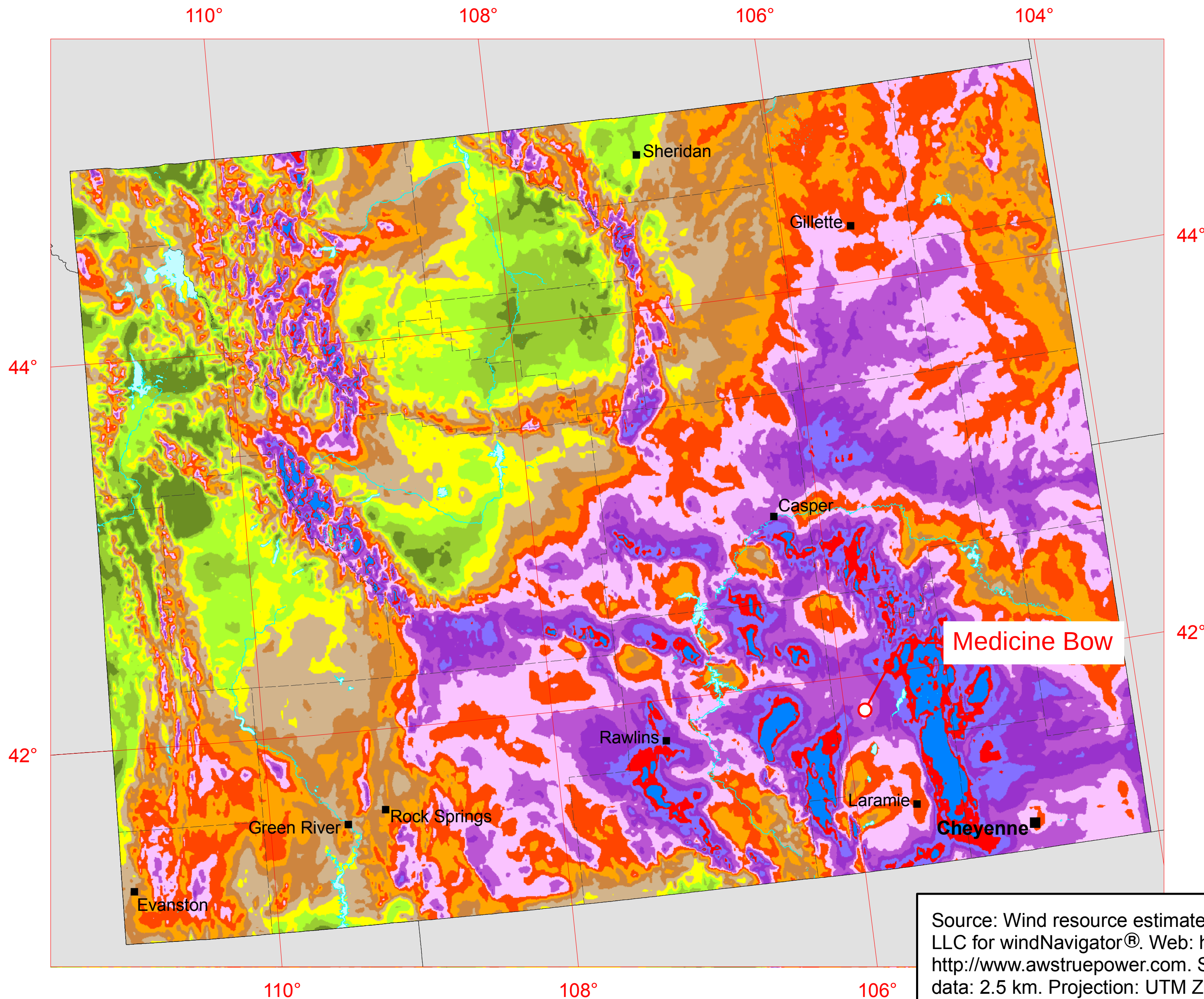
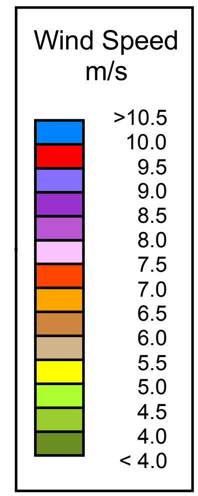
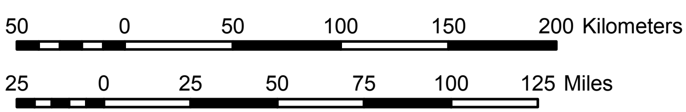
05-OCT-2010 1.1.1

Wyoming Annual Average Wind Speed at 80 m





Source: Wind resource estimates developed by AWS Truepower, LLC for windNavigator®. Web: http://www.windnavigator.com | http://www.awstruepower.com. Spatial resolution of wind resource data: 2.5 km. Projection: UTM Zone 11 WGS84.



