Welcome to
Calgary Renewable Energy Meetup
June 15th ,2019

What in the World is Energy Storage ?

Presentation by Ken Hogg M.Eng., P.Eng.
Founder
Alberta Renewable Energy Alliance

Overview

- May 31, 2018 Dispatchable Renewables and Energy Storage Report
- October 3, 2018 Stakeholder Presentation
- Jurisdictional Review Report by Energy + Environmental Economics
- AESO Conclusions and Recommendations

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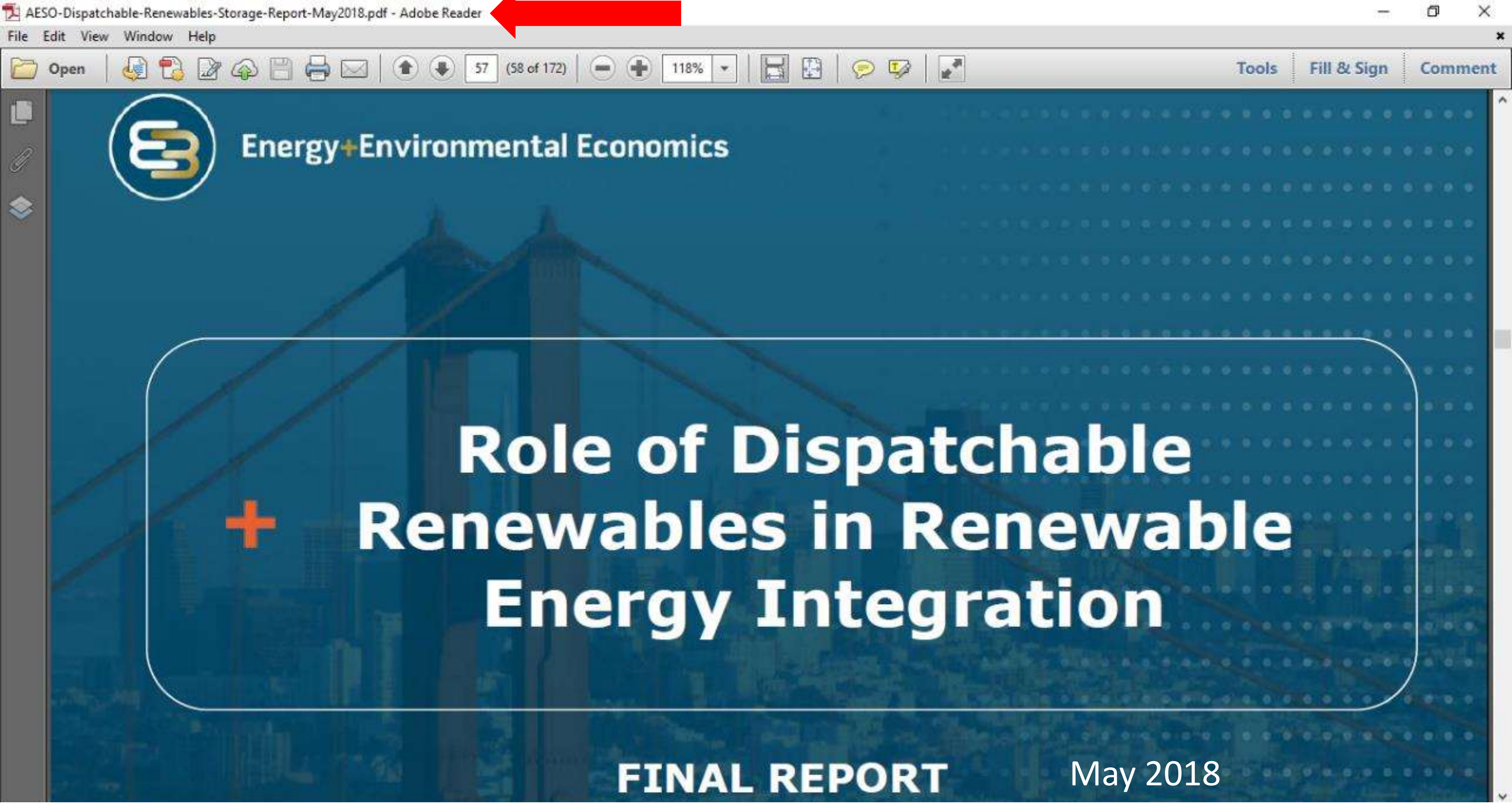
Dispatchable Renewables and Energy Storage

Submitted MAY 31, 2018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Energy+Environmental Economics
Role of Dispatchable
Renewables in Renewable
Energy Integration
FINAL REPORT
May 2018

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9. Conclusions and next steps

The AESO has concluded dispatchable renewables and energy storage are not required for system reliability leading up to 2030.

?!

5.5 Conclusion: no emerging reliability need to procure additional system flexibility

The AESO's flexibility analysis was based on scenarios that achieved the renewable energy target. The analysis revealed the following key results:

- No emerging reliability need exists to specifically procure or enable additional flexibility into the system
- Flexibility needs are connected to the timing of additional intermittent renewable generation
- The energy and regulating reserve markets are expected to provide sufficient flexibility to reliably deliver on the forecast variability to 2030 with 30 per cent renewables penetration
- Supply surplus generation is forecast to be marginal at less than one per cent of variable generation with a potential increase in generation on/off cycling
- As no procurement for flexibility is required, there will be minimal market impacts or incremental costs incurred outside of the market to meet future flexibility needs

9. Conclusions and next steps

9.1 AESO's next steps

As a result of the analysis performed for dispatchable renewables and energy storage, the AESO will proceed with the following next steps as a normal course of business:

- The AESO will develop an Integrated Flexibility Roadmap, with input from industry stakeholders, to provide a sustainable process to assess future flexibility needs
- The AESO will develop an Energy Storage Roadmap, with input from industry stakeholders, to ensure that as technologies develop, barriers to integration are not created, and that tariff structures appropriately recognize the unique aspects of storage systems
- Upon direction from the Government of Alberta, the AESO will engage stakeholders in the results of this analysis, seek feedback on the analysis and incorporate feedback into the AESO's development of the Integrated Flexibility Roadmap and Energy Storage Roadmap

9.2 Recommendation to the Government of Alberta

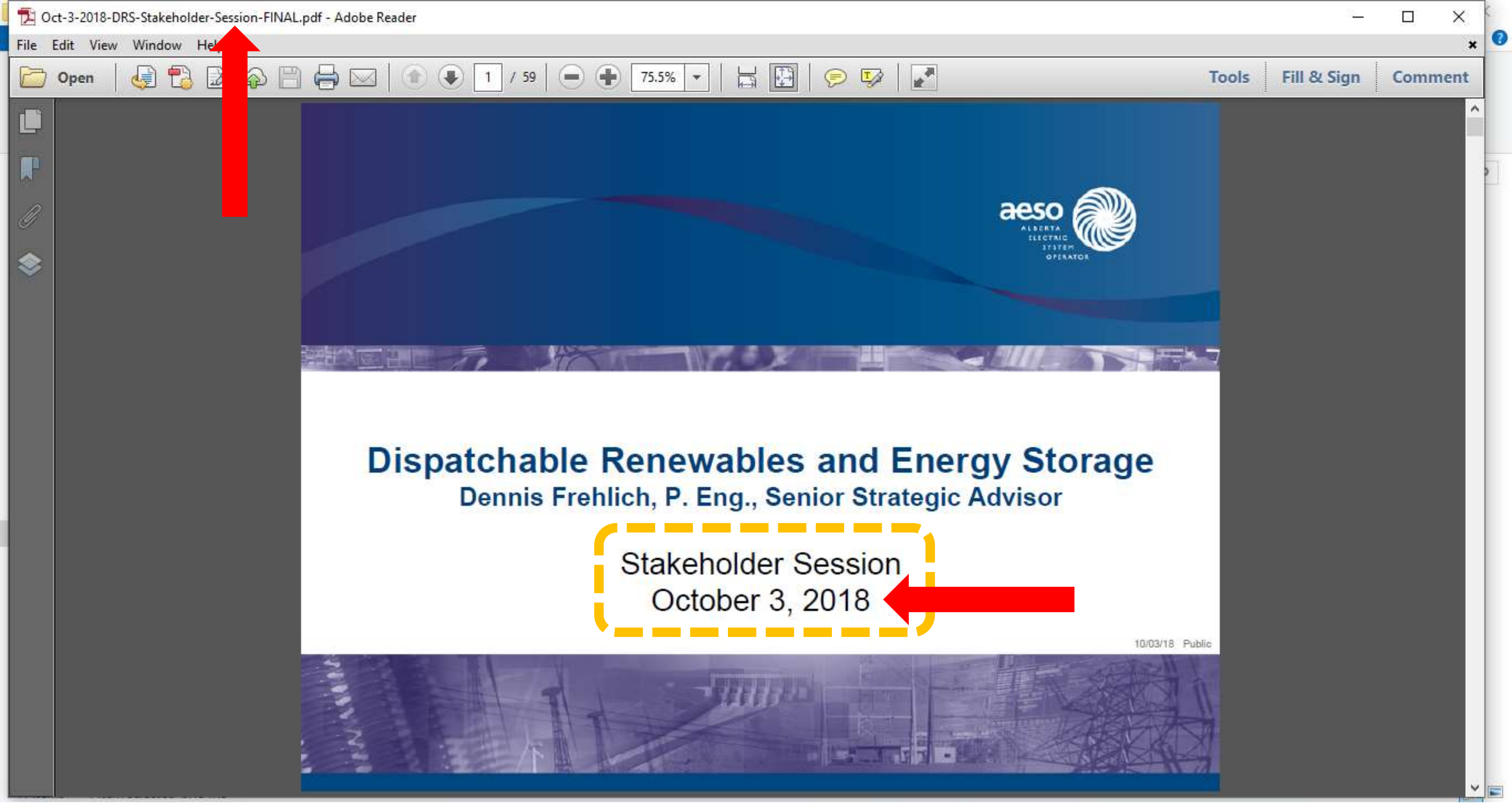
The Government of Alberta sought to gain a better understanding of whether there was a system reliability need for additional dispatchable renewables and energy storage.

The government tasked the AESO to conduct a review of the electricity system requirements leading up to 2030, and to provide a recommendation based on its findings. The recommendation was to specify if there was a need for additional products or services and, if the analysis supported a need, what market mechanisms or competitions may be required. In addition, the AESO was asked to recommend a definition for dispatchable renewables informed by the review.

Based on the analysis within this report, the AESO has concluded dispatchable renewables and energy storage are not required for system reliability leading up to 2030. Therefore, the AESO recommends that no additional products or services for these resources are needed at this time.

This recommendation is further supported by cost/benefit analysis that forecasts any dispatchable renewable resource as less cost-effective than those resources currently procured in the REP. Consideration should also be given to the impact an additional procurement may have on the effective function of the future capacity market.

The AESO recommends defining dispatchable renewables through existing legislation by combining the definition of “renewables” in the *Renewable Electricity Act* with the definition for “dispatch” in the *Electric Utilities Act.*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Dennis Frehlich, P. Eng., Senior Strategic Advisor
Stakeholder Session
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Government of Alberta request

- By May 31, assess specific need for dispatchable renewables and energy storage (DR&S) as Alberta transitions toward 30% renewables by 2030
- If a system need is identified, determine if additional products or services are required and the market mechanisms to procure them
- Ensure recommendations are consistent with government's desired outcomes
  - Maintain or improve future reliability
  - Be cost-effective
  - Ensure minimal market impacts
  - Contribute toward meeting renewables generation target

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AESO objectives

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- Listen to and learn from others
- Understand Alberta's potential reliability implications of integrating 30% by 2030
- Directionally understand cost effectiveness of different technologies, dispatchable renewables and storage
- Identify and remove barriers to enable market participation and improve competition
- Remain agnostic to technology and project types

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Broad stakeholder engagement

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- 80+ responses to stakeholder questionnaire
- 30+ meetings with industry incumbents, key associations, project developers and Indigenous working group
- Comprehensive feedback helped define review scope
  - Jurisdictions to learn from
  - Perform a comparative cost/benefit analysis
  - Technology and project cost information used in AESO analysis
  - Identified barriers to DR&S technologies entering Alberta market
  - Noted desire for long-term contract arrangements

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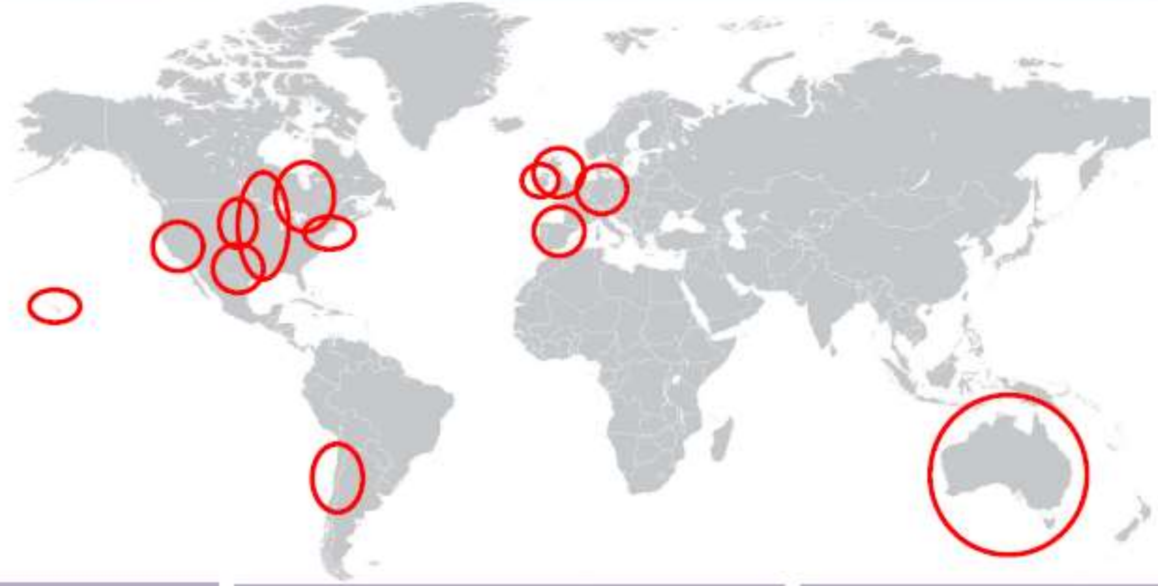
Jurisdictional review



14 regions	Typical challenges	Flexibility options
• A few nearing 30% penetration • Some are setting 40%–60% targets • Curtailments near 5%	• Dispatchable flexibility to meet increasing variability • Managing supply surpluses when renewables generating in low-demand periods	• Regional coordination • Load adjustment • Renewable diversity, curtailment • Existing resources and market products • Storage

