TURLOCK IRRIGATION DISTRICT

Energy Storage Study 2014

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9/17/2014

Contents

1. Executive Summary

Assembly Bill 2514 ("AB2514") requires publicly-owned utilities such as Turlock Irrigation District ("TID") to determine if it is appropriate to establish targets for the procurement of viable and cost-effective energy storage systems by December 31, 2016, and December 31, 2021. Such determination must be made by October 1, 2014 and reevaluated every three years thereafter. In compliance with AB2514 the TID Board of Directors ("TID Board") through Resolution 2012-10 directed staff to review available energy storage systems and recommend to the TID Board, if appropriate, energy storage procurement targets.

There are a number of energy storage technologies that are currently commercially available and several other technologies under development. Each technology has differing cost and operating characteristics. Energy storage systems can be utilized in various ways such as absorbing energy during the low price periods for use during the high price periods, to reduce the need for generation, transmission, and distribution capacity during the peak load periods, provide ancillary services, and integrate intermittent renewable generation.

As directed by the TID Board staff conducted a review of available energy storage systems which consisted of reviewing reports and publications by others regarding energy storage systems, reports by others regarding their recommended energy storage procurement targets, and modelling of several commercially available energy storage systems. The results of the staff study concluded that energy storage systems are currently not cost-effective and in most cases increased TID cost by millions each year. Furthermore, except for pumped storage systems, there is limited operational history on utility scale storage systems. Hence there is limited data on performance degradation, operation and maintenance expense, and the life of storage systems in utility applications. Given the results of the staff study, staff recommends that the Board make a determination that it is not appropriate to adopt energy storage procurement targets at this time. Even though staff is recommending no targets be set, staff believes that energy storage systems will become cost effective and will be an integral part of a utility's portfolio in the future and plans to continually evaluate storage systems periodically.

2. Introduction

On September 29, 2010 the Governor of California signed into law AB2514 which among other things require publicly-owned utilities such as TID to do the following:

- On or before March 1, 2012, initiate a process to determine appropriate targets, if any, for the utility to procure viable and cost-effective energy storage systems to be achieved by December 31, 2016, and December 31, 2021.
- If determined to be appropriate, adopt the procurement targets by October 1, 2014.
- Reevaluate the determinations made not less than once every three years.
- Report to the Energy Commission regarding the energy storage system procurement targets and policies adopted and any modifications made to those targets as a result of subsequent reevaluations.

In compliance with the above described requirements, the TID Board through Resolution 2012-10 directed staff to review available energy storage systems and recommend to the TID Board, if appropriate, energy storage procurement targets to be achieved by December 31, 2016, and December 31, 2021.

AB2514 defines energy storage systems (“Energy Storage”) as commercially available technology that is capable of absorbing energy, storing it for a period of time, and thereafter dispatching the energy. Energy Storage must be cost effective and either reduce emissions of greenhouse gases, reduce demand for peak electrical generation, defer or substitute for an investment in generation, transmission, or distribution assets, or improve the reliable operation of the electrical transmission or distribution grid. Furthermore, Energy Storage must do one or more of the following:

- Use mechanical, chemical, or thermal processes to store energy that was generated at one time for use at a later time.
- Store thermal energy for direct use for heating or cooling at a later time in a manner that avoids the need to use electricity at that later time.
- Use mechanical, chemical, or thermal processes to store energy generated from renewable resources for use at a later time.
- Use mechanical, chemical, or thermal processes to store energy generated from mechanical processes that would otherwise be wasted for delivery at a later time.

The Energy Storage may be centralized or distributed, owned by TID, by a customer of TID, by a third party, or jointly owned.

This report summarizes the evaluation done by TID staff to support staff's recommendation to the TID Board regarding the adoption of energy storage procurement targets.

3. Technology

There are a number of storage technologies that are currently commercially available and several other technologies under development. Each technology has differing cost and operating characteristics. For example, certain types of technology can provide a high output quickly but cannot provide energy for a long duration (see Figure 1 below). Hence, the appropriate storage technology would depend upon the intended use.

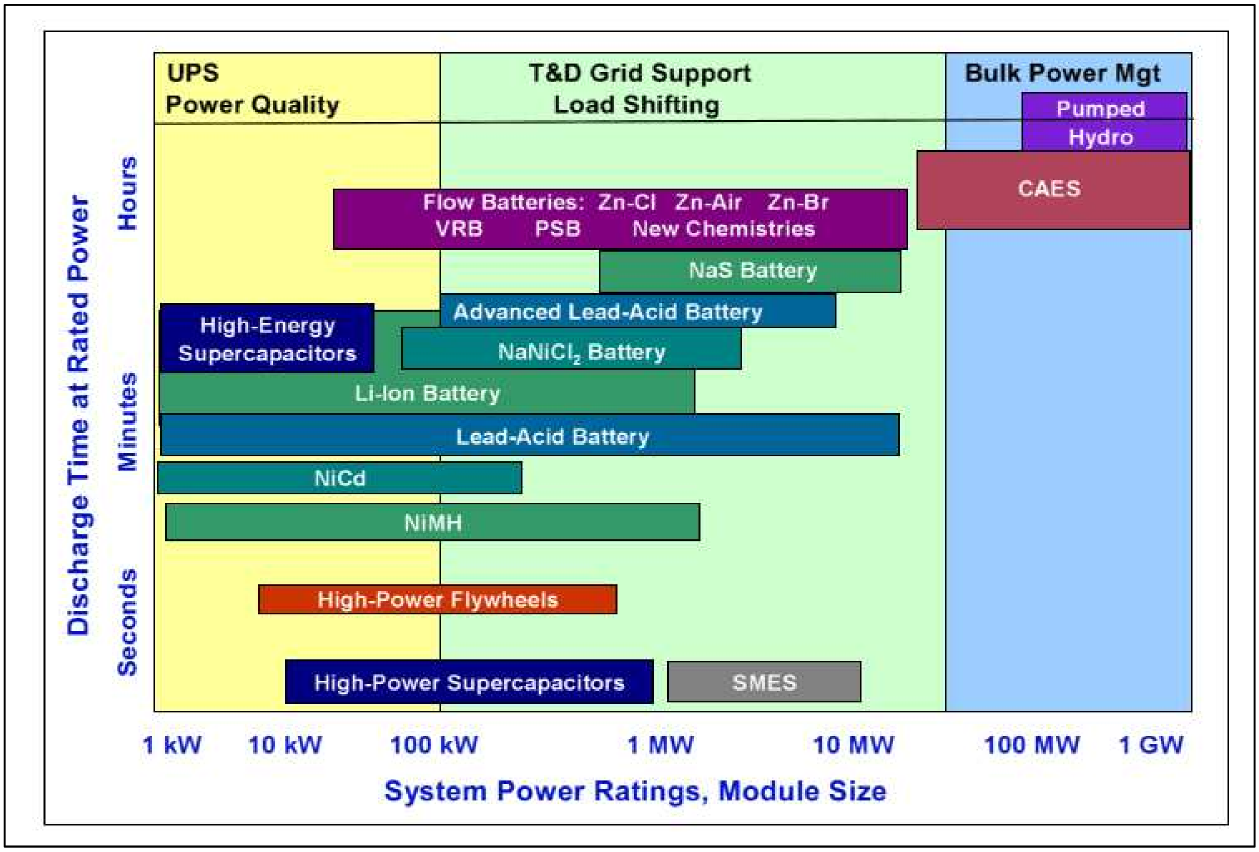


Figure 1 Energy Storage Technology Performance Matrix (Source: DOE/EPRI 2013 Electricity Storage Handbook - July 2013)

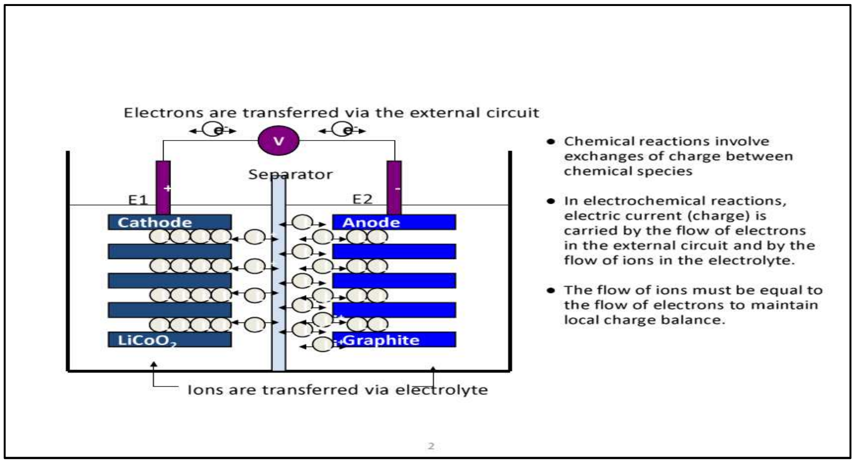
In this report we have grouped the different types of commercially available storage technologies for utility applications into the following: 1) Electrochemical, 2) Flywheel, 3) Thermal, 4) Compressed Air, and 5) Pumped Hydro.

3.1. Electrochemical

Below is a description of three types of commercially available battery technologies suitable for utility applications. Although there are other types of batteries for utility applications being develop (e.g. advanced lead-acid, sodium metal halide, and metal air) they are currently not commercially available and therefore not discussed herein.

3.1.1. Lithium Ion Battery

Lithium ion batteries ("Li-on") rely on the transfer of lithium ions between electrodes to charge and discharge and are currently used in numerous applications in the personal electronics and automobile industry. Compared to other battery storage technologies, they are usually smaller in size for the same amount of capacity and energy (i.e. they have relatively higher energy and power density) and have lower operating and maintenance costs. Li-on batteries typically have a life of 15-20 years and round trip efficiencies of about 83%. This battery technology is currently the fastest growing segment for stationary storage applications. They have been deployed in a wide range of utility energy-storage applications, ranging from a few kilowatt-hours in residential systems with rooftop photovoltaic arrays to multi-megawatt containerized batteries for the provision of grid ancillary services. Currently there are roughly 83 MW of Li-on based storage systems in operation in the United States.