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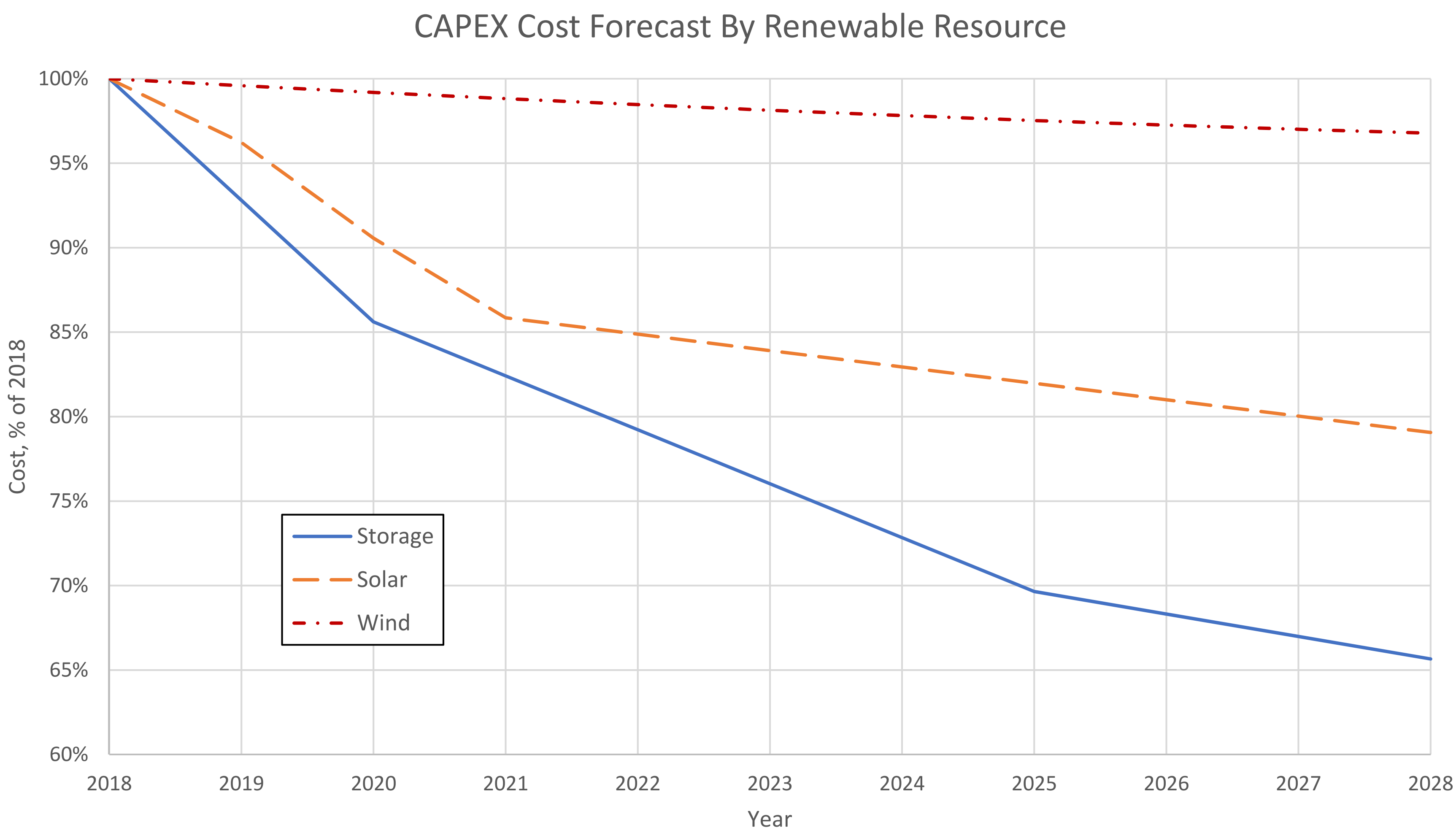
APPENDIX E – DECLINING COST CURVES



Notes:
1. The declining cost curve for onshore wind was developed using NREL Techno-Resource Group (TRG) mid CAPEX cost inforamtion. The cost for TRG 4 - TRG 8 were averaged which represent the Pacificorp identified sites.
2. The declining cost curve for utility solar photovoltaic was developed using NREL mid CAPEX cost inforamtion. From the inforamation provided, the costs for Seattle, Los Angeles, and Daggett were averaged.
3. The declining cost curve for battery storage was developed using NREL mid CAPEX cost information for an 8-hour storage device with 15-year life and 90% round-trip efficiency. Linear interpolation was used between NREL provided data points.

CREATE AMAZING.

Burns & McDonnell
9785 Maroon Circle, Suite 400
Centennial, CO 80112
O 303-721-9292
F 303-721-0563
www.burnsmcd.com