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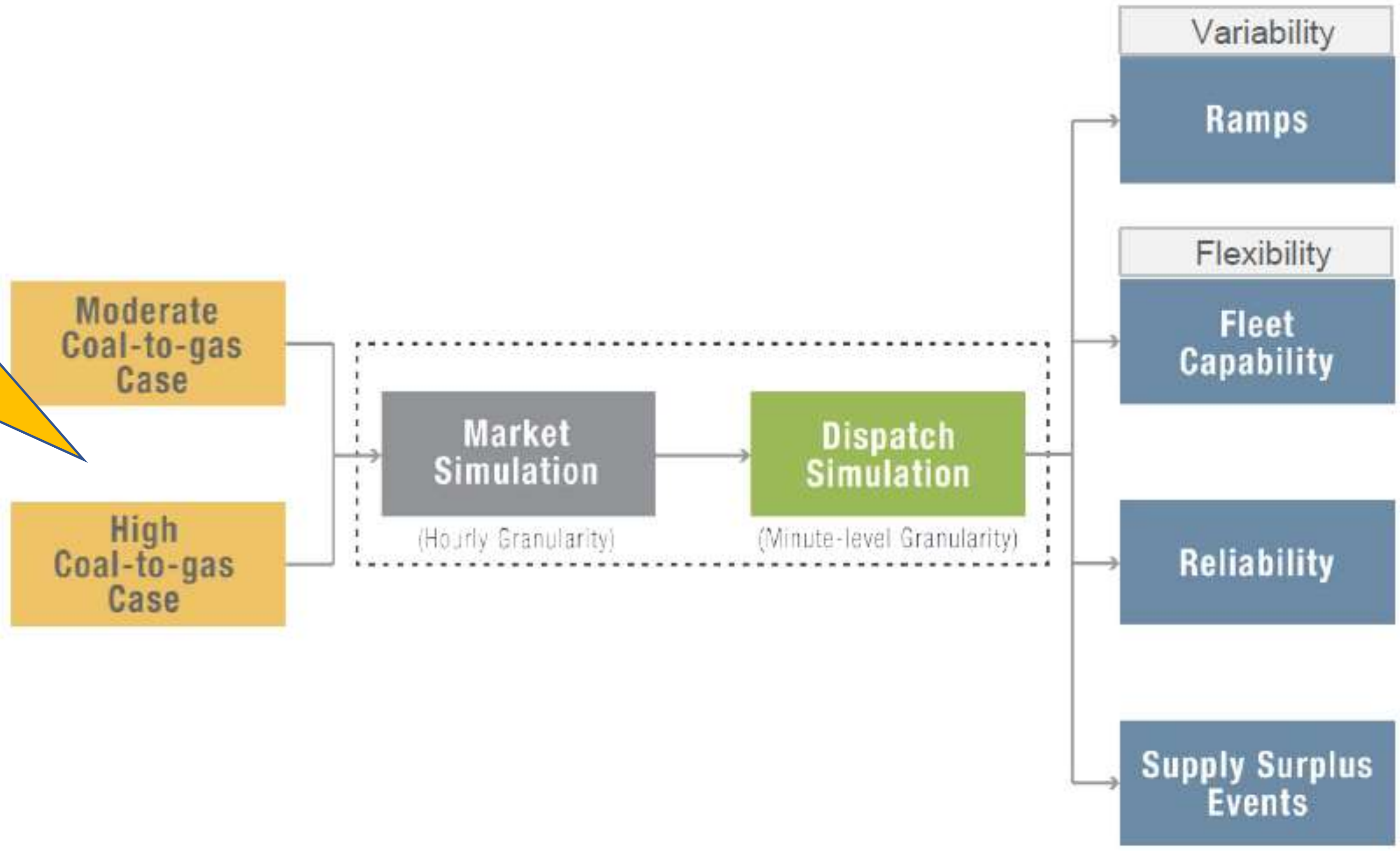
How did we assess our renewable integration needs to meet 30% by 2030?

Conversion of Coal Units to Natural Gas are assumed to occur



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Market simulation modelling assumptions

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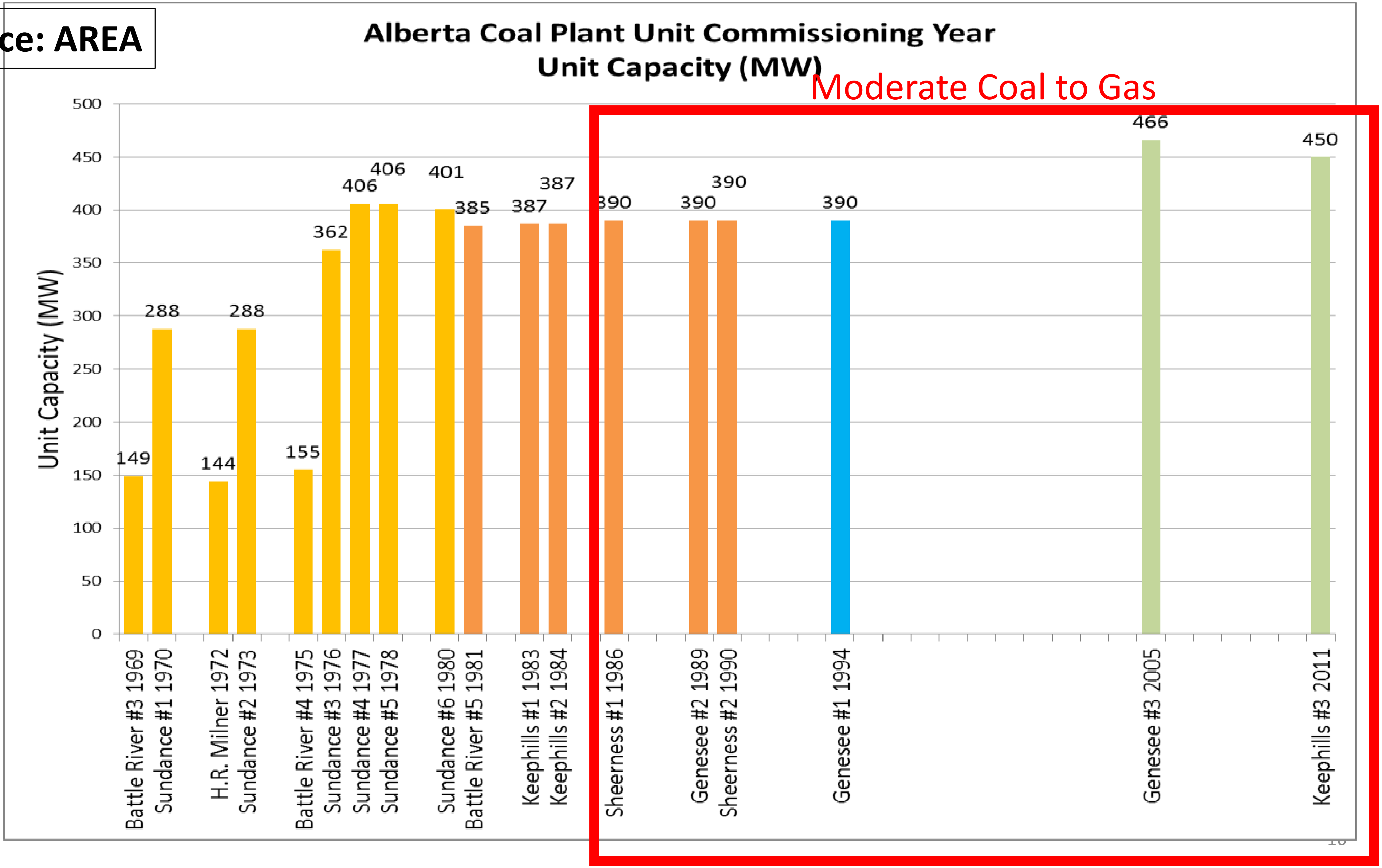
- '30 by 30' achieved with 6,200 MW of additional wind
  - Procured via Renewable Electricity Program
  - Bid energy in at $0
  - Test bookend of high variability and market price volatility
- Two cases were simulated, providing different fleet flexibility
  - 2018-MCTG; 0.9% load growth; 2,400 MW coal-to-gas conversion
  - 2018-HCTG; 5,200 MW coal-to-gas conversion, less flexible fleet
- Other market drivers are based on most recent projections

Natural gas prices	$1.50 – $2.40GJ
Carbon tax	$30/tCO2 rising to $50/tCO2
Output-based allocation	Starting at 0.370 tCO2/MWh, declining post-2020

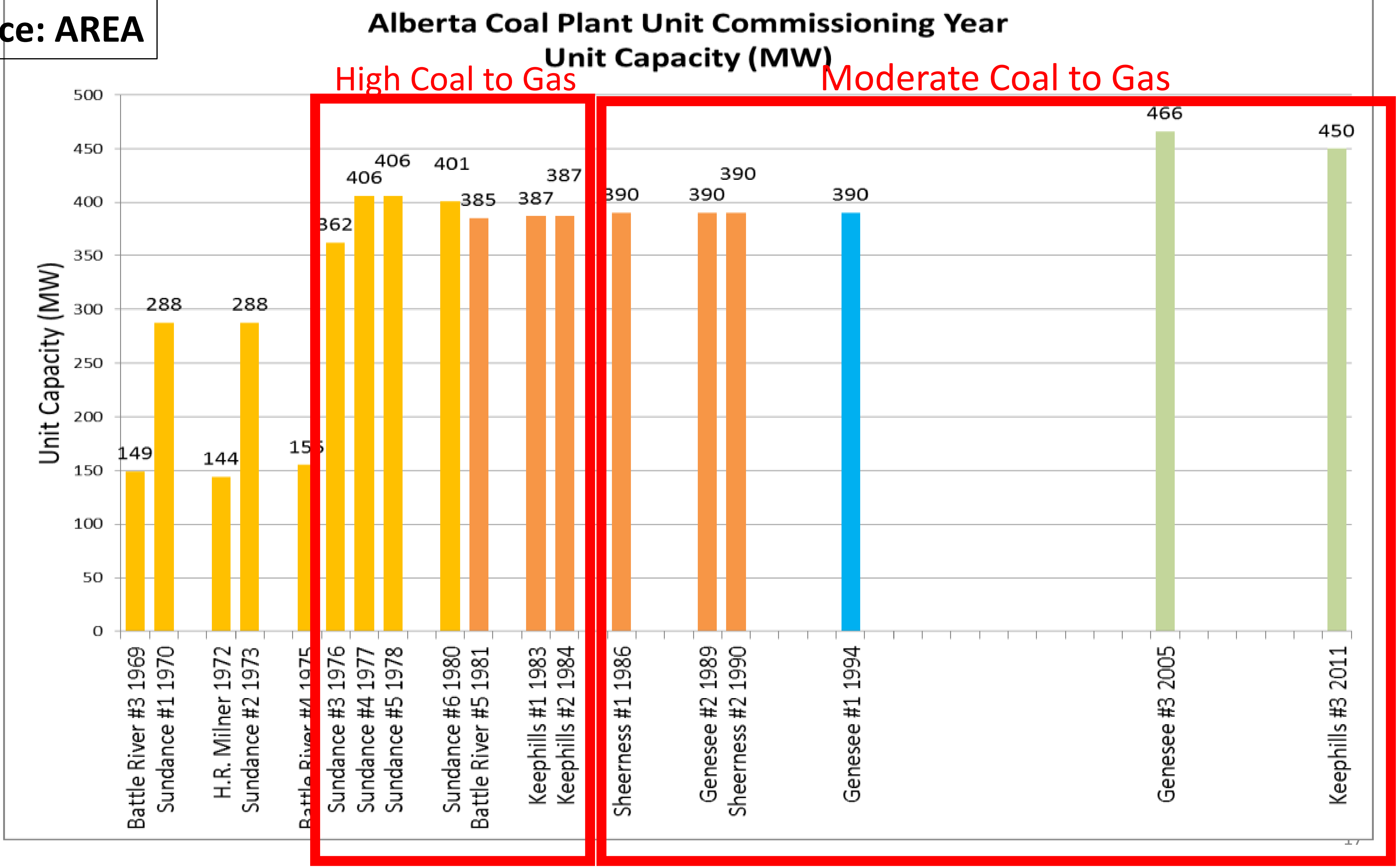
Either Moderate or High Coal to Gas Conversion

Source: AREA



Alberta Coal Plant Unit Commissioning Year
Unit Capacity (MW)
Moderate Coal to Gas
Unit Capacity (MW)
500
450
400
350
300
250
200
150
100
50
0
149
288
144
288
155
362
406
406
401
385
387
387
390
390
390
390
466
450
Battle River #3 1969
Sundance #1 1970
H.R. Milner 1972
Sundance #2 1973
Battle River #4 1975
Sundance #3 1976
Sundance #4 1977
Sundance #5 1978
Sundance #6 1980
Battle River #5 1981
Keephills #1 1983
Keephills #2 1984
Sheerness #1 1986
Genesee #2 1989
Sheerness #2 1990
Genesee #1 1994
Genesee #3 2005
Keephills #3 2011

Source: AREA



Alberta Coal Plant Unit Commissioning Year
Unit Capacity (MW)
High Coal to Gas
Moderate Coal to Gas
Unit Capacity (MW)
500
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200
150
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Battle River #3 1969
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Genesee #1 1994
Genesee #3 2005
Keephills #3 2011

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Apps | Calgary Renewable... | Alberta Renewable... | Yola.com | Login | Google | Enphase Energy - E... | HSCA Solar PV Syst... | Sign in · Shaw | PVWatts Calculator | Google Earth

TransAlta™

Sundance Power Plant

Keephills Power Plant

Coal to Gas Conversions Project February 2019

Regulatory update

TransAlta is continuing to advance its work on the Coal to Gas Conversions Project (CTG Project) as part of our transition to clean power. Plans for the CTG Project are to convert up to seven of our coal-fired generating units to natural gas at the Keephills (units 1 - 3) and Sundance (units 3 - 6) power plants.

In August 2018, TransAlta submitted applications to the Alberta Utilities Commission (AUC) and Alberta Environment and Parks (AEP). On December 21, 2018 the AUC issued approvals for the conversions of the Sundance (units 3 – 6) and Keephills (units 1 - 2) power plants. We continue to work with the AUC to respond to Information Requests specific to our Keephills unit 3 application and are awaiting approval from AEP of our environmental applications.

CTG_Newsletter_No.2_February-2

https://www.transalta.com/wp-content/uploads/2019/02/CTG_Newsletter_No.2_February-2019.pdf

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and are awaiting approval from AEP of our environmental applications.

Alterations at Sundance and Keephills Power Plants for Additional Gas Facilities

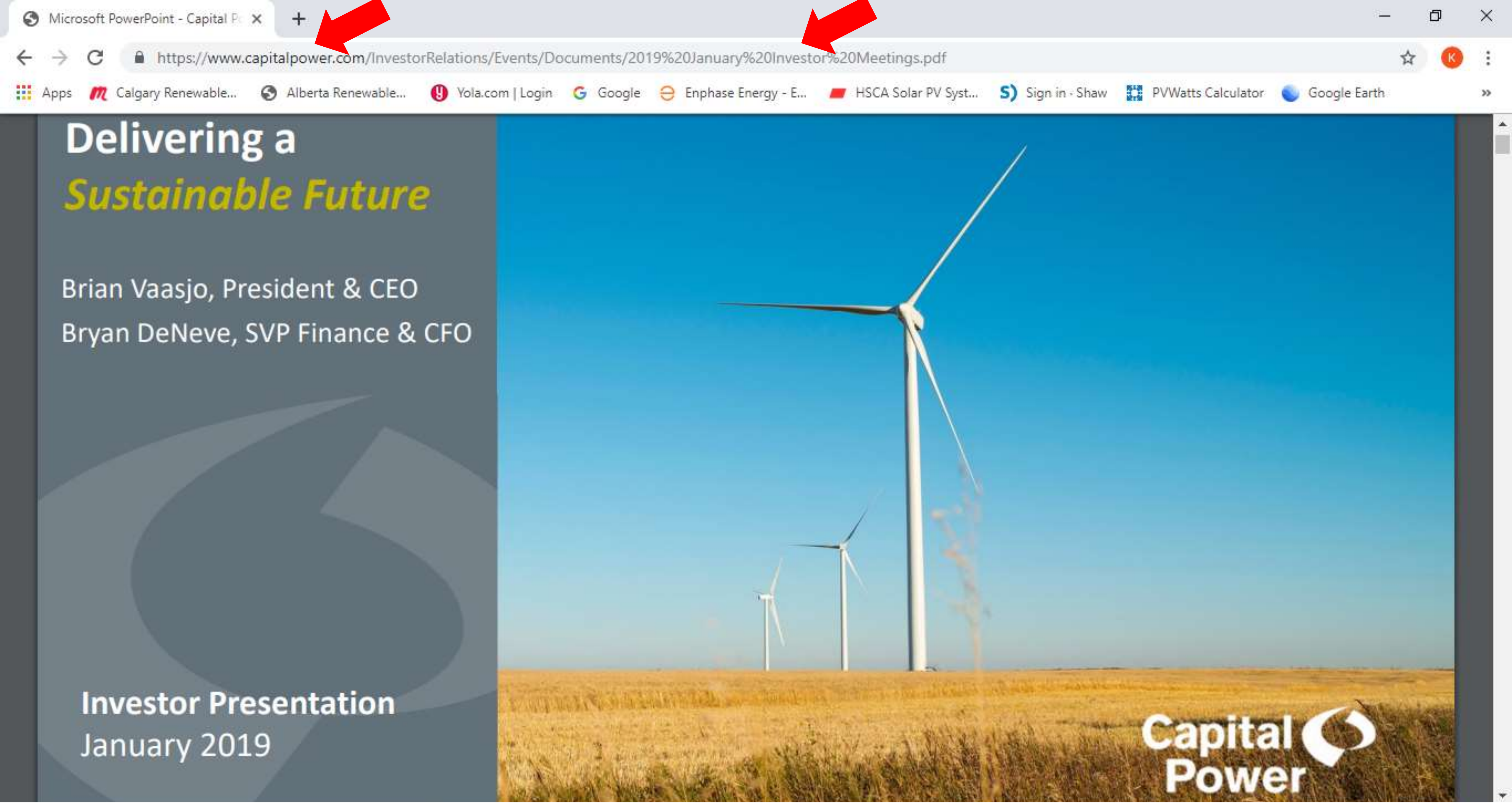
In the summer of 2018, the AUC issued Decision 23570-D01-2018 specific to TransAlta's application for minor alterations at the Sundance and Keephills power plants as part of the transition from coal-fired to natural gas-fired generation. This Decision included the installation of gas piping and pressure reduction infrastructure within each power plant site. The alterations do not change the rated capability of the power plants and allows for increased use of natural gas as a supplemental fuel source until the full conversions are complete.