- Chemical reactions involve exchanges of charge between chemical species
- In electrochemical reactions, electric current (charge) is carried by the flow of electrons in the external circuit and by the flow of ions in the electrolyte.
- The flow of ions must be equal to the flow of electrons to maintain local charge balance.

Figure 2 Li-ion Battery Diagram (Source: DOE/EPRI 2013 Electricity Storage Handbook - July 2013)

3.1.2. Sodium Sulfur Battery

Sodium sulfur batteries (“NAS”) use electrochemical reactions between sodium and molten sulfur to charge and discharge. They operate at fairly high temperature of about 300-350° C, are highly corrosive, have low power-to-energy ratios, life of 15 years, and round trip efficiencies of about 75%. There are currently 12 MW of NAS batteries that have been installed by U.S. utilities with about another 9 MW in-progress. Globally, there is 316 MW of NAS installed to date.

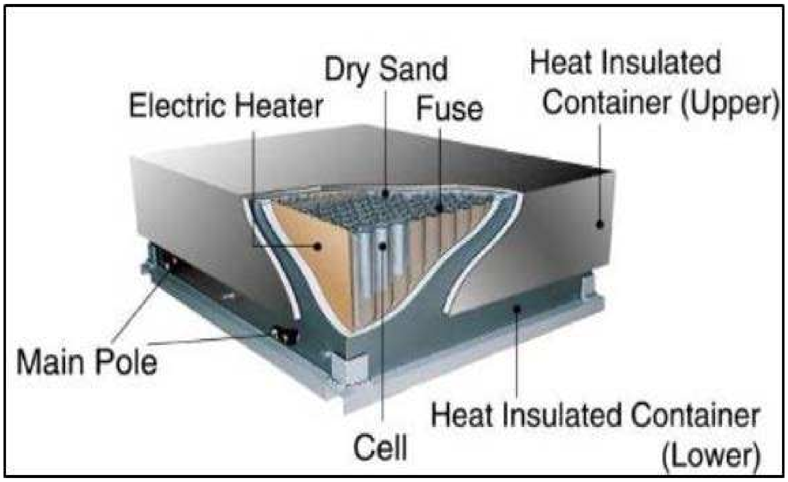


Figure 3 Sodium Sulfur Battery Diagram (Source: DOE/EPRI 2013 Electricity Storage Handbook - July 2013)

3.1.3. Flow Battery

Flow batteries use a liquid electrolyte and an electrochemical cell to store/generate electricity. The liquid electrolyte is stored externally and pumped through the cell. This allows the energy capacity of the battery to be increased at a moderate cost making them suitable for long duration applications. These types of batteries are expected to last about 15 years and have round trip efficiencies of 70-80%. Relative to integrated battery technologies such as the Li-on and NAS, flow batteries tend to have a larger footprint due to the need for flow system components. Historically, flow batteries can experience irreversible capacity loss over time and thus have not been widely used. However, recent electrolyte formulations seemed to have minimized the capacity loss and allowed the use of lower cost separator materials. While there are several different flow batteries, the vanadium redox system is the more mature type of flow battery. In the United States, there is a total of 1 MW of flow battery based storage systems operational. Recently, EnerVault's 0.25 MW/1 MWh iron-chromium flow batteries went online in Turlock.

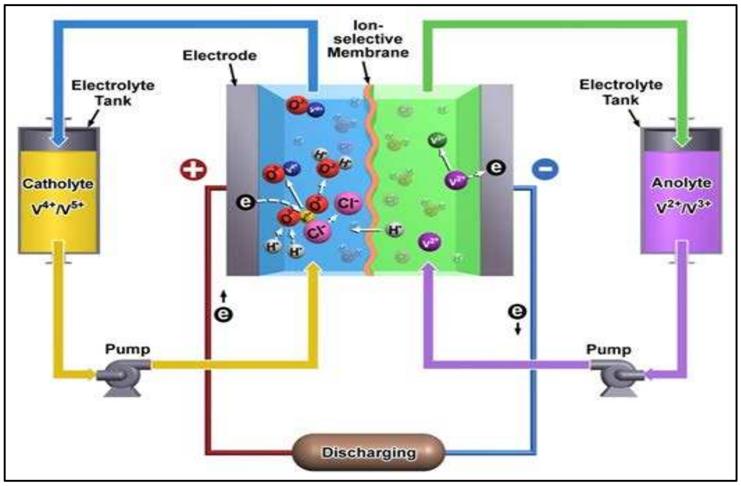


Figure 4 Vanadium Redox Battery Diagram (Source: DOE/EPRI 2013 Electricity Storage Handbook - July 2013)

3.2. Flywheel

A flywheel is a rotating mechanical device used to store rotational energy that can be called up instantaneously. At the most basic level, a flywheel contains a spinning mass in its center driven by a motor and when energy is needed, the spinning force drives a device similar to a turbine to produce electricity, slowing the rate of rotation.   A flywheel is recharged by using the motor to increase its rotational speed once again. Some of the key advantages of flywheel energy storage are low maintenance, long life (some flywheels are capable of well over 100,000 full depth of discharge cycles and the newest configurations are capable of greater than 175,000 full depth of discharge cycles), and negligible environmental impact. They have high energy density and substantial durability which allows them to be cycled frequently with no impact to performance. They also have very fast response and ramp rates. They generally can respond to regulation signals in milliseconds and can go from full discharge to full charge within a few seconds or less. Round trip efficiencies are between 70-80%. Flywheel energy storage systems (FESS) are well suited for high power, relatively low energy applications such as power quality maintenance and frequency response. There are two flywheel installations operating in the United States for a combined total of 32 MW.

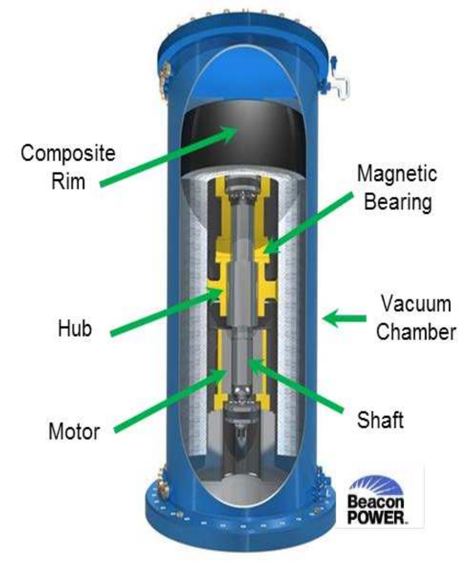


Figure 5 Flywheel System Diagram (Source: DOE/EPRI 2013 Electricity Storage Handbook - July 2013)

3.3. Compressed Air

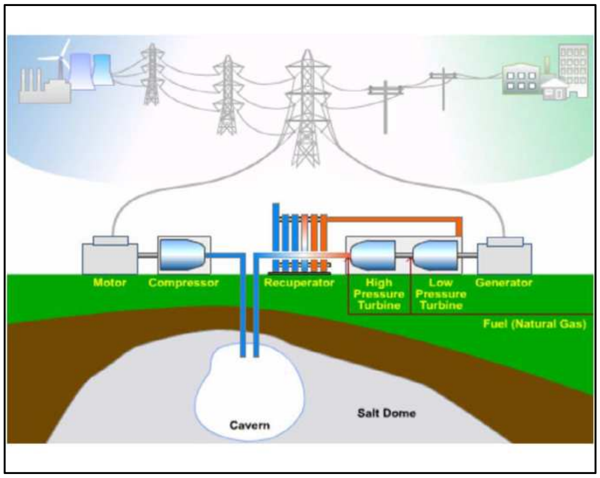


Figure 6 Compressed Air Energy Storage Plant (Source: DOE/EPRI 2013 Electricity Storage Handbook - July 2013)

Compressed air energy storage ("CAES") has been used since the 1870's. However, the first utility scale deployment came online in the 1970's. CAES stores energy by compressing and storing ambient air under pressure (typically at 1,015 psia) in an underground cavern or above ground pressure vessels or pipes. To generate electricity, the pressurized air is heated and expanded in a turbine that drives a generator. There are currently only two operating utility sized CAES plants, the 321 MW plant in Huntorf, Germany (operating since December 1978) and the 110 MW plant in McIntosh, Alabama (with 18 years of operating history). These systems typically have round trip efficiencies of 42-55%. Future improvements in the heat recovery systems of CAES plants are expected to increase efficiency up to

70%. Salt caverns in deep salt formations have traditionally been used. The use of natural aquifers and depleted natural gas fields are currently being studied.

3.4. Thermal

3.4.1. Ice Thermal

Ice storage supplements existing HVAC systems by creating ice during the off-peak periods which is then used during the on-peak periods to reduce the cooling load of the HVAC system. The City of Redding and several Southern California Public Power Agency member utilities have deployed ice storage technologies. There are currently 36 MW of ice storage systems online in the United States. These systems are designed to last 20-25 years.