The alterations will be entirely within the existing fence lines and on the existing footprints of the power plants. This work is scheduled to commence in the first quarter of 2019.

Timeline update

The conversion of the seven units from coal to gas is scheduled to start in 2020 and continue to the end of 2023. This is an update from the timeline previously published in our Project newsletter of May 2018.

	2018 Q1/Q2	2018 Q3/Q4	2019	2020 - 2023
Public Engagement				
Environmental Studies				
Regulatory Review				
Preliminary Engineering & Design				
Vendor Selection & Procurment				
Construction & Commissioning of Additional Gas Facilities				
Construction - Unit Conversions				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Alberta Renewable...
Yola.com | Login
Google
Enphase Energy - E...
HSCA Solar PV Syst...
Sign in · Shaw
PVWatts Calculator
Google Earth
Delivering a
Sustainable Future
Brian Vaasjo, President & CEO
Bryan DeNeve, SVP Finance & CFO
Investor Presentation
January 2019
Capital
Power

2019 January Investor Meetings.pdf - Adobe Reader Capital Power pdf

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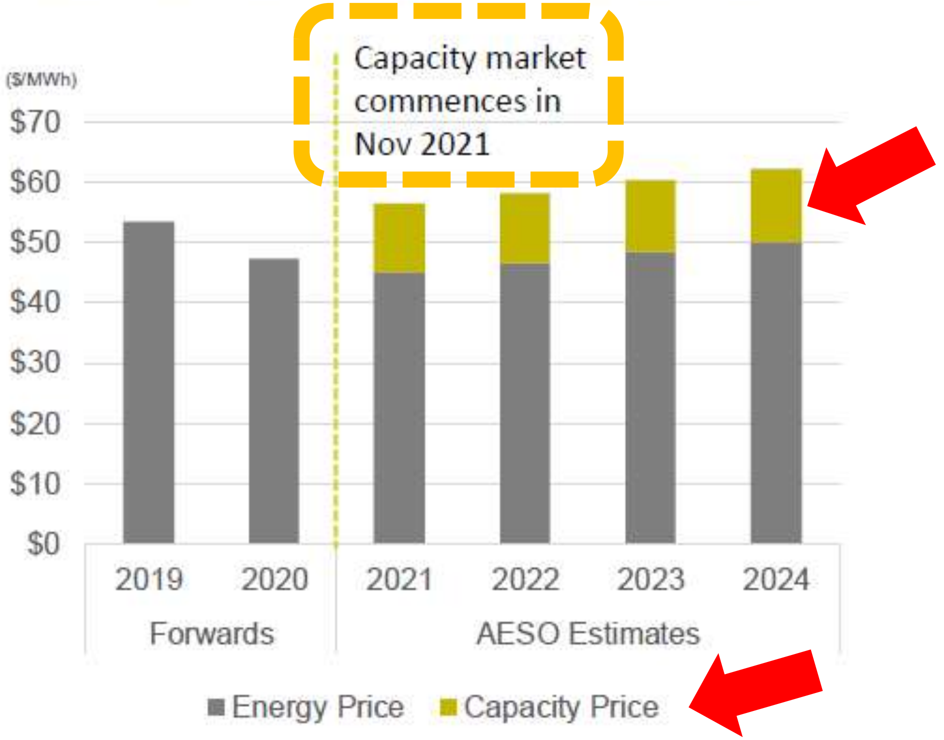
Capacity market design

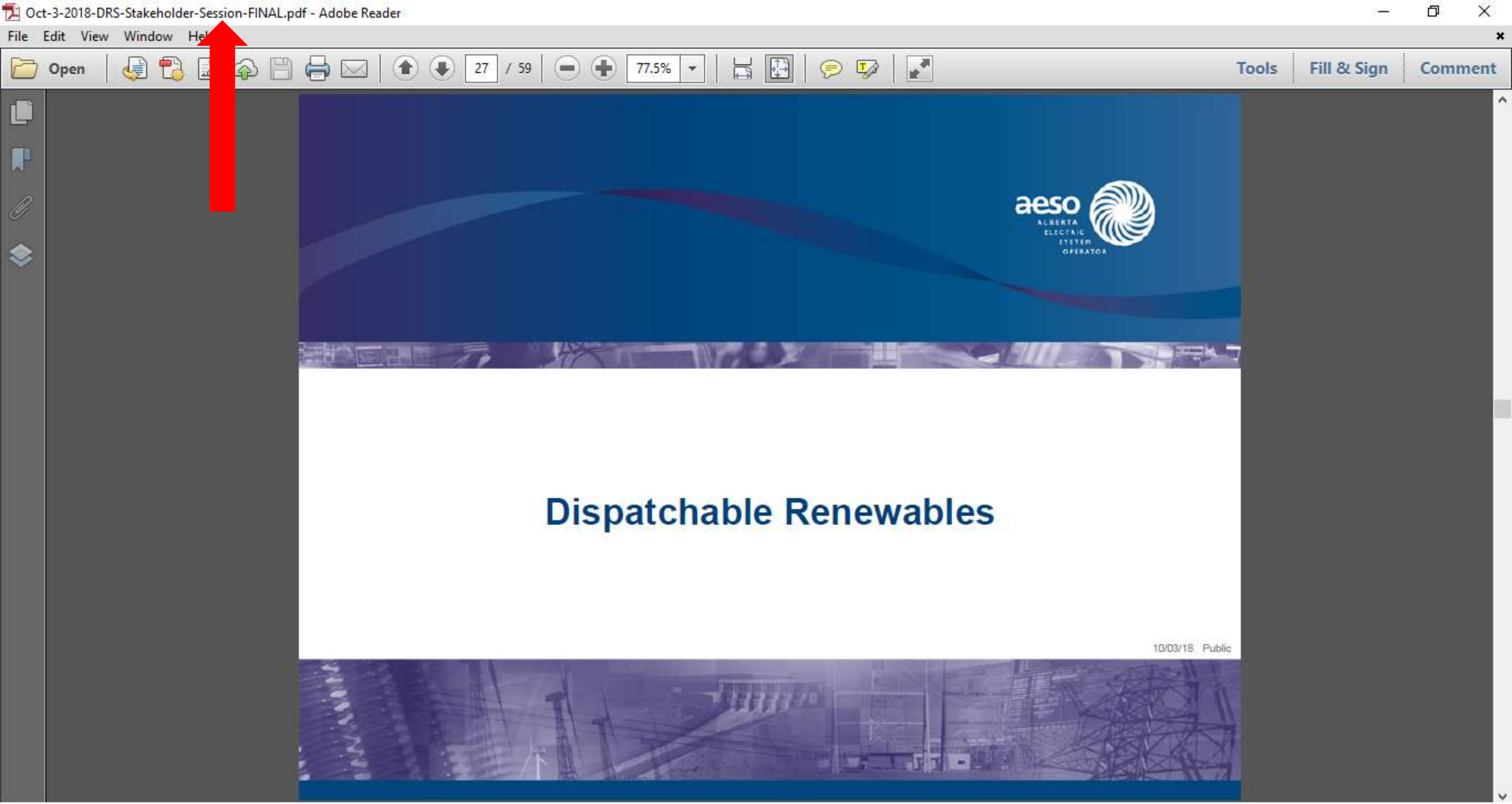
Final design is consistent with our view of a properly designed capacity market for Alberta

- AESO has finalized its proposed market design
- Design is constructive and provides an equal opportunity for existing and new assets to earn a return on and of capital
- Next steps:
  - Alberta Utilities Commission (AUC) approval expected by mid-2019
  - First capacity auction in late 2019
  - Capacity commitments awarded in 2020 for delivery in November 2021

AESO's forecast revenue for baseload facilities



AESO's forecast of $55-$65/MWh for the combined capacity and energy payments will allow existing and future assets an opportunity to earn a return on/of capital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What directionally is the cost/benefit of dispatchable renewables?

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FIGURE 11: Comparative scenario analysis approach

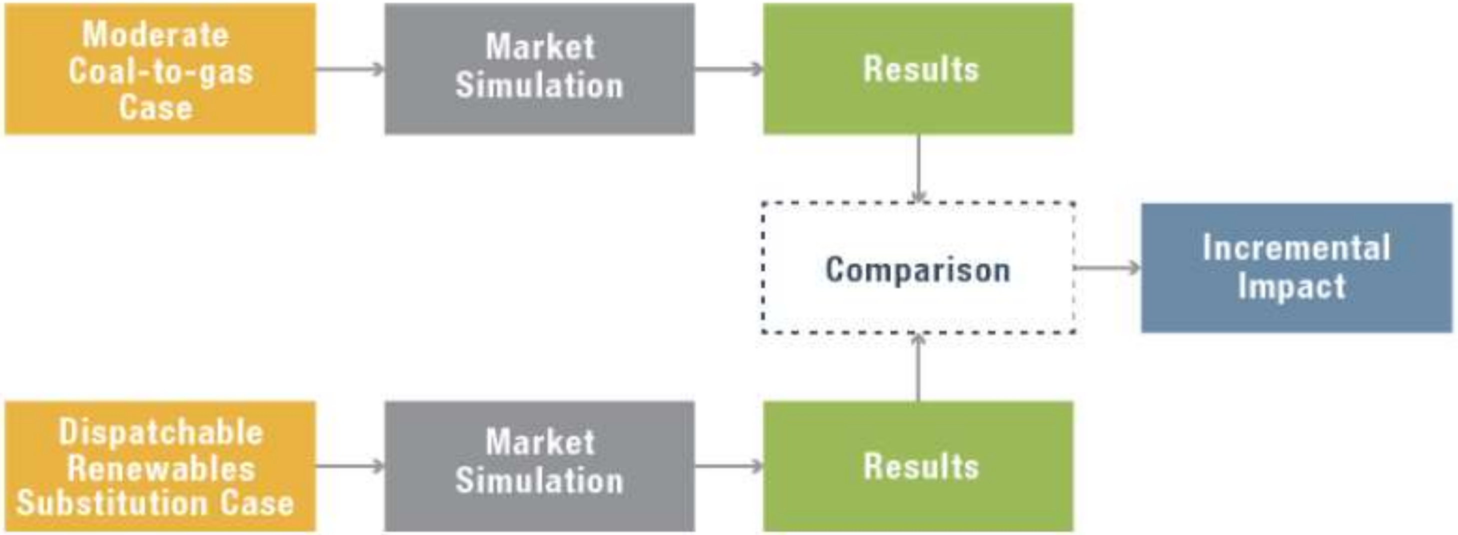

FIGURE 12: Substitution cases

	Run-of-river Hydro	Biomass	Geothermal
Substitution Case Inputs	250 MW	250 MW	250 MW
	500 MW	500 MW	500 MW
	1,000 MW	1,000 MW	1,000 MW

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LCOE ranges incorporate various cost risks including capacity factor, technology, financial life and construction