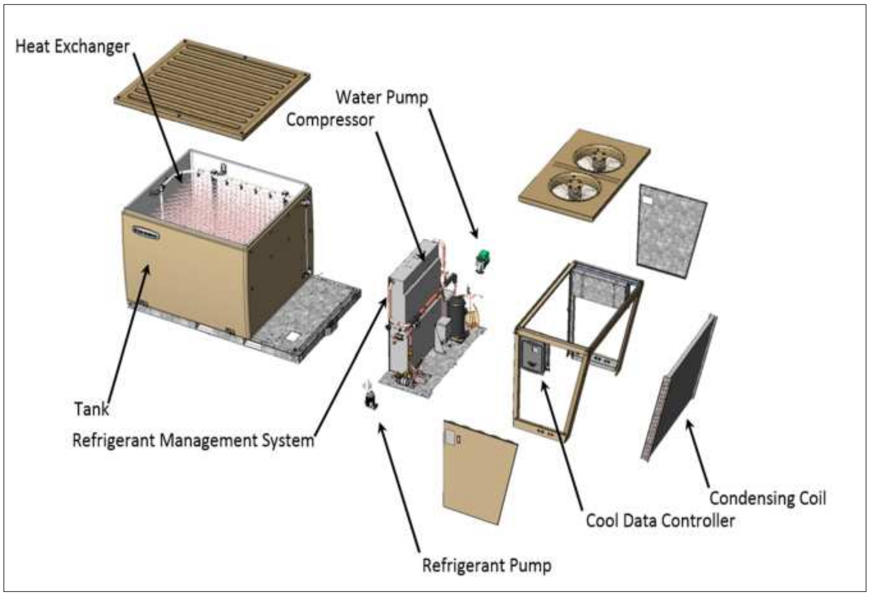


Figure 7 Ice Bear Distributed Energy Storage (Source: Ice Energy)

3.4.2. Solar Thermal

Solar thermal power plants store energy by heating a medium (typically oil or molten salt) to store thermal energy and later using such medium to generate steam that drives a turbine to produce electricity. In 2013 the 280 MW Solana Generation Station in Arizona came online. The project consists of a concentrated solar plant using parabolic trough coupled with six hours of storage capacity using molten salt. The 150 MW Rice Solar Energy Project to be located in Riverside County, CA also will consist of a concetrated solar plant coupled with molten salt thermal storage. The project is expected to be online in 2016.

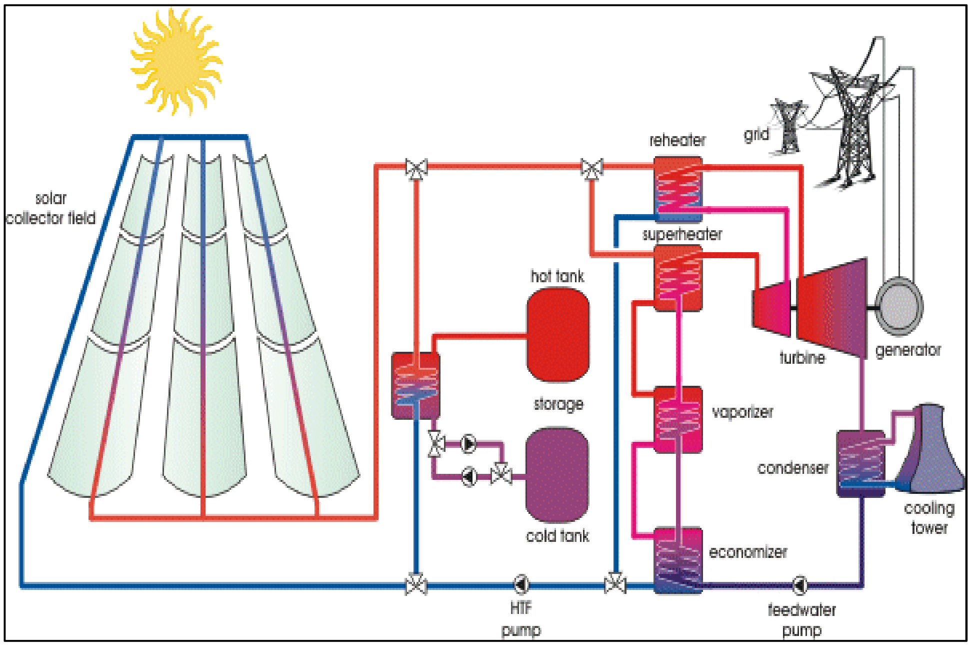


Figure 8 Schematic diagram of concentrated solar thermal power plant with thermal storage (Source: Renewable Energy World 06/2003)

3.5. Pumped Hydro

Pumped hydro is one of the most established energy storage technologies and has been used since the 1920s. Energy storage is achieved by pumping water uphill (typically during the off-peak low energy cost periods) to an upper reservoir. When energy is needed the water pumped uphill is released and allowed to flow downhill through a hydro turbine. Pumped storage power plants are unlike traditional hydroelectric power plants in that they are a net consumer of electricity, due to hydraulic and electrical losses incurred in the cycle of pumping from lower to upper reservoirs. These plants typically have round-trip efficiencies of 76-85%.

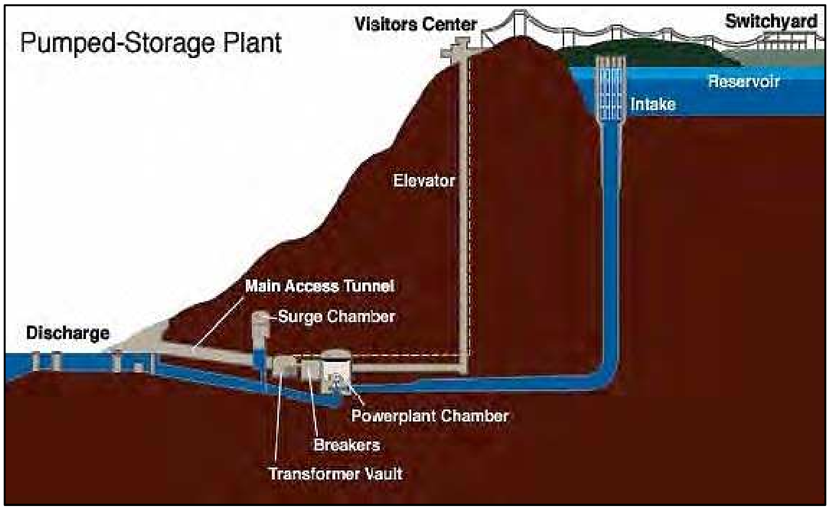


Figure 9 Typical Pumped Storage Plant (Source: DOE/EPRI 2013 Electricity Storage Handbook - July 2013)

4. Storage Applications

Storage systems can be used in the electric system in various ways. In certain cases a storage system performs several services (referred to as "Stacking"). For example, a storage system can provide peak capacity during certain hours of the year and provide regulation in other hours. Several storage applications are described below:

4.1. Time-of-Day Arbitrage

In this application, the storage device is charged during periods when electricity prices are lower (generally during the off-peak periods) and discharged during periods when electricity prices are higher (generally during the on-peak periods). This application also allows for efficient operations of baseload generation resources. Often baseload generation has to be operated at less efficient output levels during the off-peak periods. Installing a storage system may allow a baseload generation to generate at a higher output (more efficient) level during the off-peak periods resulting in fuel cost savings.

4.2. Peak Capacity

A storage system can be used to serve peak load and thus reducing the need for capacity from traditional generating resources. In this application, the storage system is charged in low load periods and discharged during the high load periods. This is somewhat similar to the previous application since generally low electricity prices occur during the low load (off-peak) periods and high electricity prices occur during the high load (on-peak) periods. This application also allows for efficient operations of baseload generation.

4.3. Ancillary Service

Western Electricity Coordinating Council ("WECC") regulations require us to maintain minimum operating reserves that consist of regulating, spinning, and non-spinning reserves. Storage systems could be used to provide regulation, spinning, and non-spinning reserves and therefore freeing up capacity on existing generating resources for other uses such as power sales or reducing the need for additional generating capacity.

4.4. Load Following and Renewable Integration

In order to balance supply and demand, generator output is constantly varied to match demand. At TID, generally the output of Don Pedro or Walnut Energy Center ("WEC") is varied up or down in order to balance the system. The constant movement of output puts additional wear and tear on the power plants particularly thermal units such as WEC. Storage systems can be used to assist in balancing system supply and demand.

The presence of intermittent resources (such as wind or solar) in a system presents additional challenges to balance supply and demand in an electric system. Storage systems can be located at or near intermittent resources to smooth the output from the intermittent resource prior to it entering the electric system thereby reducing system imbalance.

4.5. Voltage Support

Storage systems could be used to assist in maintaining the electric grid's voltage in lieu of traditional tools such as generators, capacitors, and voltage regulators.

4.6. Black Start

During catastrophic grid failures, a storage system can be used to energize the grid and provide station power so power plants can be brought back on-line. In this application, the storage system is charged and remains charged until a grid failure occurs.

4.7. Transmission and Distribution Upgrade Deferral

Transmission and distribution ("T&D") facilities generally do not operate close to their capacity. In most cases the load on a T&D facility only approach capacity limits a few hours a year. Rather than increasing the capacity of the T&D facility that is reaching its limits, a storage device could be used to serve a portion of the load during the few peak hours in a year thereby delaying and possibly avoiding T&D upgrades. Hence, installing a storage system allows the T&D capacity to be optimized and could extend the life of the T&D facilities since the facility is not subjected to higher loading. Storage systems could also be designed to be mobile and therefore could be move around an electric utility system where it is needed. For example, a storage system could be installed to defer upgrades to a substation. Once that substation is eventually upgraded the storage system could then be moved to another substation.

5. Analysis

AB2514 also required the California Public Utilities Commission ("CPUC") to initiate a process to determine appropriate energy storage procurement targets for load serving entities under their jurisdiction. On December 16, 2010 the CPUC opened Rulemaking 10-12-007 to initiate a proceeding ("CPUC Storage Proceeding") to comply with the requirements of AB2514. The CPUC Storage Proceeding involved several stakeholders including the three California investor-owned utilities, other California load-serving entities, storage vendors, and several consumer advocacy groups. The CPUC Storage Proceeding identified several applications for energy storage in an electric utility system. Several of the applications identified were modelled by the Electric Power Research Institute ("EPRI") and DNV Kema to evaluate the cost effectiveness of energy storage in such applications ("CPUC Analysis"). Staff has reviewed the reports on the CPUC Analysis, several documents related to the CPUC Storage Proceeding, the Department of Energy/EPRI Energy Storage Handbook and database, and numerous other energy storage related reports/studies to guide the evaluations done herein.

To determine whether an electric storage system will benefit TID, several types of commercially available electric storage systems were added to TID's resource portfolio to determine their effect on TID's operating cost. The storage technologies modelled in this study were a 30 MW and 50 MW lithium-ion batteries both with 2 hour durations, a 30 MW flywheel with 0.25 hour duration, and a 6 MW thermal storage system with a 6 hour duration. The lithium ion battery was selected for modelling since it is the more commonly used battery type for utility applications in the United States relative to the other types of electrochemical storage devices. Flywheels and thermal storage have seen some interest from other utilities and were analyzed in this study as well. Compressed air storage was not modelled in this study since there have been limited installations to date (only two projects are operating in the United States). Pumped Hydro was also not modelled in this study since TID has some recent analysis on the proposed Red Mountain Bar project.

5.1. Lithium-Ion Battery (without Regulation Reserve Sales)

In this scenario we model a 30 MW Lithium Ion battery ("30 MW Li-on") with 2 hour duration that can provide capacity, energy, regulation, spinning reserve, and non-spinning reserve. Sales of energy, spinning reserves, and non-spinning reserves from TID's generation resources and the storage system are permitted in this scenario. However, sales of regulation reserves are not permitted which reflects current operations. Below are the assumptions used for the 30 MW Li-on:

Technology	Lithium Ion
Capacity	30 MW
Duration	2 Hours
Capital Cost	$1,800/kW ($900/kWh)
Fixed O&M Cost	$10/kW-yr
Variable O&M Cost	$0.3/MWh
Project Life	20 years
Battery Replacement Cost	$244/kWh
Battery Replacement Yr of Occurrence	11th year
Roundtrip Efficiency	83%
Debt Interest Rate (20 Yr Term)	4%
Debt Interest Rate (10 Yr Term)	3%
O&M Escalation Rate	2%/yr

As shown in Chart 1 below, adding a 30 MW Li-on into TID's resource portfolio increases TID's Net Purchase Power Cost ("NPP") by $0.9-3.0 million per year. The 30 MW Li-on provided energy, capacity, regulation reserve, spinning reserve, and non-spinning reserve. However, the reduction in variable costs due to the addition of the 30 MW Li-on was less than the annual fixed cost of the 30 MW Li-on (see Chart2 below).

Chart 1

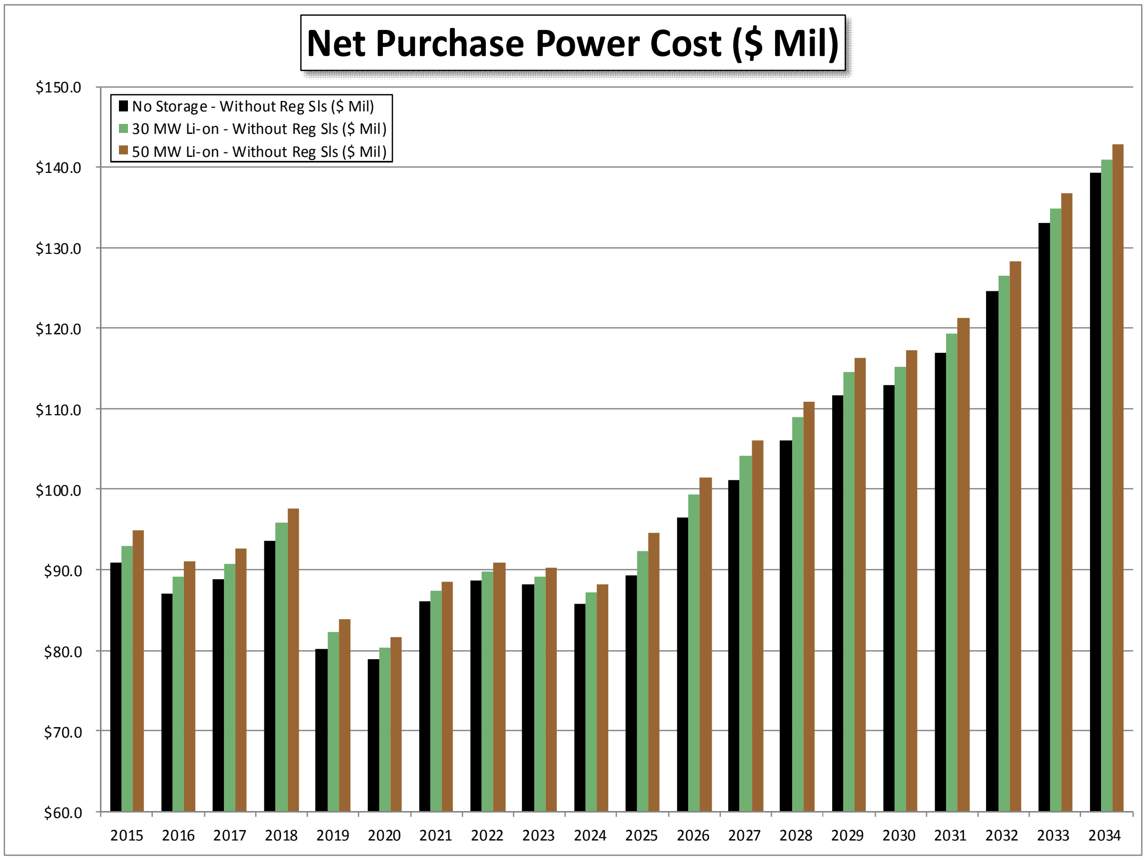

Net Purchase Power Cost ($ Mil)
■ No Storage - Without Reg Sls ($ Mil)
■ 30 MW Li-on - Without Reg Sls ($ Mil)
■ 50 MW Li-on - Without Reg Sls ($ Mil)
$150.0
$140.0
$130.0
$120.0
$110.0
$100.0
$90.0
$80.0
$70.0
$60.0
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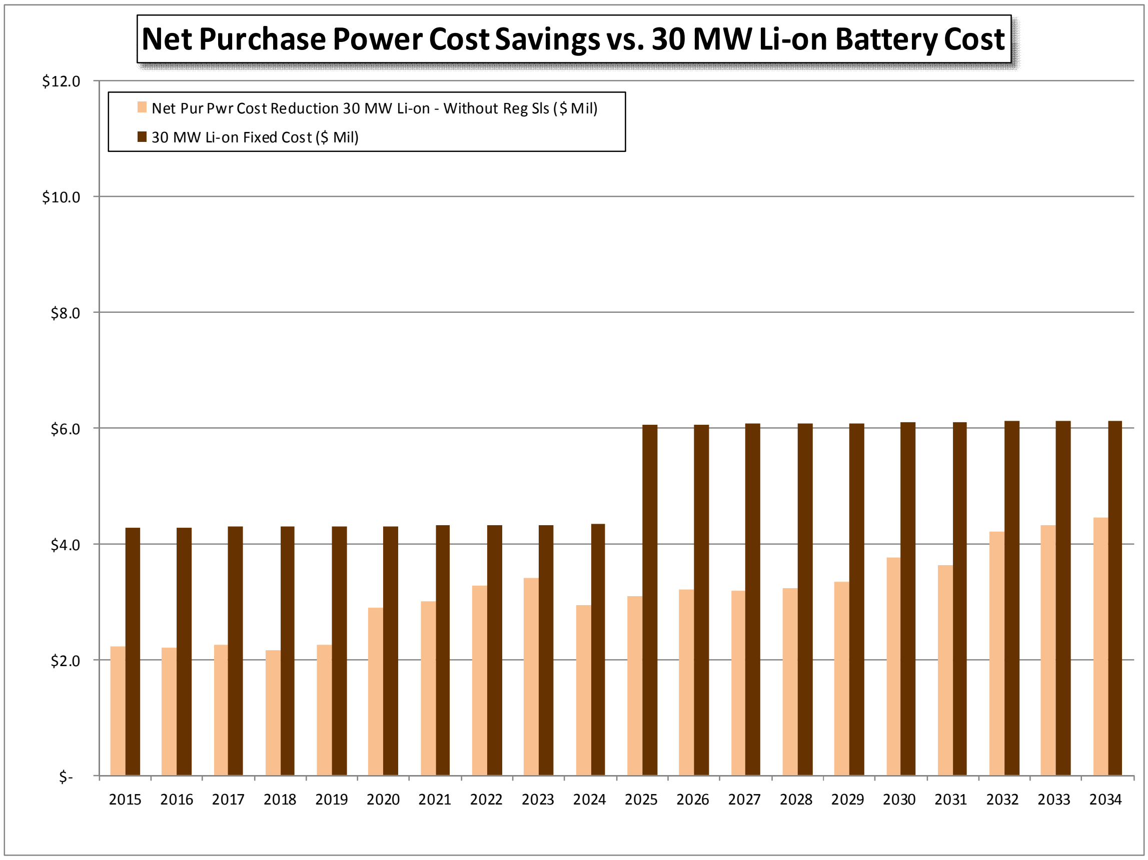
Chart 2