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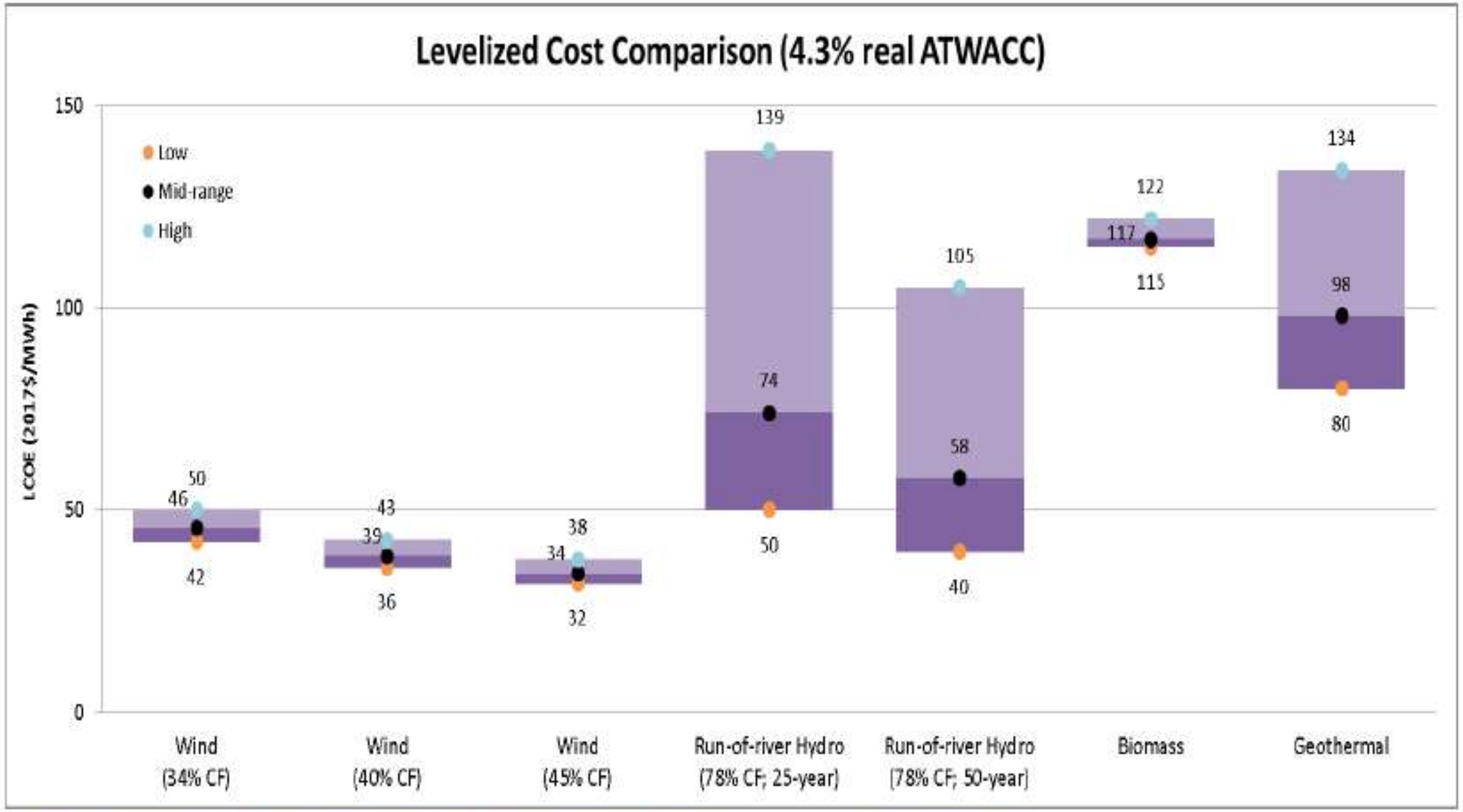
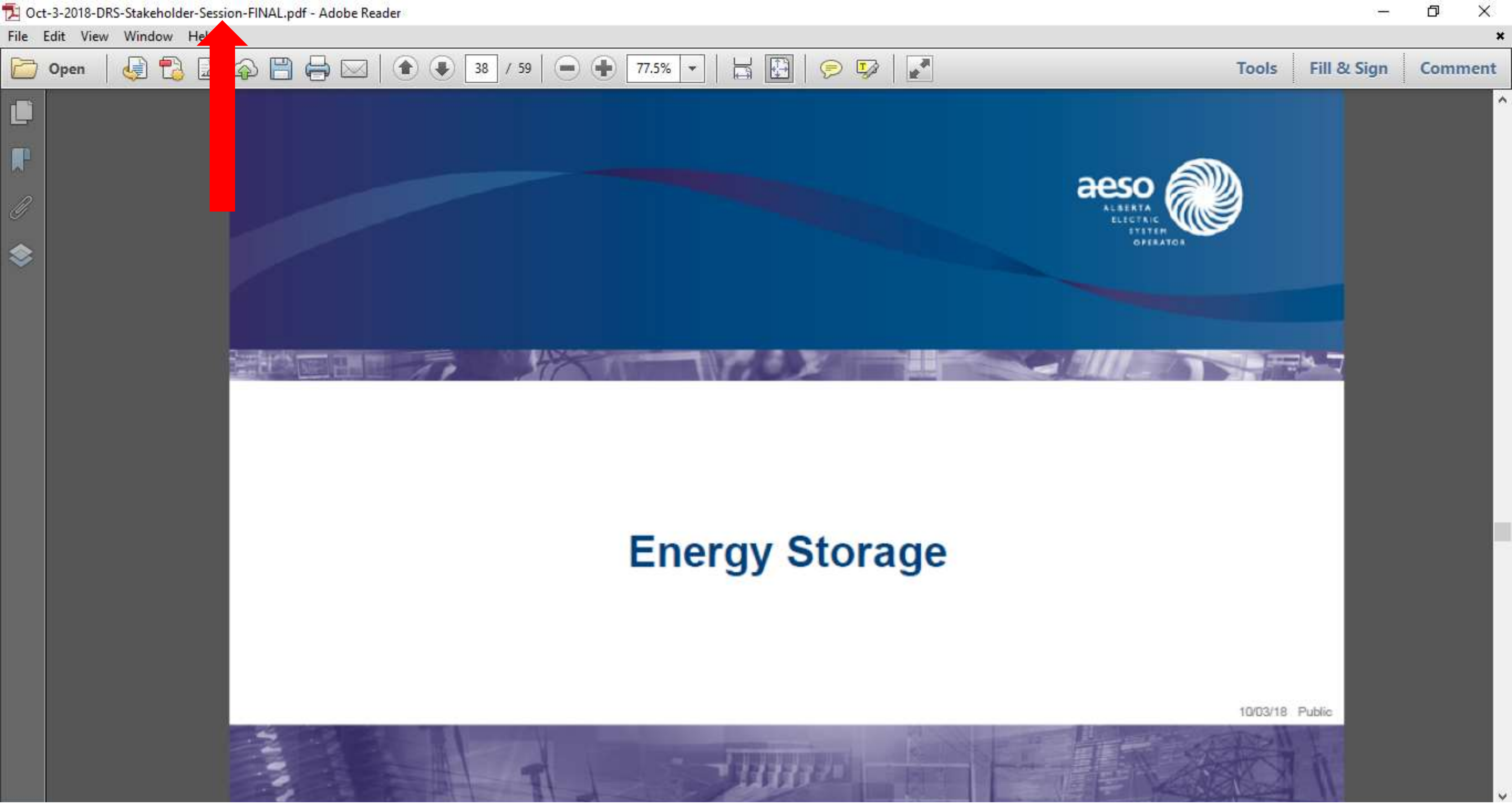


Note: levelized cost estimates based on 25 year life, unless noted otherwise *CF = capacity factor*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Energy Storage
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How is energy storage defined?

The Federal Energy Regulatory Commission (FERC), which regulates the transmission and wholesale sale of electricity in the U.S., after an extensive review and industry engagement process, recently defined an electric storage resource as:

> "a resource capable of receiving electric energy from the grid and storing it for later injection of electric energy back to the grid."

The AESO supports a definition that focuses on three defining characteristics of an energy storage facility, namely its ability to charge, store and discharge energy. This approach does not impose restrictions on where, when, and how these functions occur, or the application of the energy storage facility.

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Performed a wide range of storage scenarios

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Technologies

- **Lithium-ion batteries**: 2-hour, 4-hour and 12-hour
- **Pumped storage hydro**: 6-hour and 12-hour

Market Conditions

- **Future Alberta generation mix:** moderate vs high coal conversion, no intertie
- **Saturation:** effect of increased storage on operating reserve and pool prices

Cost Projections

- **Technology uncertainty**: range of potential costs for batteries and pumped storage
- **Cost changes by year of installation:** 2021 and 2025

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Storage duration beyond two hours provides diminishing incremental value in Alberta

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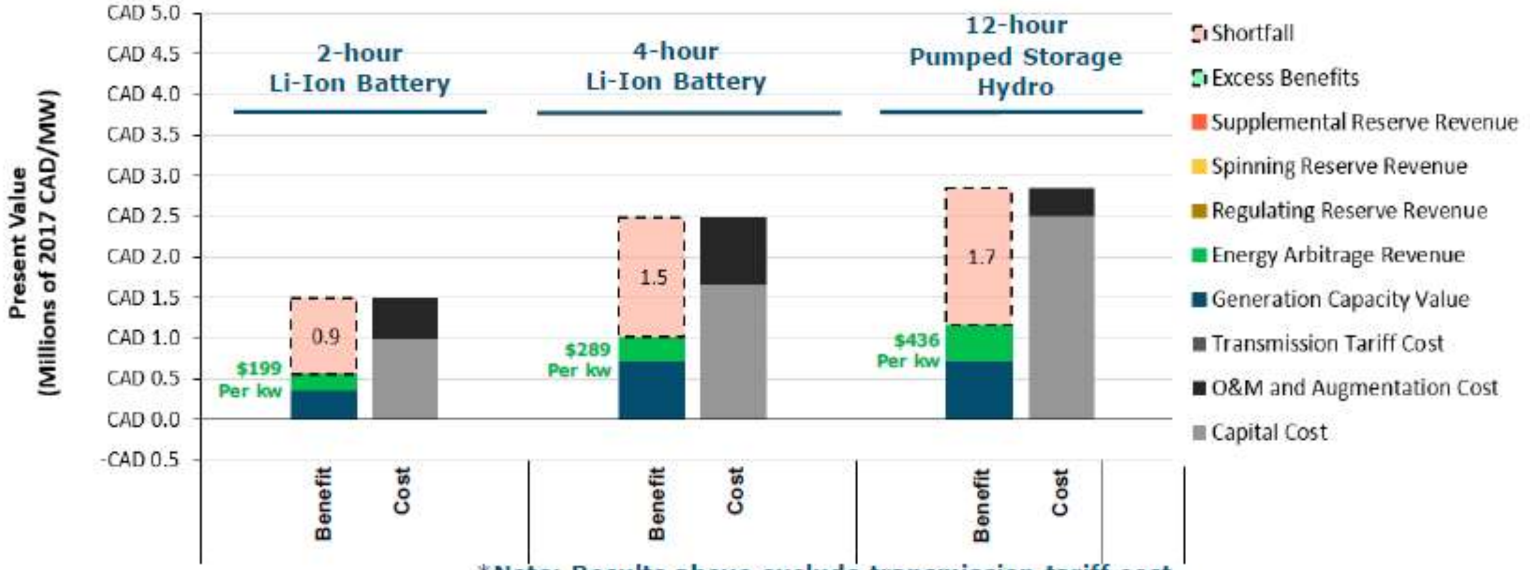
1 MW Storage; 2021 Install
(excludes operating reserve revenue opportunities)



***Note: Results above exclude transmission tariff cost, do not assume price saturation from storage installation**

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Battery storage costs are declining; the pace of the cost curve decline is uncertain

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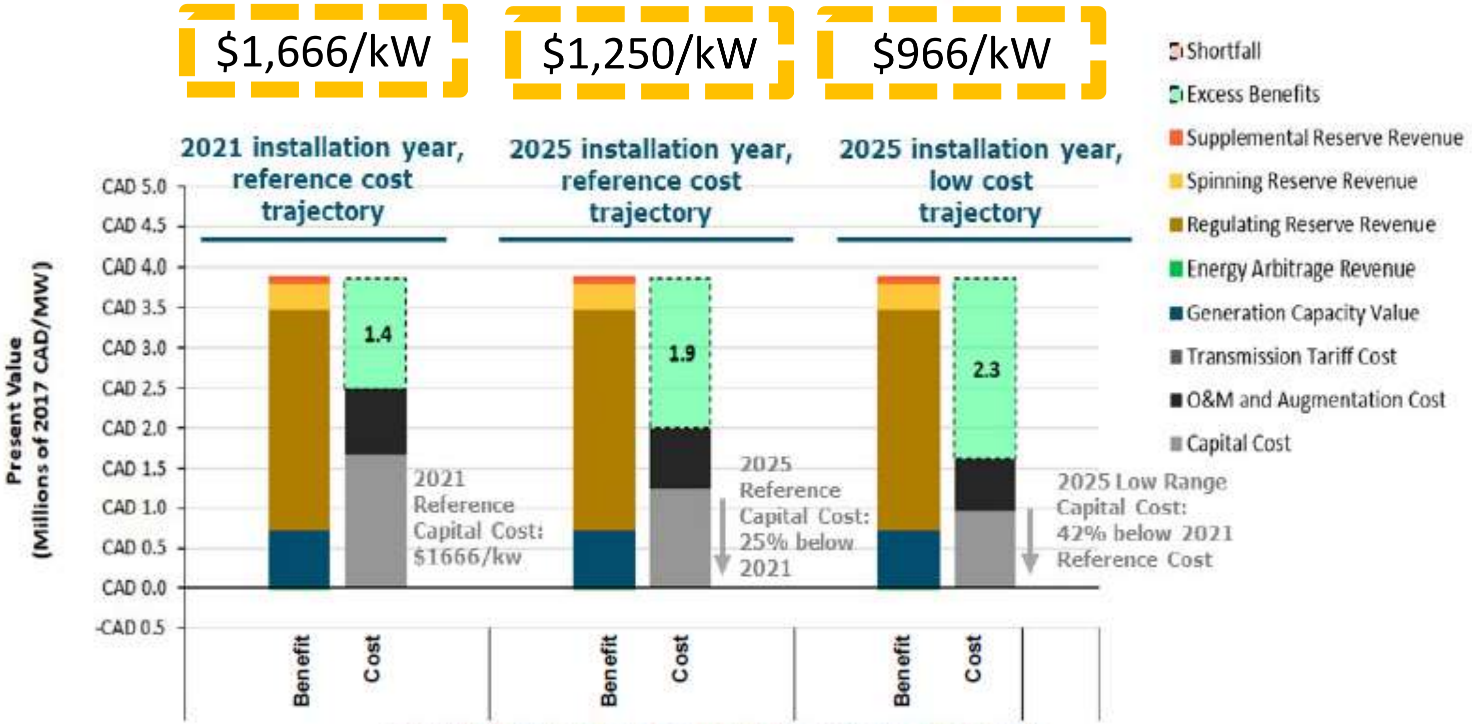
1 MW, 4-hour Lithium-Ion Battery



*Note: Results above exclude transmission tariff cost, do not assume price saturation of operating reserve markets

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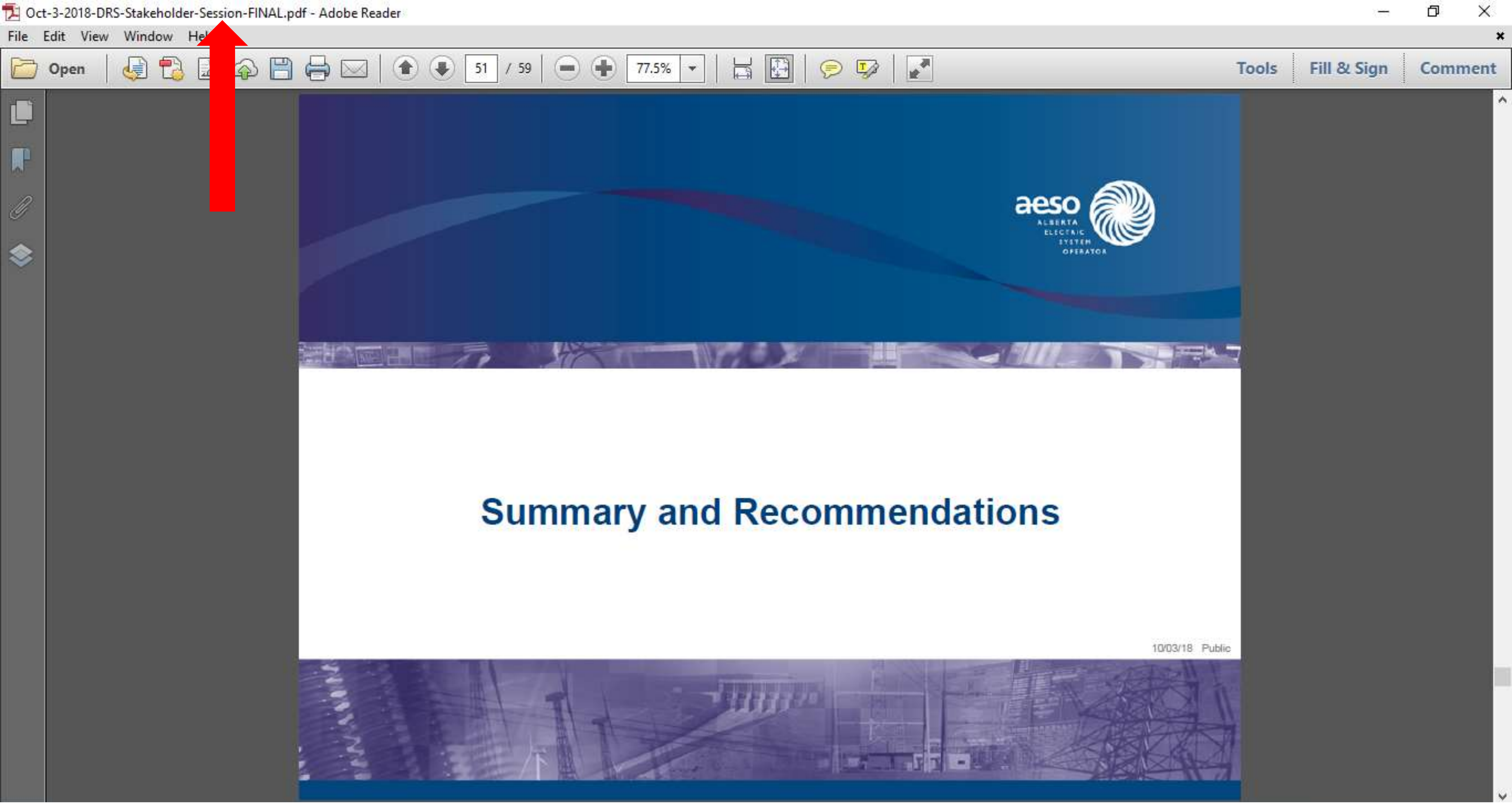
Key energy storage findings

- Transmission tariff likely to be a material cost for storage
- Smaller sizes and volume of storage (<50 MW) may be cost-effective, primarily in the ancillary services market
- Larger sizes and volumes of storage (>50 MW) unlikely to be cost-effective due to insufficient energy price spreads
- Storage will be able to participate in the capacity market
- As energy storage costs continue to fall, future cost curves will drive the level of market penetration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Reliable, renewable, affordable, and market aligned

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RELIABLE

- Reliability maintained at 30% x 2030
- Existing and planned transmission will enable renewables to connect
- Generation surpluses to be <1% of renewable energy (<0.3% total energy)
- Reaffirms no reliability concerns with coal phase-out

RENEWABLE

- 30% x 2030 achievable
- REP achieves best $/tonne carbon reduction

AFFORDABLE

- Wind is currently the least-cost renewable
- Capacity market reduces price volatility and value of storage

MARKET ALIGNMENT

- Flexibility and supply surplus not forecast to create material market impacts

What is the status of CLEAN energy in Clause G ?