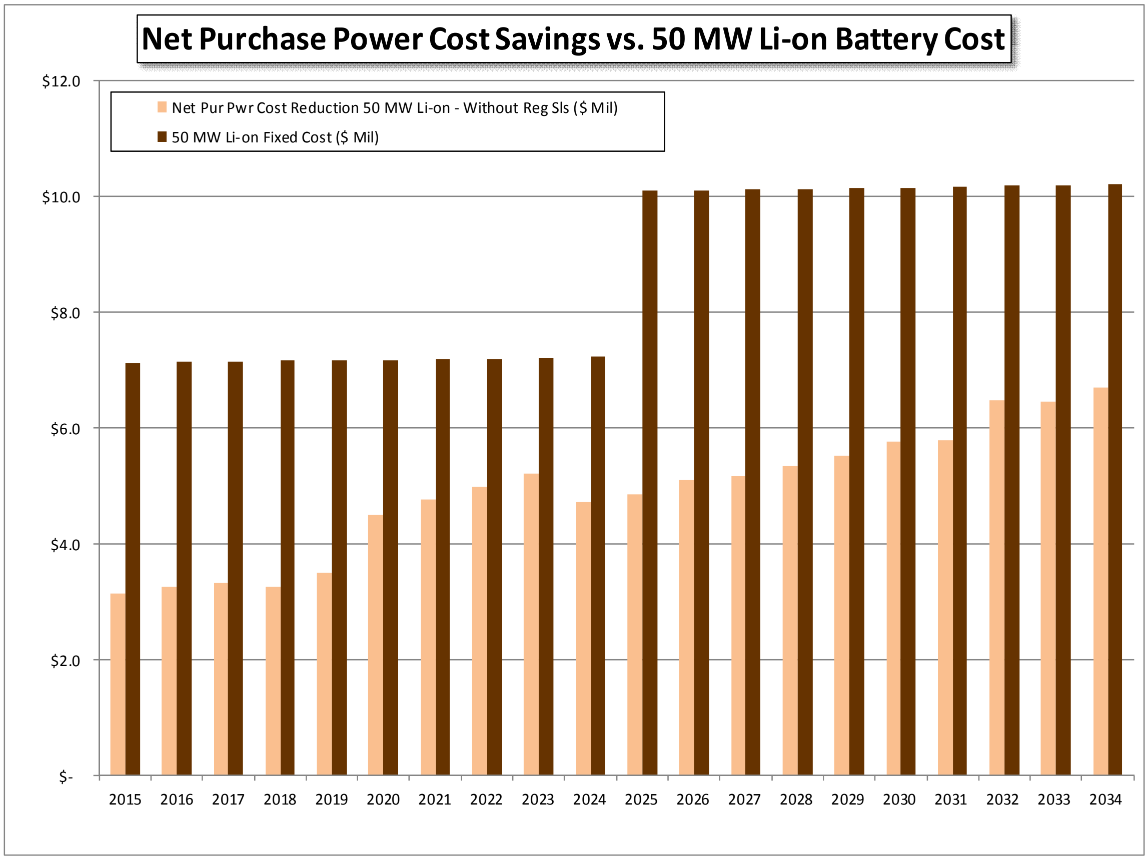


Staff also ran a sensitivity case using a 50 MW Lithium Ion battery ("50 MW Li-on") with 2 hour duration. Below are the assumptions used for the 50 MW Li-on:

Technology	Lithium Ion
Capacity	50 MW
Duration	2 Hours
Capital Cost	$1,800/kW ($900/kWh)
Fixed O&M Cost	$10/kW-yr
Variable O&M Cost	$0.3/MWh
Project Life	20 years
Battery Replacement Cost	$244/kWh
Battery Replacement Yr of Occurrence	11th year
Roundtrip Efficiency	83%
Debt Interest Rate (20 Yr Term)	4%
Debt Interest Rate (10 Yr Term)	3%
O&M Escalation Rate	2%/yr

Adding the 50 MW Li-on into TID's resource portfolio increased TID's NPP by $2.0-5.2 million per year (see Chart 1 above) again due to the fact that the savings in TID'S NPP is less than the annual fixed cost of the storage system (see Chart 3 below).

Chart 3



5.2. Lithium-Ion Battery (with Regulation Reserve Sales)

Regulation reserve prices have historically been higher than spinning and non-spinning reserves prices. Since Li-on storage systems are capable of providing regulation, we ran the same scenarios and using the same assumptions discussed in Section 5.1 above except that the new scenarios allowed regulation reserve sales.

As can be seen from Chart 4, Chart 5, and Chart 6 below, permitting regulation reserve sales increase the value of the Li-on storage system because of higher value regulation reserve sales. However, despite allowing the higher value regulation reserve sales, adding the 30 MW Li-on and 50 MW Li-on into TID's resource portfolio increases NPP by $0.6-2.6 million per year and by $1.2-4.4 million per year respectively.

Chart 4

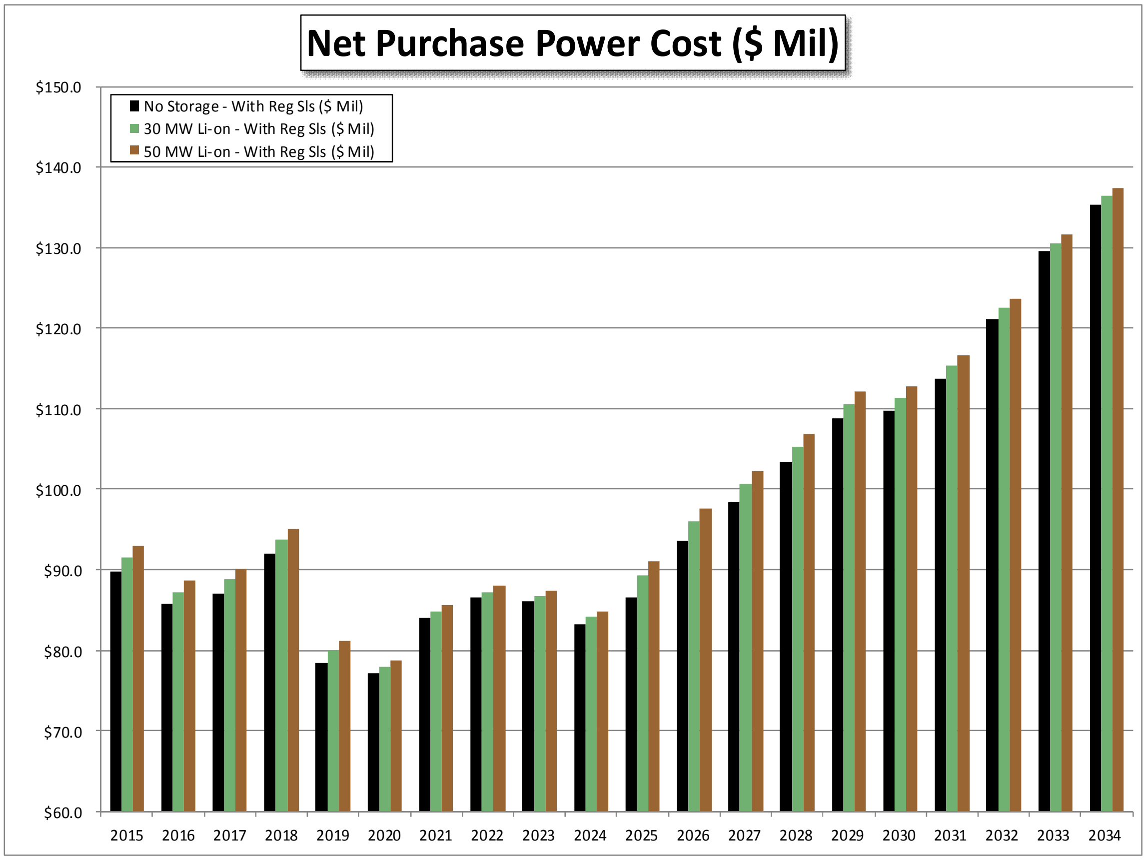
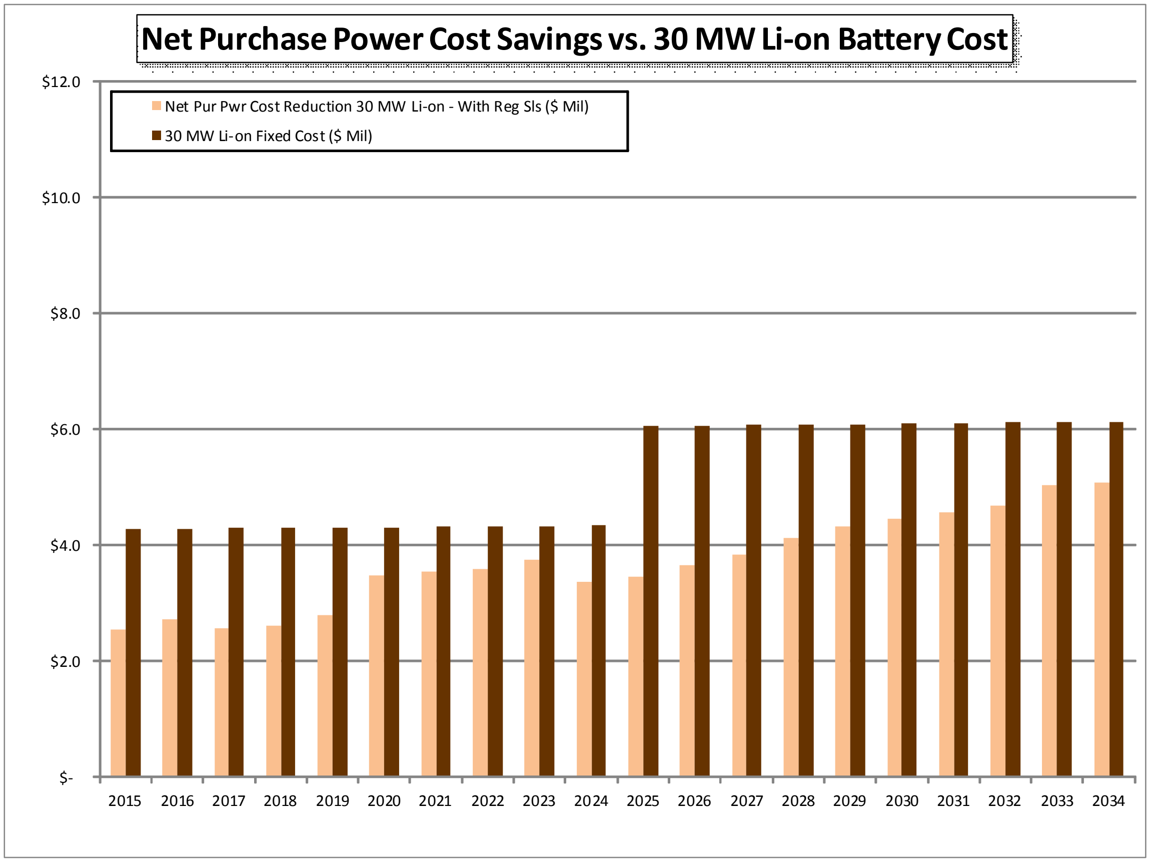


Chart 5



Net Purchase Power Cost Savings vs. 30 MW Li-on Battery Cost
Net Pur Pwr Cost Reduction 30 MW Li-on - With Reg Sls ($ Mil)
30 MW Li-on Fixed Cost ($ Mil)
$12.0
$10.0
$8.0
$6.0
$4.0
$2.0
$-
2015
2016
2017
2018
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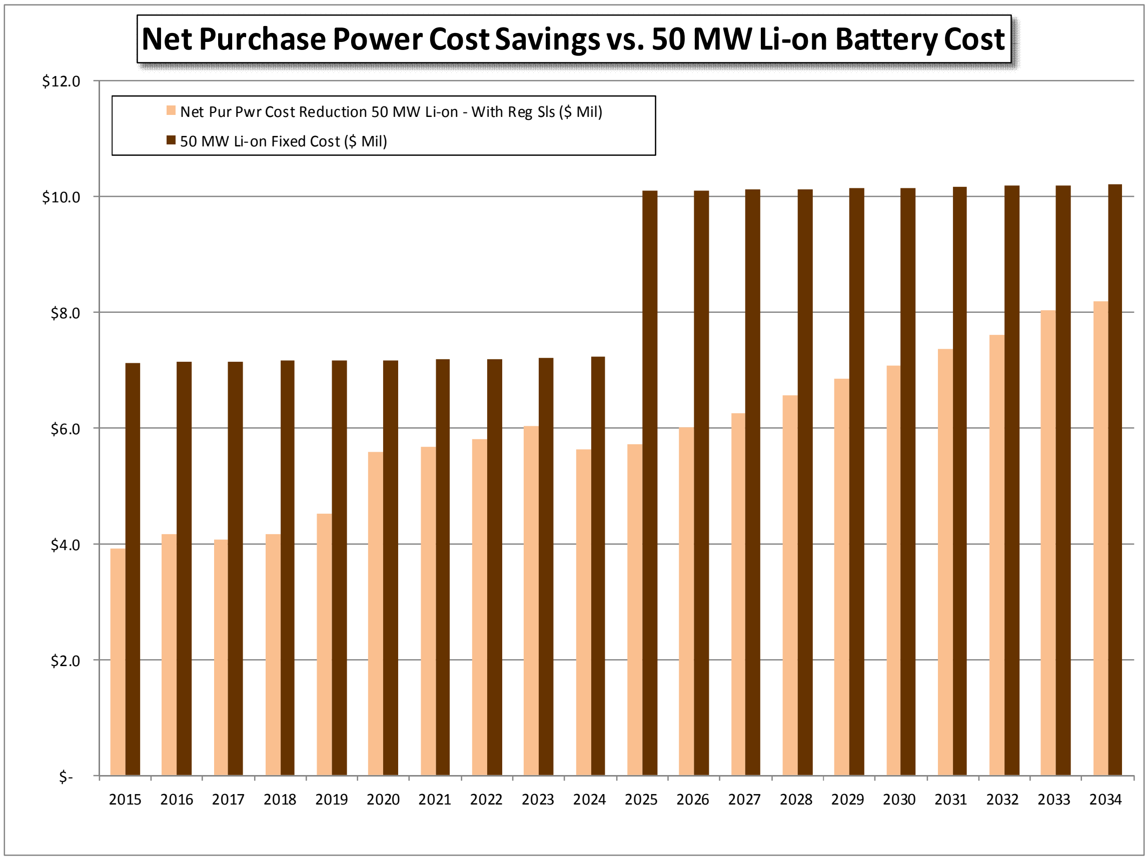
Chart 6



5.3. Flywheel

As mentioned earlier, flywheel energy storage systems are well suited for high capacity low power quick response applications such as regulation. In this study we modeled a 30 MW flywheel with a 0.25 hour ("Flywheel") that can provide capacity, energy, regulation, spinning reserve, and non-spinning reserve. Similar to the analysis done for the Li-on, the Flywheel was analyzed with and without regulation reserve sales. Below are the assumptions used for the Flywheel:

Technology	Flywheel
Capacity	30 MW
Duration	0.25 Hours
Capital Cost	$2,000/kW ($8,000/kWh)
Fixed O&M Cost	$5.8/kW-yr
Variable O&M Cost	$0.3/MWh
Project Life	20 years
Roundtrip Efficiency	81%

Debt Interest Rate (20 Yr Term)	4%
Debt Interest Rate (10 Yr Term)	3%
O&M Escalation Rate	2%/yr

Adding the Flywheel to TID’s resource portfolio increased TID’s NPP by $3.5 to 4.0 million per year without regulation sales modeled (see Chart 7 below), and by $3.3-4.0 million per year with regulation sales (see Chart 8 below). The Flywheel provided energy, capacity, regulation reserve, spinning reserve, and non-spinning reserve. But, similar to the Li-on, the benefit (reduction in variable cost) provided by the Flywheel did not exceed the additional annual fixed cost of the Flywheel (see Chart 9). Furthermore, the Flywheel provides minimal capacity value since it only had 0.25 hour duration.