O.C. 120 /2017

MAR 2 9 2017

Province of Alberta
Order in Council

ORDER IN COUNCIL

Approved and ordered:

Lieutenant Governor
or
Administrator

The Lieutenant Governor in Council

(a) orders the Alberta Utilities Commission to inquire into and report to the Minister of Energy on matters relating to Electric Distribution System-Connected Generation, in accordance with the terms of reference in the attached Schedule,

and

(b) determines that the Alberta Utilities Commission has the same power with respect to ordering by whom and to whom its costs and other costs of, or incidental to, the inquiry described in clause (a) are to be paid as the Commission has with respect to its hearings and other proceedings.

CHAIR

SCHEDULE

Terms of Reference for an Inquiry into and Report to the Minister of Energy on Matters Relating to Electric Distribution System-Connected Generation

WHEREAS:

A. the Government of Alberta has set a firm target for 30 per cent of electric energy produced in Alberta to be generated from renewable sources such as wind, hydro and solar by 2030;

B. significant growth in distribution system-connected generation, including micro- and small-scale community generation, will contribute to the 30 per cent renewable electricity generation target;

C. the Government of Alberta is interested in the current and potential opportunities to enable and facilitate the development of alternative and renewable distribution system-connected generation, including micro- and small-scale community generation, throughout Alberta; including in distribution service territories operated by investor-owned utilities, municipalities, and Rural Electrification Associations;

D. renewable energy refers to energy obtained from resources that can be naturally replenished within a human lifespan, such as solar, wind, hydro, geothermal, and biomass;

E. alternative energy refers to energy obtained from non-conventional energy resources (i.e., not fossil fuels) or obtained from low-carbon intensity conventional sources of energy in a more efficient manner (e.g., combined heat and power applications);

F. Alberta's distribution systems, billing and settlement systems, and supporting Acts, Regulations and rules play a significant role in enabling and facilitating broader deployment of alternative and renewable distribution system-connected generation in Alberta;

G. the development of alternative and renewable distribution system-connected generation in Alberta, including micro- and small-scale community generation, should be in line with the Government of Alberta's objectives of providing clean, affordable and reliable energy to Albertans.

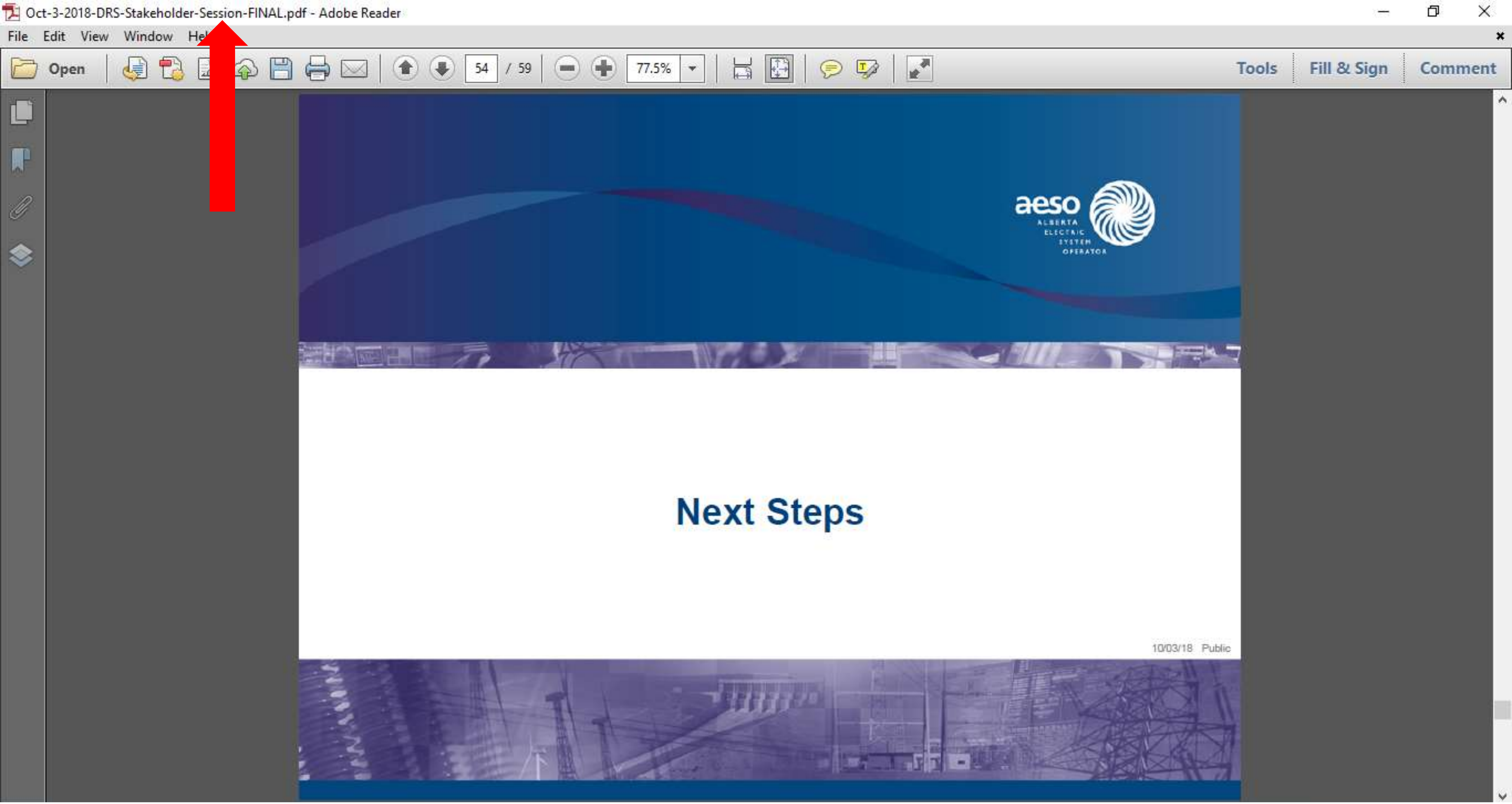
H. in order to permit the Government of Alberta to consider a full range of options on all issues relating to growth in alternative and renewable distribution system-connected generation, it is desirable that a review be conducted by the Alberta Utilities Commission;

……. specifically Schedule Clause G

G. the development of alternative and renewable distribution system-connected generation in Alberta, including micro- and small-scale community generation, should be in line with the Government of Alberta's objectives of providing clean, affordable and reliable energy to Albertans.

There has *never* been a definition of 'Clean' energy; therefore a definition is required.

Renewable Generation with Energy Storage will be far '**cleaner**' than any electricity generation fueled by natural gas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Next Steps
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Predicting the future is tricky

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AESO's next steps

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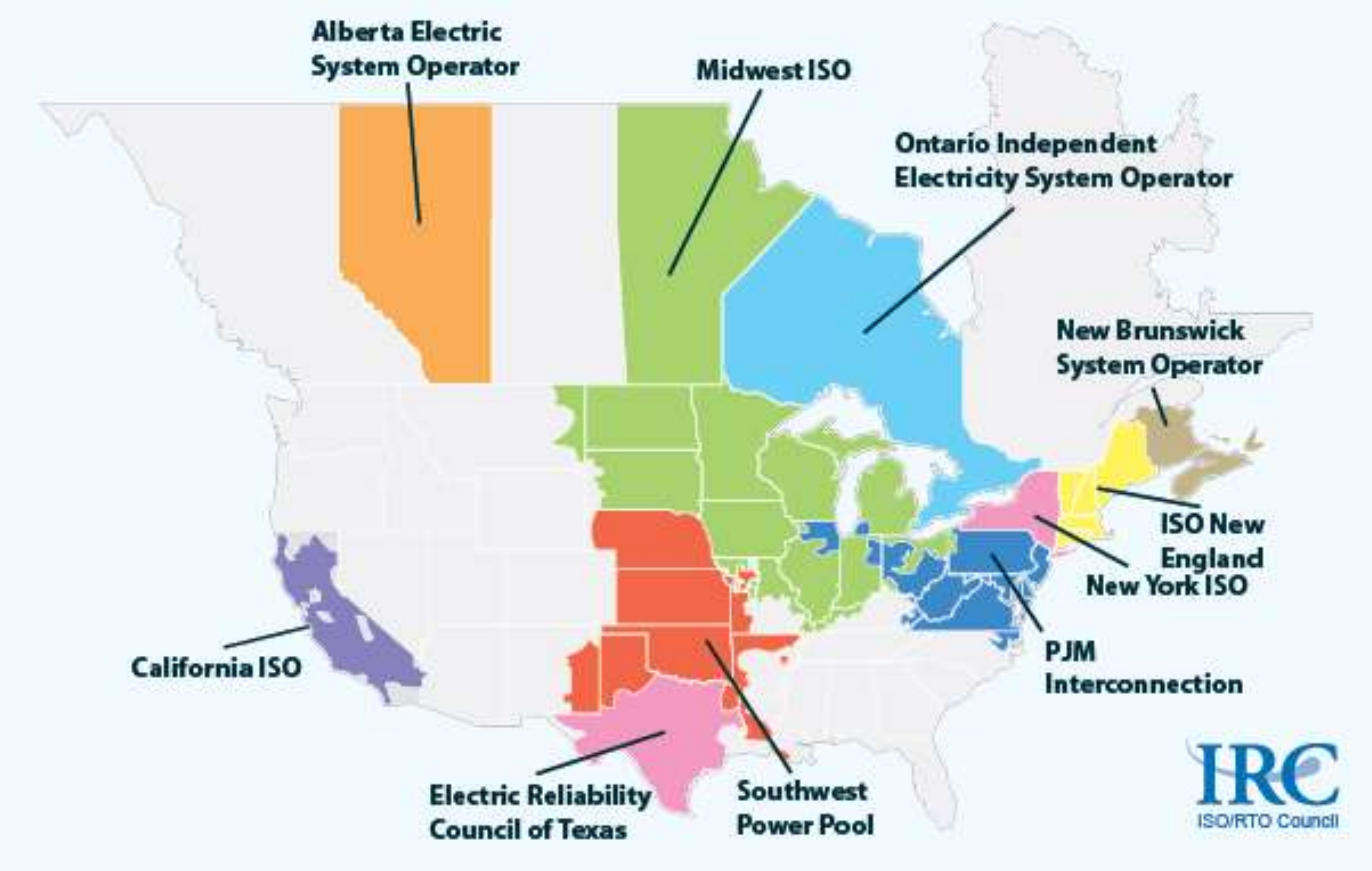
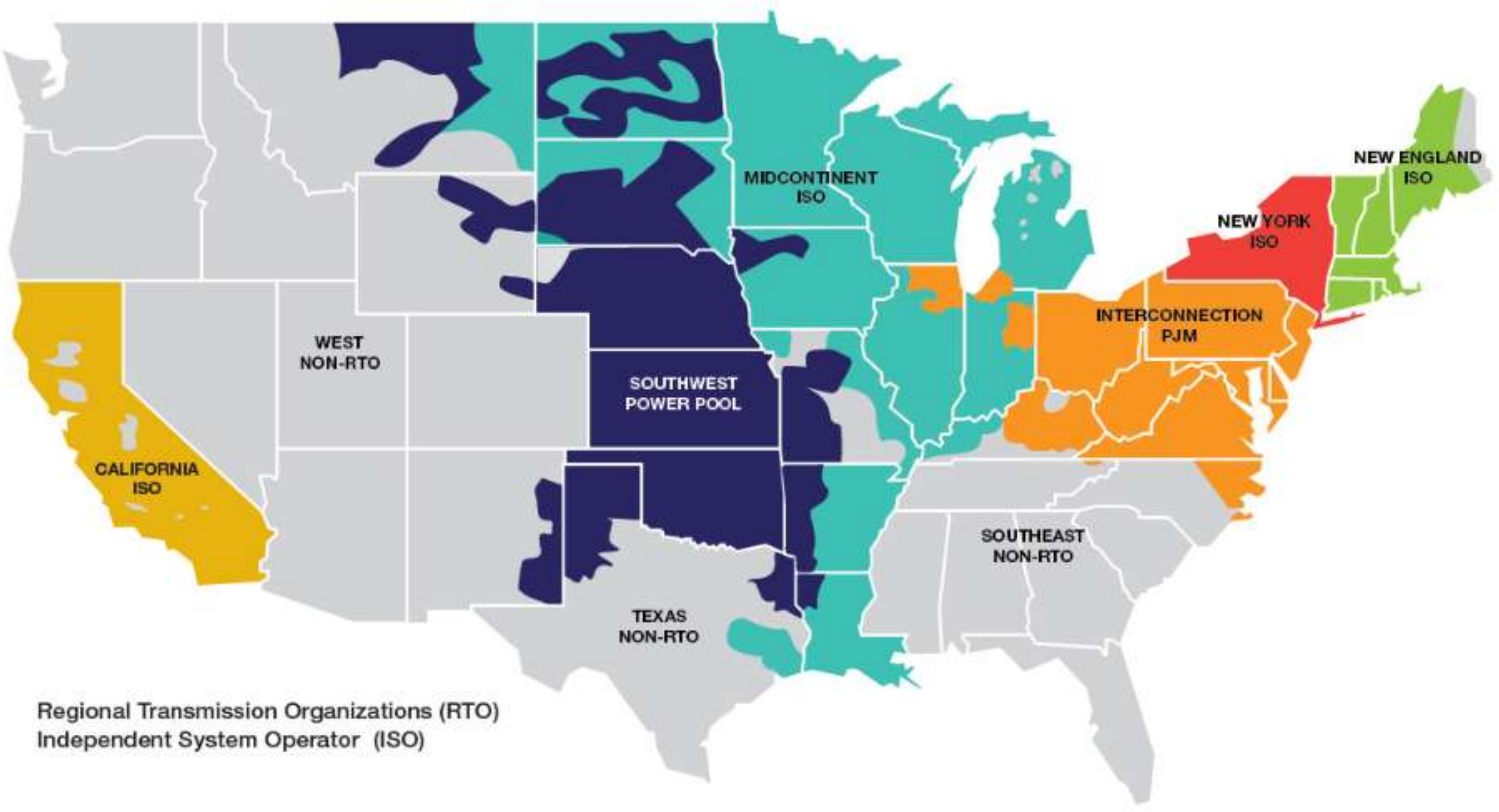
- Energy Storage Roadmap
  - AESO will lead the development
  - Create an Energy Storage Stakeholder Group in October/November
  - Integrate with other action already underway
- Flexibility Roadmap
  - AESO will lead the development
  - Energy and Ancillary Services roadmap already progressing some elements of the Flexibility Roadmap
  - Integrate with other action already underway
- Open to additional feedback or questions on report
  - Contact dennis.frehlich@aeso.ca

ISOs (Independent System Operators) in Canada and USA



RTO (Regional Transmission Organizations) & ISOs (Independent System Operators) in USA



ISO RTO Operating Region

Source: The Sustainable FERC Project

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Energy+Environmental Economics

Role of Dispatchable + Renewables in Renewable Energy Integration

FINAL REPORT May 2018

California

Current and projected renewable energy deployment

- High solar and wind capacity (10 GW utility-scale solar, 6 GW BTM solar, 6 GW wind)
- Goal of 50% RE by 2030, likely to be increased to 100% by 2050
- Likely to meet goals with additional solar, up to 40 GW total by 2030

Storage deployment

- 4,000 MW of pumped storage hydro capacity statewide, primarily legacy plants
  - Castaic: 1,623 MW (COD 1973) tied to major aqueduct and reservoirs for LA water management
  - Helms: 1,212 MW (COD 1984) used as source of flexibility for Diablo Canyon nuclear plant
- Storage mandate: 1,325 MW of energy storage by 2020 (no large pumped hydro)

Grid challenges

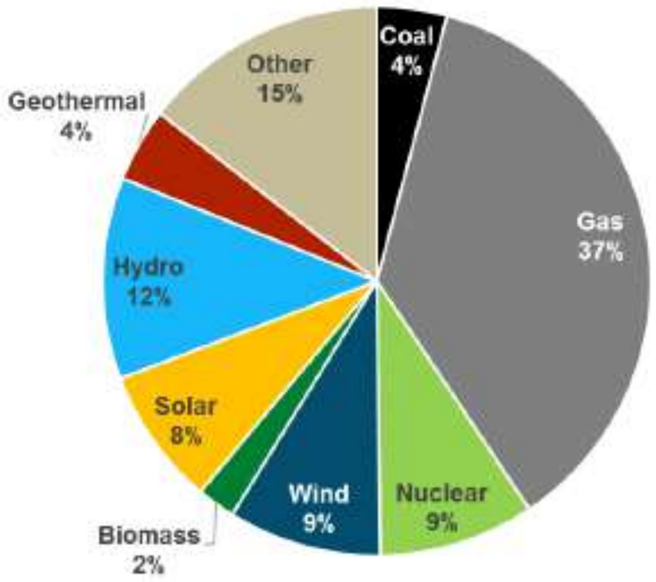
- Midday overgeneration and curtailment around midday solar peak
- Steep ramping requirements to meet early evening peak load as solar declines

Policy initiatives that support RE integration

- Storage mandate has led to battery storage deployment and may increase in future
- IOUs required to participate in demand response auction mechanism: 200 MW procured in 2017, growing in scale each year with BTM battery storage bidding as a DR resource

Market mechanisms that support RE integration

- Economic curtailment. Max to date: 3,500 MW in March 2017
- Reform of flexible capacity market underway (proposed increases in ramping and cycling requirements)
- Flexible ramping product implemented at 15- and 5-minute intervals in Nov. 2016



2016 Energy Mix
Total Load: 291 TWh
Peak Demand: 46.2 GW

Jurisdiction	Dominant RE Regime	RE % 2016 (2030 goal)	Peak RE to date (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
California	Solar	36%* (62%)*	72%	15,000+	3,500	0.9%	4,200+	15,000	Overgeneration	Economic curtailment

* Hydro is not part of California RPS, but is included and held constant at current levels for comparison

Electric Reliability Council of Texas

Current and projected renewable energy deployment

- Currently 21 GW of wind, just 556 MW of utility-scale solar, 500 MW of hydro
- Interconnection queues: 8,500 MW wind, 2,000 MW solar; 4,200 MW of coal to retire by 2018
- State RE targets achieved and surpassed; wind increasingly economic as merchant generation

Storage deployment

- No pumped storage; 317 MW CAES project (Bethel Energy Center) approved, expected COD 2020
- No storage mandate but >50 MW battery storage installed in 2017 alone; 600 MW in interconnection queue

Grid challenges

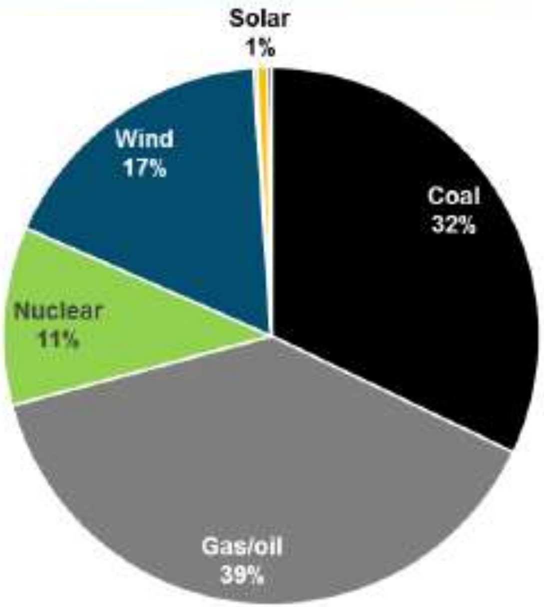
- Two main congestion constraints: import from North Texas to Houston area and export from the Panhandle region. Plans for $6.1 billion of transmission investment between 2018 and 2023
- Wind unpredictability: Improved forecasting of 'wind ramps' using ELRAS (ERCOT Large Ramp Alert System) – Warns about large ramps 6 hrs ahead; Wind curtailment in spring and winter (up to 1,000 MW)

Policy initiatives that support RE integration

- Wholesale storage is exempt from transmission service rates (PUC Rule 25.192)
- Distributed Resource Energy and Ancillaries Market (DREAM) Task Force created to identify how solar PV, batteries, DR and other DER could participate in ERCOT energy market. Recommendations include aggregation and increased market participation and controls for distributed resources
- Competitive Renewable Energy Zone (CREZ) program led to development of new transmission for 18.5 GW of total wind capacity in 2013-2014 at a cost of approximately $6.8 billion, helping reduce wind curtailment from 17% in 2009 to 4% in 2013

Market mechanisms that support RE integration

- Economic dispatch and curtailment for renewables
- NPRR 581 (2013) – Created a new ancillary service subset of Regulation Service known as Fast Responding Regulation Service (Fast Frequency Response)

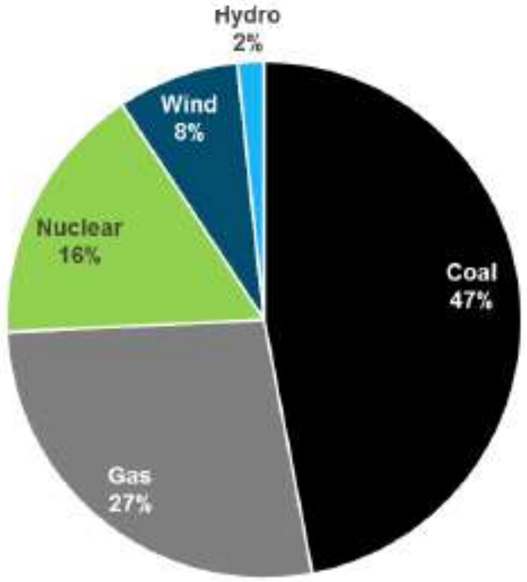


2017 Energy Mix
Total Load: 357.4 TWh
Peak Demand: 69.5 GW

Jurisdiction	Dominant RE Regime	RE % 2016 (2030 goal)	Peak RE to date (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
ERCOT	Wind	18% (n/a)	54%	17,400	1,000	3%-4%	70	1,100	Tx congestion, curtailment	Tx upgrade, market redesign

MISO Midcontinent Independent System Operator

- **Current and projected renewable energy deployment**
  - Currently ~15 GW of wind, minimal solar (first 100 MW integrated in 2017)
  - 58.8 GW in interconnection queue, almost 80% renewable: 31 GW of wind, 16 GW of solar
  - RE targets achieved and surpassed; wind deployment now driven by economics
- **Storage deployment**
  - Two pumped storage facilities make up a majority of the storage in MISO
    - Taum Sauk: 440 MW, COD in 1963
    - Ludington Pumped Storage Facility: 2,061 MW, COD in 1973
  - No policy mandates for new storage, but 140 MW of battery storage has requested interconnection
- **Grid challenges**
  - Congestion from high wind penetration in northwest MISO away from load centers farther east and south. Difficulty building new transmission in certain states (e.g. Missouri) to alleviate congestion
- **Policy initiatives that support RE integration**
  - MISO continuing to develop definition for storage and rules for storage's participation in markets. Under pressure from stakeholders to accelerate process
- **Market mechanisms that support RE integration**
  - Dispatchable Intermittent Resource (DIR) protocol launched in 2011 switched MISO from manual curtailment to economic curtailment. Requires wind plants to bid into real-time market and automates dispatch down (curtailment)



2016 Energy Mix
Total Load: 615 TWh
Peak Demand: 112 GW

Jurisdiction	Dominant RE Regime	RE % 2016 (2030 goal)	Peak RE to date (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
MISO	Wind	10% (none)	24%	13,600	~500–1,300	0.3%	2,530	14,000 in / 8,000 out with PJM alone	Tx congestion	New Tx

SPP Southwest Power Pool

Current and projected renewable energy deployment

- >16 GW installed wind capacity, minimal solar
- 95% of active interconnection requests are renewable: 77 GW wind and 17 GW solar
- Minimal RE targets: SPP states have exceeded RPS goals, wind development driven by low costs

Storage deployment

- Three pumped storage projects: Salina (260 MW, COD 1968), Truman (186 MW, COD 1979), Clarence Cannon (31 MW, COD 1984)
- Gregory County 800 MW pumped storage project discussed for decades, still seeking permits
- No policy mandates, but 840 MW of battery storage interconnection request

Grid challenges

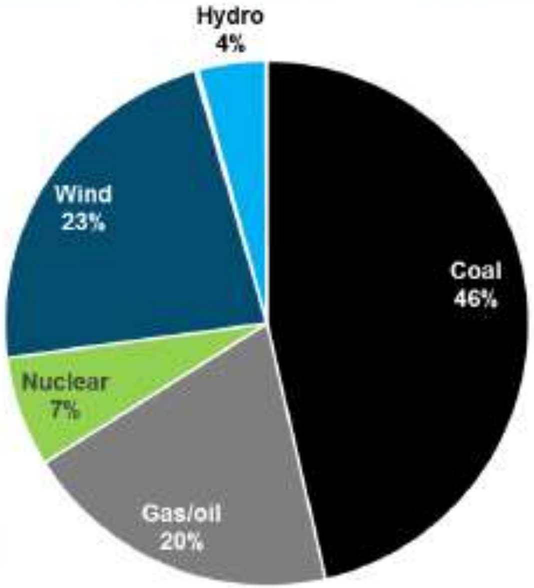
- Transmission congestion between wind in west and load in the east , alleviated by high Tx investments ($8 bn in the last decade)
- Reliability study found minimal curtailment at 30% wind, but major curtailment as wind increases to 45% and 60% penetration. Peak curtailment as high as 5 GW in 60% scenario

Policy initiatives that affect RE integration

- SPP Wind Integration Task Force Wind Integration Study in 2010 and in 2016 led to major transmission reinforcements and market developments
- Limited capacity market: Use of reliability must run (RMR) plants for capacity to maintain resource adequacy compensated at their bid price

Market mechanisms that support RE integration

- Launched new "Integrated Marketplace" in 2014 to combine separate balancing areas into single SPP balancing authority. Moved from priority dispatch to economic dispatch and increased automation and controls for renewables

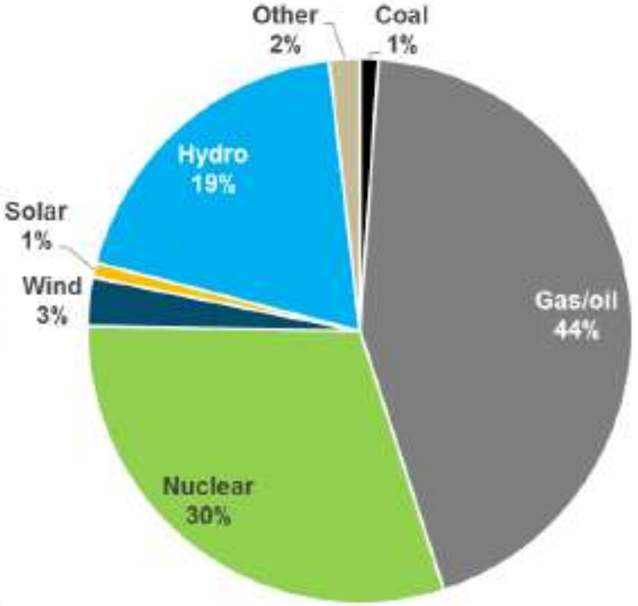


2017 Energy Mix
2016 Total Load: 253 TWh
2016 Peak Demand: 50.6 GW

Jurisdiction	Dominant RE Regime	RE % 2016 (2030 goal)	Peak RE to date (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
SPP	Wind	27%	54.2%	12,078	2,000	< 1%	475	1,200	Tx congestion	Tx upgrade

New York

+ **Current and projected renewable energy deployment**
  - Currently, 1,740 MW of installed wind, 32 MW of installed solar and 4,250 MW of hydro
  - Clean energy standard (CES): 50% RE by 2030
  - Mandate for 2,400 MW of offshore wind power by 2030
+ **Storage deployment**
  - Existing 1,407 MW pumped hydro; 240 MW more proposed
  - Upcoming mandate for 1,500 MW of storage by 2025; NYSERDA developing 2030 roadmap
+ **Grid challenges**
  - Major congestion between renewable resources upstate and high demand in load centers downstate with limited ability to build new transmission capacity
  - Lack of natural gas pipelines; Strong anti-pipeline political view
+ **Policy initiatives that support RE integration**
  - NY REV (Reforming the Energy Vision) places strong focus on distributed resources, storage, demand response, rate reform, etc. to make grid more flexible on distribution side
  - Storage and offshore wind mandates are being used to promote resource diversity, create jobs, and encourage market development
+ **Market mechanisms that support RE integration**
  - Coordinated transaction scheduling (CTS) with PJM since 2014 – Reduces uneconomic flows across RTO borders by allowing traders to submit 'price differential' bids that would clear when the price difference between the regions exceeds a threshold



2016 Energy Mix
Total Load: 159.2 TWh
Peak Demand: 33.2 GW

Jurisdiction	Dominant RE Regime	RE % 2016 (2030 goal)	Peak RE to date (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
New York	Wind	23% (50%*)	32%	7,700 MW	unknown	0.85%	2,240 MW	5,000 MW	Transmission congestion	Tx upgrade

* 50% target includes imports from Canada and New England

Hawaii

Jurisdiction of Hawaiian Electric Companies only (excludes Kauai)

Current and projected renewable energy deployment

- 543 MW rooftop solar (out of 991 MW RE capacity) in 2016
- By 2021, planned addition of: 326 MW DG-PV, 31 MW Feed-in-Tariff solar, 115 MW DR, 360 MW grid-scale PV, 157 MW grid-scale wind

Storage deployment

- 17 planned projects currently exist, totaling over 90 MW of grid scale storage
- "Smart Export" program for BTM PV + storage systems, allowing customers to export power to the grid at night for credit (35 MW program cap)

Grid challenges

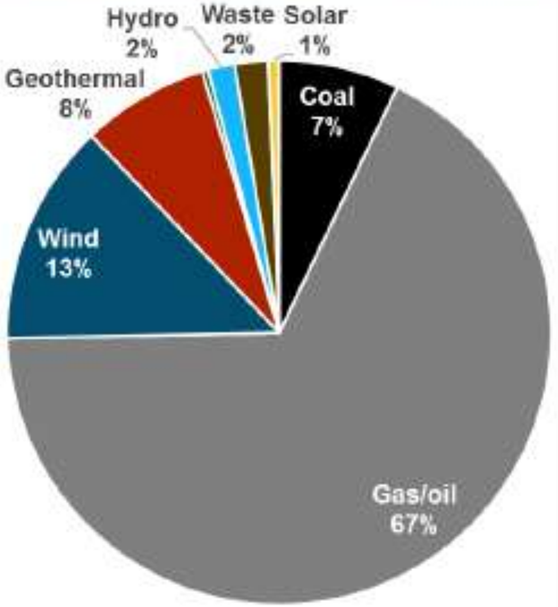
- Small, intra-island networks with limited grid hosting capabilities

Policy initiatives that support RE integration

- Release of NEM successor programs (implemented minimum charge fee and limits on export credit)
- Integrated Grid Planning detailing near-term action plan to achieve RPS targets, including:
  - Evaluation of an interisland transmission network
  - Distribution grid improvements to increase hosting capacity
  - Smart Grid upgrades to enable two-way communication and appliance control

Market mechanisms that support RE integration

- Development of new contracting methods to move away from renewables as "must-take"
- Pilot TOU rate studies and possible adoption in future



2016 Energy Mix
Total Load: 8.9 TWh
Peak Demand: 1.2 GW (Oahu)
188 MW (Hawaii
201 MW (Maui)

Jurisdiction	Dominant RE Regime	RE % 2016	Peak PV & Wind (% system peak, 2015-2016)	Curtailment (% of RE) 2016	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
Hawaii	BTM solar	25.8%	Oahu: 35% Maui: 72%	Oahu: 0.27% Maui: 5.5%	>35 MW	None	Overgeneration	Curtailment

Ontario

+ Current and projected renewable energy deployment

- Already >90% of electricity is carbon-free (only about 7% VRE)
- Behind the meter: additional 2 GW of distributed solar, 0.6 GW of distributed wind

+ Storage deployment

- 400 MW of existing pumped storage
- 2017 RFP for storage for regulation reserves selected two battery storage projects (55 MW). 2014 RFP selected 14 projects (50 MW), mostly lithium-ion battery but also flow battery, flywheel, compressed air, etc.