Chart 7

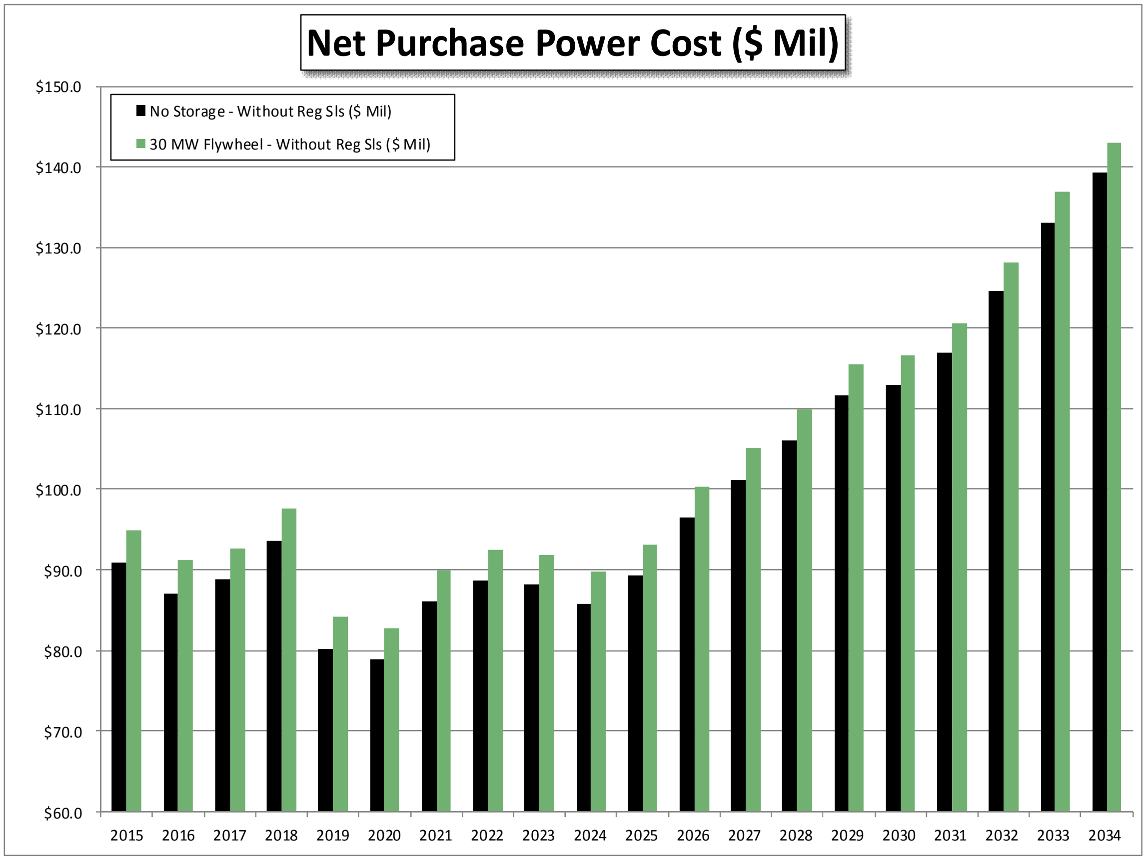


Chart 8

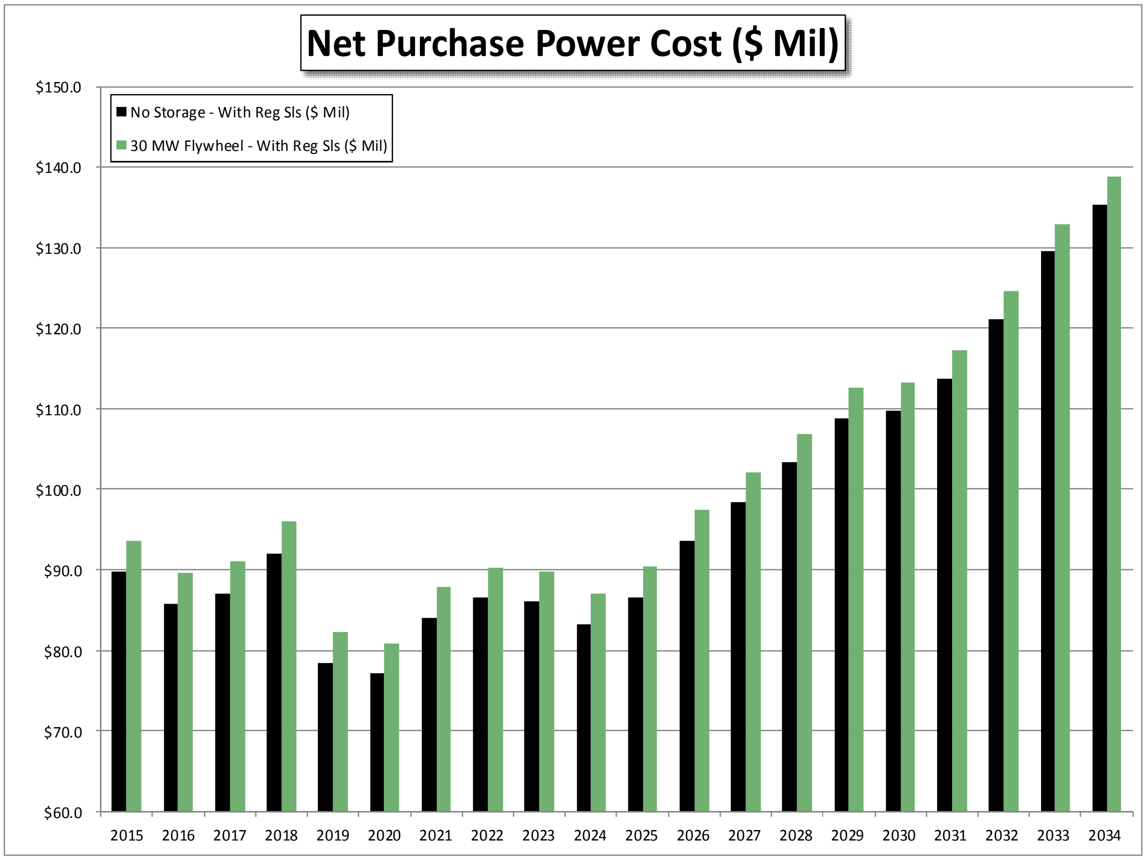

Net Purchase Power Cost ($ Mil)
■ No Storage - With Reg Sls ($ Mil)
🟩 30 MW Flywheel - With Reg Sls ($ Mil)
$150.0
$140.0
$130.0
$120.0
$110.0
$100.0
$90.0
$80.0
$70.0
$60.0
2015
2016
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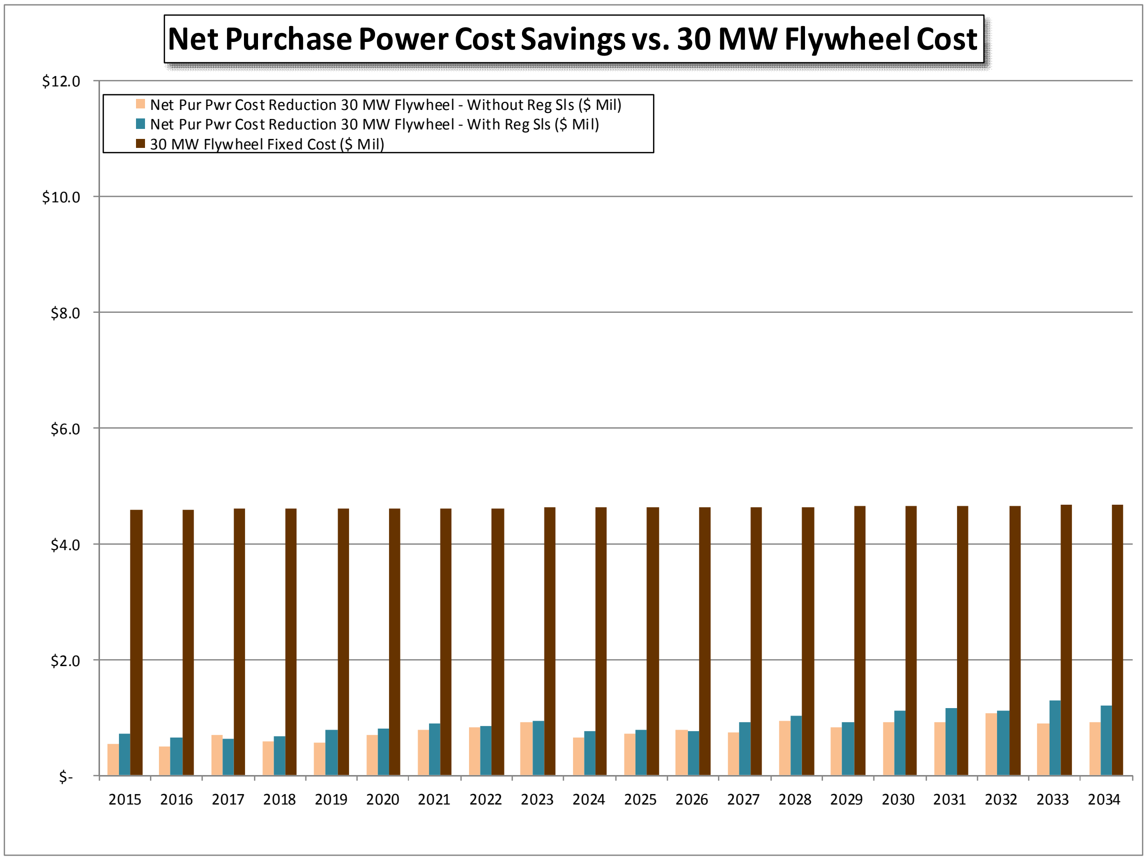
Chart 9



5.4. Thermal Storage

For this analysis, we assumed that 1,000 Ice Bear systems are deployed in the TID service area. The Ice Bear systems reduce afternoon cooling load by 6 MW combined for six hours. Below are the assumptions used for the Ice Bear systems:

Technology	Ice Thermal Storage
Capacity	6 MW (combined)
Duration	6.00 Hours
Capital Cost	$1,700/kW ($284/kWh)
Fixed O&M Cost	$54/kW-yr
Variable O&M Cost	NA
Project Life	20 years
Roundtrip Efficiency	120%
Debt Interest Rate (20 Yr Term)	4%
Debt Interest Rate (10 Yr Term)	3%

O&M Escalation Rate	2%/yr

As shown in Chart 10 and 11 below, deploying the Ice Bear systems resulted in an average increase in the NPP by $0.2 million per year. Similar to other energy storage technologies studied, the reduction in variable costs achieved due to the Ice Bear systems were less than the fixed costs of the Ice Bear systems deployed (see Chart 12 below).