+ Grid challenges

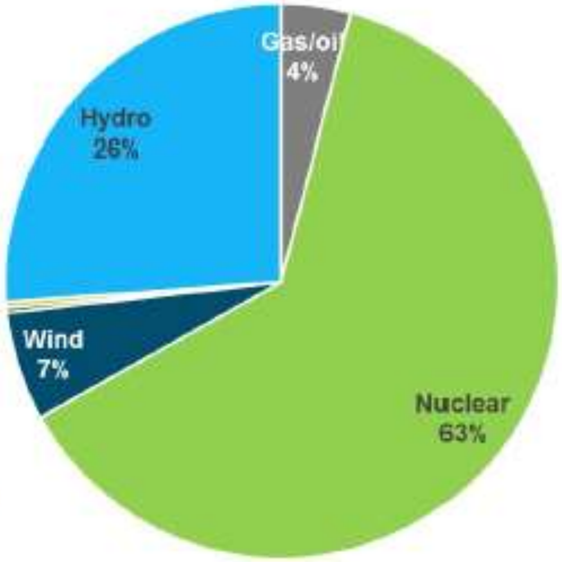
- Curtailment: "Dispatch down wind", spilled hydro, nuclear reductions

+ Policy initiatives that support RE integration

- Flexible load initiatives: DR goal of 10% by 2025, Demand Response Auctions (570 MW summer/ 712 MW winter peak), AGC-controlled Dispatchable Loads (AS and energy wholesale markets), TOU Rates
- Grid-LDC coordination initiative (data sharing and enhanced reliability)
- Renewable Integration Initiative (centralized forecasting and dispatchable VRE)
- Flex nuclear: 8 units at Bruce Power can dispatch down 300 MW each via condenser steam discharge, allowing cheaper curtailment than renewable PPA prices

+ Market mechanisms that support RE integration

- Move from priority dispatch to economic dispatch for renewable generation
- "Market Renewal" program: movement to more frequent intertie scheduling and market product improvements to value flexibility, ramping, etc. in AS market



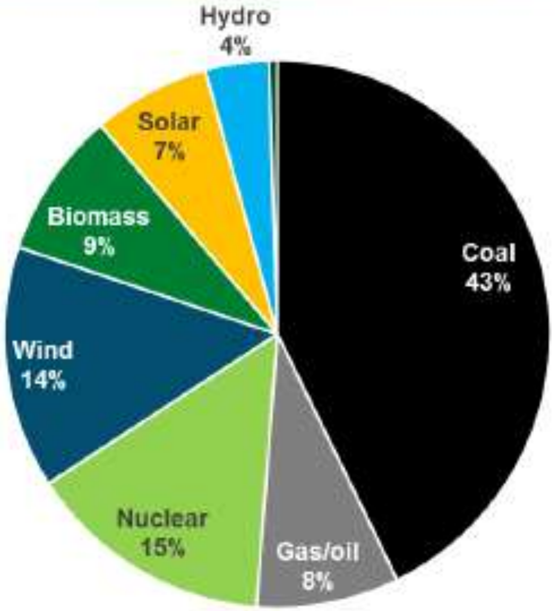
2017 Energy Mix
2017 Total Load: 132.7 TWh
2016 Peak Demand: 23.21 GW

Jurisdiction	Dominant RE Regime	RE % 2017 (2025 goal)	Peak ZE (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
Ontario	Hydro & Wind	33.1%	>100%	unknown	unknown	5.66%* (SBG estimate)	>224	> 6600 MW	Surplus Baseload Generation (SBG)	Dispatch down VRE

* Out of total load – 1.66% is dispatched down wind, 0.57% is reduced nuclear and 3.43% is lost hydro

Germany

+ **Current and projected renewable energy deployment**
  - Over 50 GW installed wind, 5 GW offshore wind and 43 GW solar PV installed capacity
  - Goal of 65% RE by 2030 and 100% RE by 2050
  - Offshore wind targets: 7.6 GW by 2020 and as much as 26 GW by 2030
+ **Storage deployment**
  - 67 MW of energy storage (128 MWh) as of 2015; 161 MW in 2016
  - 6,800 MW of pumped storage in 2016; 200 MW project proposed
+ **Grid challenges**
  - Transmission congestion from power-producing North to industrial South
  - Overgeneration during periods of high wind and solar. Reliance on must-run conventional generation to manage regulation down
  - Difficulty exporting energy during overgeneration periods
+ **Policy initiatives that support RE integration**
  - Future wind farms to be sited by the government (Centralized Danish model)
  - Existing coal-fired plants to be retrofitted for flexible operations
  - Load-following control in Nuclear PP (down to 50% of total capacity at a rate of up to 30 megawatts per minute without intervention) – Prohibited in the US
+ **Market mechanisms that support RE integration**
  - Limited use of curtailment as integration tool. Priority dispatch of RE; curtailments compensated by 95% of DA Market price



2016 Energy Mix
Total Load: 548 TWh
Peak Demand: 83 GW

Jurisdiction	Dominant RE Regime	RE % 2016 (2030 goal)	Peak RE to date (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
Germany	Wind and Solar	29.5% (65%)	85%	55,000	1,580	1.16%	7,200	20,000 MW*	Overgeneration and ramping	Curtailment and flexible coal & nuclear

*Less than half of the intertie capacity has ever been utilized

Spain

Current and projected renewable energy deployment

- Wind dominant system: 23 GW of wind capacity, 17 GW of hydro, and 7 GW of solar PV
- Solar growth is more recent: 2017 installations of 3,909 MW solar and 1,128 MW wind
- Goal of 20% of all energy to be renewable by 2020, already surpassed

Storage deployment

- Nearly 8 GW of pumped hydro storage. 5 GW legacy, 3+ GW new, more underway
  - La Muela 2,000 MW (2013), €1.2 billion
  - Aguayo II 1,000 MW expansion (2014), estimated €600 million
- Li-ion storage projects around 20 MW being developed

Grid challenges

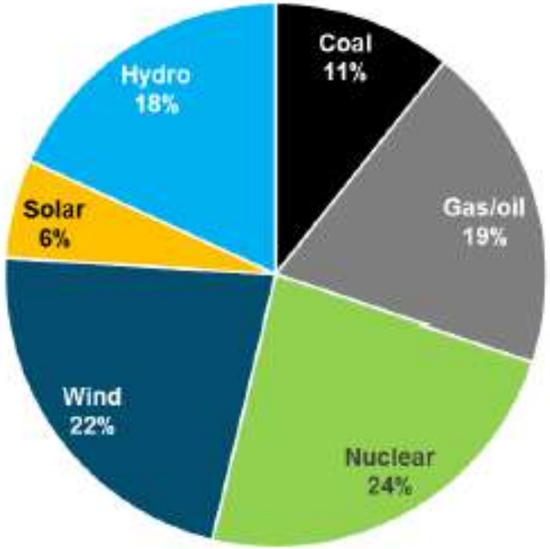
- Wind overgeneration and transmission congestion

Policy initiatives that support RE integration

- Renewables receive priority dispatch, but manual curtailment is managed day ahead based on relative bids. Curtailments compensated at 15% of DA price and can still participate in AS markets
- Control Center of Renewable Energies (CECRE) monitors and controls production from large RE facilities in real time
- Transmission expansion to increase export capacity: proposed DC interconnection with France of 5,000 MW exchange capacity- to start in 2025

Market mechanisms that support RE integration

- Rejected wind bids from day-ahead bids can still contribute to regulation up/down in reserves market

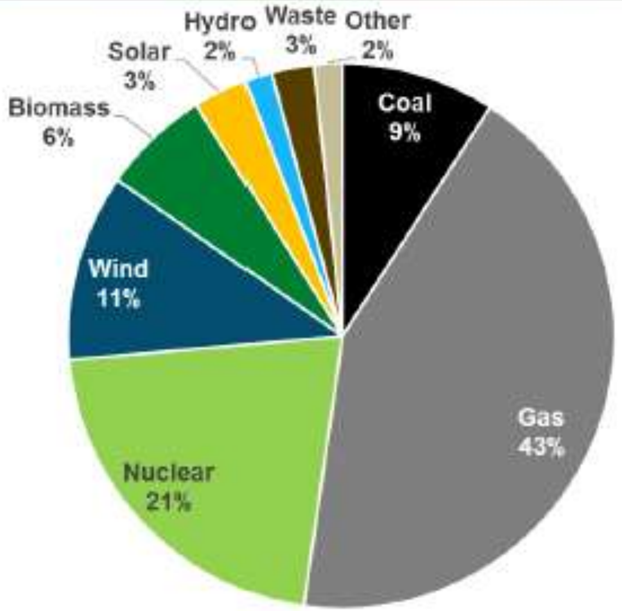


2016 Energy Mix
2017 Total Load: 262.6 TWh
2016 Peak Demand: 40.5 GW

Jurisdiction	Dominant RE Regime	RE % 2016 (2030 goal)	Peak RE to date (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
Spain	Wind, increasingly solar	36%	~70%	17,000+	unknown	5%	8,000	5,700 MW	Overgeneration	Increased interconnection & export capacity

United Kingdom

- **Current and projected renewable energy deployment**
  - Rapid shutdown of coal with much capacity converted to biomass
  - Offshore wind makes up over 33% of 18+ GW in wind capacity
  - Goal of 57% GHG reduction by 2032 and 80% by 2050 (1990 baseline)
- **Storage deployment**
  - 2,800 MW of pumped storage
  - 60 MW of battery storage today, plus approximately 500 MW under development to serve capacity contracts starting in 2020
- **Grid challenges**
  - Large wind deployment in Scotland with transmission constraints to loads in south. Western Link HVDC subsea transmission line with 2,200 MW capacity, due in 2018, should relieve constraint temporarily
  - Historical curtailment policy was costly, reformed in 2017 to prevent costly PPA payments during overgeneration hours
- **Policy initiatives that support RE integration**
  - Increased transmission buildout within UK and to neighbors. 1 GW lines to Belgium and France due online in 2019
- **Market mechanisms that support RE integration**
  - Economic curtailment, capacity market with long-term contracts
  - Reform of ancillary services and flexible capacity markets to allow energy storage to better monetize different types of value it provides



2016 Energy Mix
Total Load: 336 TWh
Peak Demand: 50.6 GW

Jurisdiction	Dominant RE Regime	RE % 2016 (2030 goal)	Peak RE to date (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
United Kingdom	Wind	25% (N/A)	54%	19,300	unknown	4.1%	2,900	4,000+ MW	Transmission, overgeneration	Curtailment

http://www.ncl.ac.uk/media/wwwnclacuk/cesi/files/Intro%20to%20highRES%20model%20from%20wholeSEM%20-%20Dr%20Price%20-%20UCL.pdf

Ireland (incl. Northern Ireland)

Current and projected renewable energy deployment

- 40% RE by 2020
- 4,000+ MW of wind today, likely to exceed 2026 target of 5,000 MW
- Ireland: Up to 100 MW of solar by 2023. Northern Ireland: 80 MW solar currently, 250 MW in development

Storage deployment

- Single 292 MW pumped storage facility, commissioned in 1974
- Battery storage: 10 MW Kilroot Power Station pilot project is connected at transmission level, provides frequency regulation. Plan for 100 MW storage array next to Kilroot.
- Connection agreement for a new 70 MW facility
- 330 MW (out) / 250 MW (in) CAES project under discussion, no investment decision yet

Grid challenges

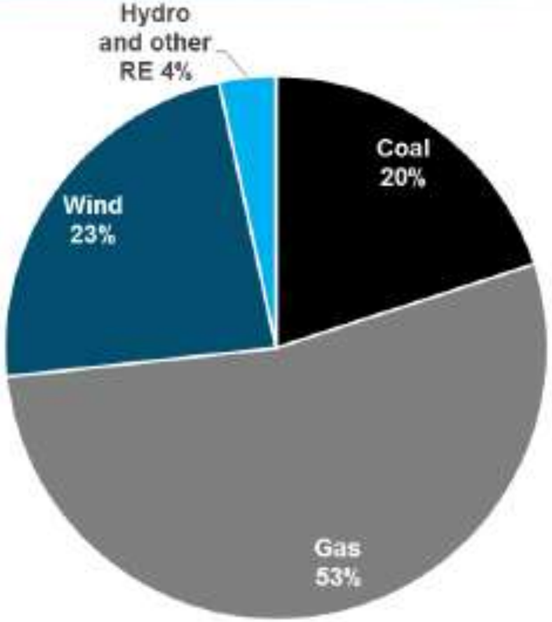
- Transmission congestion has lead to significant curtailment of wind

Policy initiatives that support RE integration

- REFIT 3 provides an incentive for biomass-fired CHP

Market mechanisms that support RE integration

- Wind has priority dispatch with sequential curtailment tiers. SO has automatic controls
- Delivering a Secure, Sustainable Electric System ("DS3") program has introduced new ancillary service products for inertia, fast frequency response, ramping margin (1-, 3-, and 8-hr), etc. to increase system's maximum nonsynchonous capacity from 50% to 75% by 2020



2016 Energy Mix
Total Load: 37.2 TWh
Peak Demand: 6.8 GW

Jurisdiction	Dominant RE Regime	RE % 2016 (2030 goal)	Peak RE to date (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
Ireland	Wind	26%	~60%	2,815	est. 500 MW	3.2%	302	1,000	Transmission capacity, grid stability	Curtailment, new Tx, market reform