Chart 10

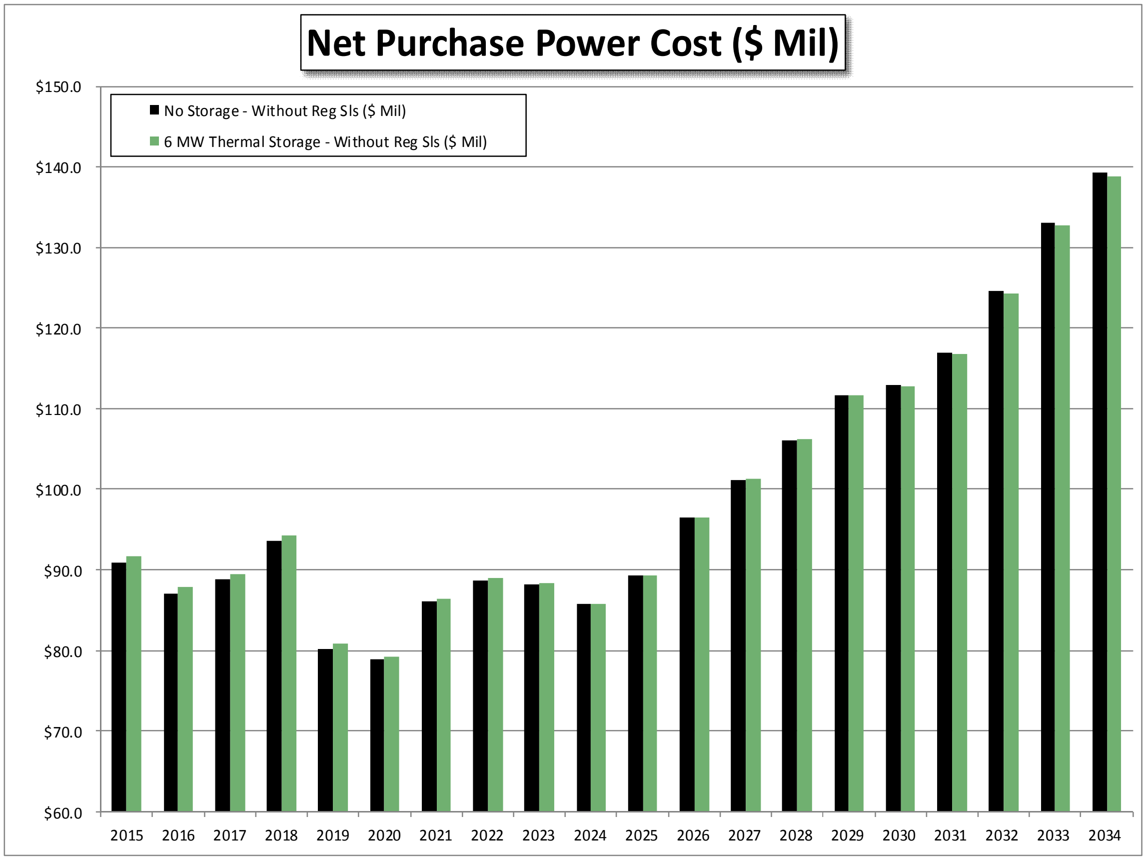


Chart 11

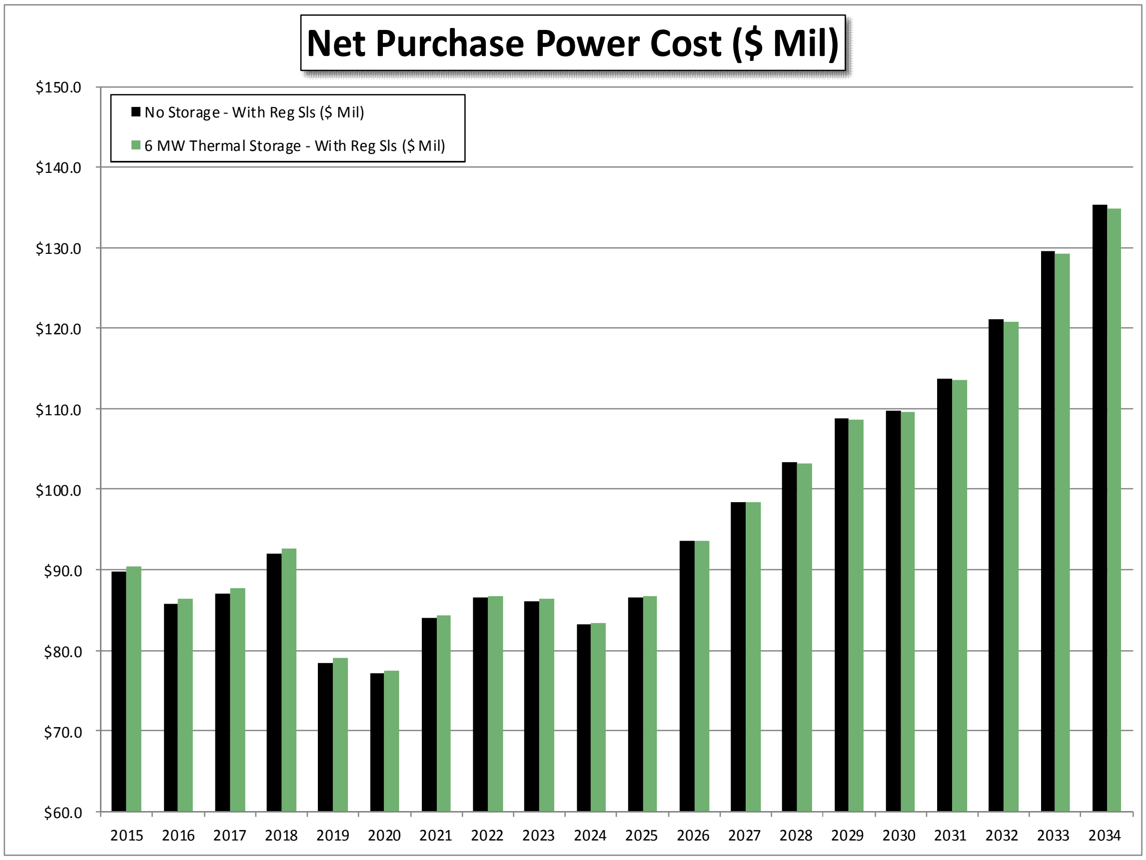
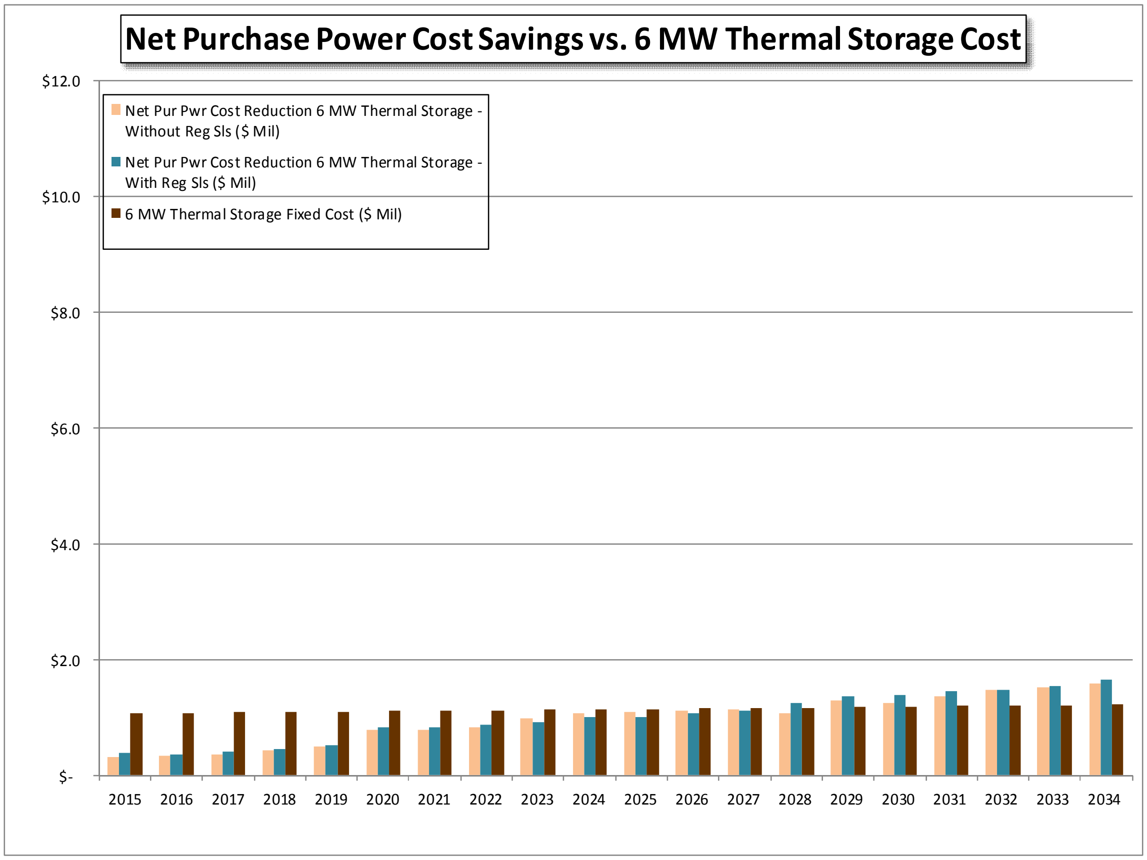

Net Purchase Power Cost ($ Mil)
No Storage - With Reg Sls ($ Mil)
6 MW Thermal Storage - With Reg Sls ($ Mil)
$150.0
$140.0
$130.0
$120.0
$110.0
$100.0
$90.0
$80.0
$70.0
$60.0
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034

Chart 12



5.5. Transmission and Distribution Upgrade Deferral

When a substation approaches its limits generally a new transformer or new substation are added. Storage systems can be used to defer such distribution system upgrades. For this analysis, we used the following assumptions:

Substation Size	25 Mva
New Substation Cost	$6,000,000
New Transformer Cost	$1,000,000
Substation Annual Load Growth	1.0%
Technology	Lithium Ion
Capital Cost	$1,800/kW ($900/kWh)
Fixed O&M Cost	$10/kW-yr
Variable O&M Cost	$0.3/MWh
Project Life	20 years
Battery Replacement Cost	$244/kWh
Battery Replacement Yr of Occurrence	11th year

Roundtrip Efficiency	83%
Debt Interest Rate (20 Yr Term)	4%
Debt Interest Rate (10 Yr Term)	3%
O&M Escalation Rate	2%/yr

A review of historical substation loading shows that in order to effectively reduce the peak loading on a substation by 0.5 MW the storage system has to be able to discharge a minimum of 3 hours and to effectively reduce peak loading by 1.0 MW the storage system has to be able to discharge a minimum of 5 hours. Assuming an annual load growth of 1.0%, a 25 Mva substation's load will grow 0.25 MW per year. Therefore, a 0.5 MW-3 hour duration storage system could defer a substation upgrade for 2 years and a 1.0 MW-5 hour duration storage system could defer a substation upgrade by 4 years. Deferring the installation of a 25 Mva substation results in an annual savings of $240,000/yr ($6,000,000 x 4%). The capital cost of a 0.5 MW-3 hour duration storage system is $1,350,000. Since the storage system can only defer the substation upgrade by 2 years the savings realized by deferring the substation upgrade is not sufficient to pay for the storage device. A 1 MW-5 hour duration storage system will have a capital cost of $4,500,000. Since the storage system can only defer the distribution system upgrade by 4 years the savings realized by deferring the substation upgrade is not sufficient to pay for the storage device. Also, the savings calculated above assumed a new substation was installed. If a new transformer is added instead, the annual savings would be reduced from $240,000/yr to $40,000/yr ($1,000,000 x 4%) making the storage system an even less economic solution for the purpose of deferring the distribution upgrade. Some storage systems are designed such that they can be moved to different locations to defer upgrades on several substations. But at current storage system cost, one would have to defer upgrades at more than a few substations to become cost effective. Even if a mobile storage system prove to be a cost-effective way to defer transmission and distribution upgrades there are currently no anticipated upgrades needed in TID's transmission and distribution system that can be deferred by installing a storage system. For example, TID has 22 distribution substations and only 2 experience peak loads that reach 80% of capacity.

6. Recommendation

The analysis performed shows that the benefits of deploying various types of storage systems fall short of the capital cost of such systems. Furthermore, except for pumped storage systems, there is limited operational history on utility scale storage systems. Hence there is limited data on performance degradation, operation and maintenance expense, and the life of storage systems in utility applications. Given that the analysis show that storage systems are currently not cost effective and that there is limited operating history, staff recommends that the Board make a determination that it is not appropriate to adopt energy storage procurement targets at this time. Even though staff is recommending no targets be set, staff believes that energy storage systems will become cost effective and will be an integral part of a utility's portfolio in the future and plans to evaluate storage systems periodically. For example, bids for storage systems were requested in TID's recent renewable resource solicitation.