Australia

Current and projected renewable energy deployment

- >6 GW Hydro, 3 GW Wind; 42% target by 2030 – now abandoned
- Significant installation of BTM solar PV
- Most of the load and wind plants are located in South Australia (SA), Victoria and NSW
- South Australia (SA): committed to 80% RE by 2022. Currently 57% solar + wind, supported by strong interconnection with Victoria (Melbourne)

Grid challenges

- Flexibility and ancillary service constraints in SA due to priority dispatch of renewables and lack of synchronous generation: frequency deviations, frequency control AS
- In SA, wind constrained at 1,200 MW cap and export to Victoria limited to 250 MW

Storage deployment

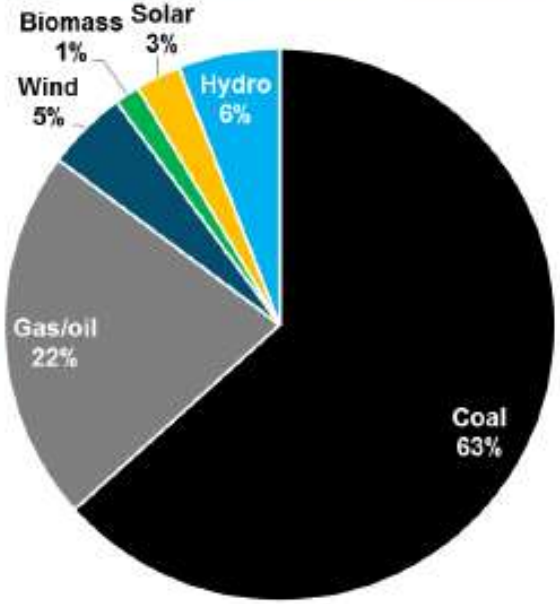
- 1,800 MW pumped storage
- 100 MW (129 MWh) in a single project by Tesla – the largest in the world – funded by the Australian government. Tesla to build another 20 MW battery system with wind farm

Policy initiatives that affect RE integration

- SA: Automatic Under Frequency Load Shedding (AUFLS): last resort safety net to prevent system collapse (initially started in New Zealand) – mandatory load shedding during non-credible contingency events; Designing an Over Frequency Generation Shedding (OFGS)

Market mechanisms that support RE integration

- Undergoing reform of ancillary services market to support frequency regulation issues

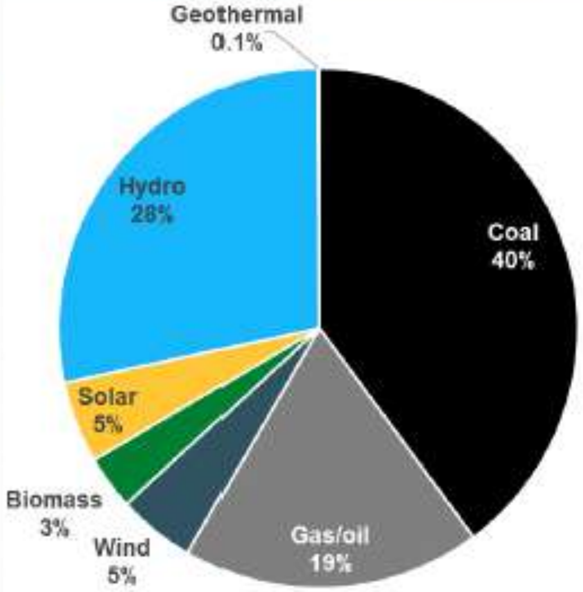


2017 Energy Mix
2016 Total Load: 257.3 TWh
2016 Peak Demand: 34.8 GW

Jurisdiction	Dominant RE Regime	RE % 2016 (2020 goal)	Peak RE to date (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
Australia	Wind	16% (23.5%)	unknown	unknown	unknown	unknown	1,900	None	Congestion, overgeneration	Curtailment, demand response

Chile

+ **Current and projected renewable energy deployment**
  - Currently 16.3% renewable (34% with hydro); ahead of schedule for 2025 goal
+ **Storage deployment**
  - 60 MW installed mainly for frequency regulation and spinning reserves
  - 110 MW CSP plant with 18 hour storage under construction
  - Proposals for additional 710 MW of CSP and 300 MW Pumped hydro (Valhalla)
+ **Grid challenges**
  - Curtailment of resources due to transmission congestion
  - Increased cycling in thermal facilities
  - Expecting 0 $/MWh prices by 2021-24 with potential duck curve due to solar
  - Frequency regulation and other AS studies underway
+ **Policy initiatives that support RE integration**
  - New centralized transmission planning function for ISO
  - Ambitious Transmission Expansion Plan (over US$ 1bn)
  - International Interconnections
+ **Market mechanisms that support RE integration**
  - Restructure of AS procurement and compensation mechanisms, RE auctions



2017 Energy Mix
Total Load: 68.27 TWh
Peak Demand: 10.4 GW

Jurisdiction	Dominant RE Regime	RE % 2017 (2025 goal)	Peak RE to date (% hourly)	Peak RE (MW)	Curtailment (Peak MW)	Curtailment (% Annual)	Storage (MW)	Import/Export Capacity (MW)	Primary challenge	Primary solution
Chile	Wind & Solar*	16.3% (20%)*	31-42%	4,610	Unknown	>2% (2016)	60 MW	200 MW	Transmission congestion	Tx upgrade

* RE definition does not include large scale hydro

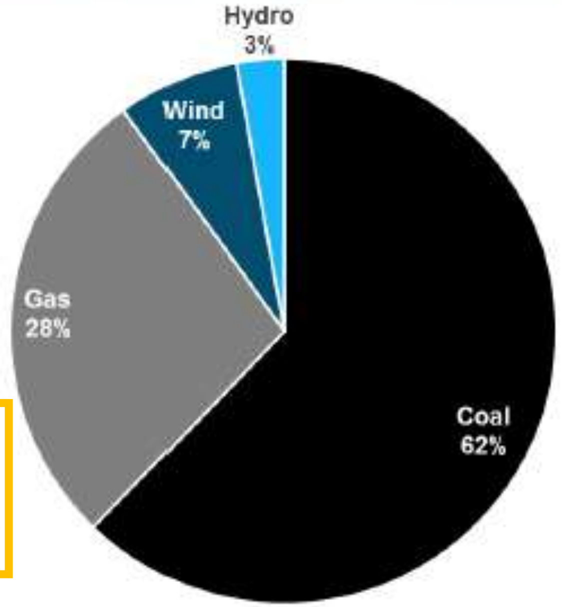
Summary of RE integration metrics for all jurisdictions

Jurisdiction	Dominant RE regime	RE gen% 2016 (2030 goal)	Peak hourly RE share (% of load)	Peak hourly RE (MW)	Peak hourly curtailment (MW)	Curtailment (% annual energy)	Storage (MW)	Import/export capacity (MW)	Primary challenge	Primary solution
California	Solar	36%* (62%)*	72%	15,000+	3,500	0.9%	4,200+	15,000	Overgeneration	Curtailment
ERCOT	Wind	18% (n/a)	54%	17,400	1,000 MW	3%–4%	70	1,100	Tx congestion	Tx upgrade, market redesign
MISO	Wind	10% (n/a)	24%	13,600	~500–1,300	0.3%	2,530	14,000 in / 8,000 out w/ PJM alone	Tx congestion	New Tx
SPP	Wind	27% (n/a)	54%	12,078	2,000	< 1%	475	1,200	Tx congestion	Tx upgrade
New York	Wind	23% (50%*)	32%	7,700	unknown	0.85%	2,240	5,000	Transmission congestion	Tx upgrade
Hawaii	BTM solar	25.8%	Oahu: 35% Maui: 72%	unknown	unknown	Oahu: 0.27% Maui: 5.5%	35+	None	Overgeneration	Curtailment
Ontario	Hydro and Wind	33.1%	unknown	unknown	unknown	5.66% surplus baseload gen	224+	6,600+	Overgeneration	Dispatch down VRE
Germany	Wind and Solar	29.5% (65%)	85%	55,000	1,580	1.2%	7,200	20,000	Overgeneration and ramping	Curtailment and flexible coal & nuclear
Spain	Wind, increasingly solar	36% (35%)	~70%	17,000+	unknown	5%	8,000	5,700	Overgeneration	Increased interconnection
United Kingdom	Wind	25% (N/A)	54%	19,300	unknown	4.1%	2,900	4,000+	Tx congestion, overgeneration	Curtailment
Ireland	Wind	26% (40%)	~60%	2,815	est. 500 MW	3.2%	302	1,000	Tx congestion, grid stability	Curtailment, new Tx, market reform
Australia	Wind, BTM solar	16% (23.5%)	unknown	unknown	unknown	Unknown	1,900	None	Congestion, overgeneration	Curtailment, demand response
Chile	Wind and Solar	16.3% (20%)*	31-42%	4,610	unknown	>2%	60	200	Transmission congestion	Tx upgrade

Where Alberta stands today

Reported as of May 2018

+ **Best comparables: high wind, low solar, low hydro, coal switching to gas**
  - Currently similar in RE penetration to MISO, Australia
  - On long-term path similar to Ireland and SPP where wind is dominant RE resource
+ **Renewable energy deployment and policies**
  - Currently 1,500 MW of wind capacity, 880 MW of hydro
  - Round 1 of Renewable Energy Program (REP) procured nearly 600 MW of wind in 2017
  - Rounds 2 and 3 announced February 2018, will procure additional 700 MW in 2018
  - Target of additional 5,000 MW of renewable capacity by 2030
+ **Storage deployment and policies**
  - No large transmission-scale storage projects
  - 2015 AI-EES funding of $1.5m for six storage project demonstrations: lithium-ion, fuel cell, flow battery, compressed air
+ **Grid challenges**
  - New curtailment policy defined in latest Alberta RFP: risk sharing between wind owner and AESO. Unpaid curtailment due to Tx constraints capped at 200 hours, then paid by AESO
  - Limited curtailment today: just two days in 2016 and 6 hours with curtailment
+ **Balancing and reliability solutions**
  - Gas and hydro generation are greatest existing sources of flexibility
  - Available export capacity increasing in recent years, nearly full availability
  - Capacity market under development



2016 Generation Mix
Total Load: 79.6 TWh
Peak Demand: 11.5 GW

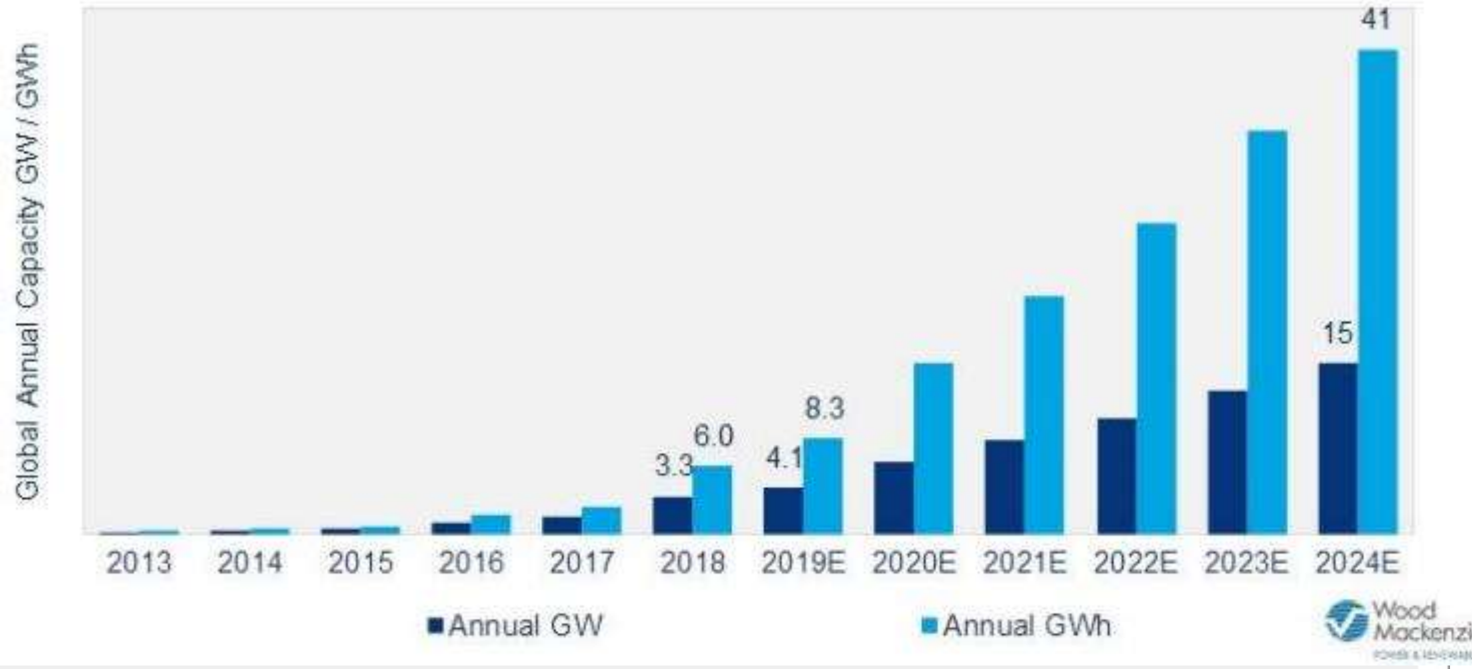
Jurisdiction	Dominant RE Regime	RE % 2016 (2030 goal)	Storage (MW)	Import/Export Capacity (MW)
Alberta	Wind	7% (30%)	<5	1,400

Alberta tomorrow?

Reported as of May 2018

- **Increased wind deployment to meet 30% RE goal by 2030**
  - Potential increase in curtailment if:
    - a) Transmission congestion arises in areas with high wind buildout
    - b) Wind generation exceeds AESO demand and export capacity in certain hours
  - More variable wholesale market dynamics with increased prevalence of zero prices
- **Increased coal to gas repowering**
  - Flexible gas likely to cycle more frequently
  - New capacity market may help support gas generation as energy revenues decline
- **Potential for stricter GHG or RE goals after 2030**
  - At higher RE penetration, value of resource diversity and storage increases and different types of assets may become economical

Wood Mackenzie Power & Renewables projects a thirteenfold increase in grid-scale storage over the next six years.
APRIL 10, 2019



WE NEED MORE HEADLINES LIKE THIS !

https://reneweconomy.com.au/battery-storage-shit-we-need-this-in-the-market-now-71976/?utm_source=RE+Daily+Newsletter&utm_campaign=72dca2c855-EMAIL_CAMPAIGN_2019_06_12_10_47&utm_medium=email&utm_term=0_46a1943223-72dca2c855-40347849

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SOLAR RENEWABLES STORAGE ELEC

Battery storage: "Shit, we need this in the market now"

Sophie Vorrath 13 June 2019 0 Comments Share

GOODWE Explore your next growth phase in energy storage & commercial solar markets

Aerial view of battery energy storage system multi-mixed energy power station

WindCharger Battery Storage | Tr

https://transalta.com/facilities/plants-operation/windcharger/

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TransAlta CLEAN POWER

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WindCharger Battery Storage

TransAlta is excited to introduce Alberta's first utility-scale lithium-ion battery storage facility located in the MD of Pincher Creek.

TransAlta has been investigating the viability of battery storage at our various wind farm locations over the past number of years. Our Summerview Wind Farm location was selected for its many desirable features, which are conducive to siting a battery storage facility of this nature.

The Project will utilize TESLA battery technology and once built will have a nameplate capacity of 10 MW with total storage capacity of 20 MWh. The Project is situated next to our Summerview Wind Farm substation on previously disturbed lands.

The Project qualified for co-funding from Emissions Reduction Alberta ("ERA").

ERA works with government, industry, and innovators on projects that reduce greenhouse gas emissions, attract investment, create jobs, and secure Alberta and Canada's success in a lower carbon economy.

At a Glance

- Location: MD of Pincher Creek, 13km northeast of Pincher Creek, AB
- Technology: TESLA lithium-ion battery

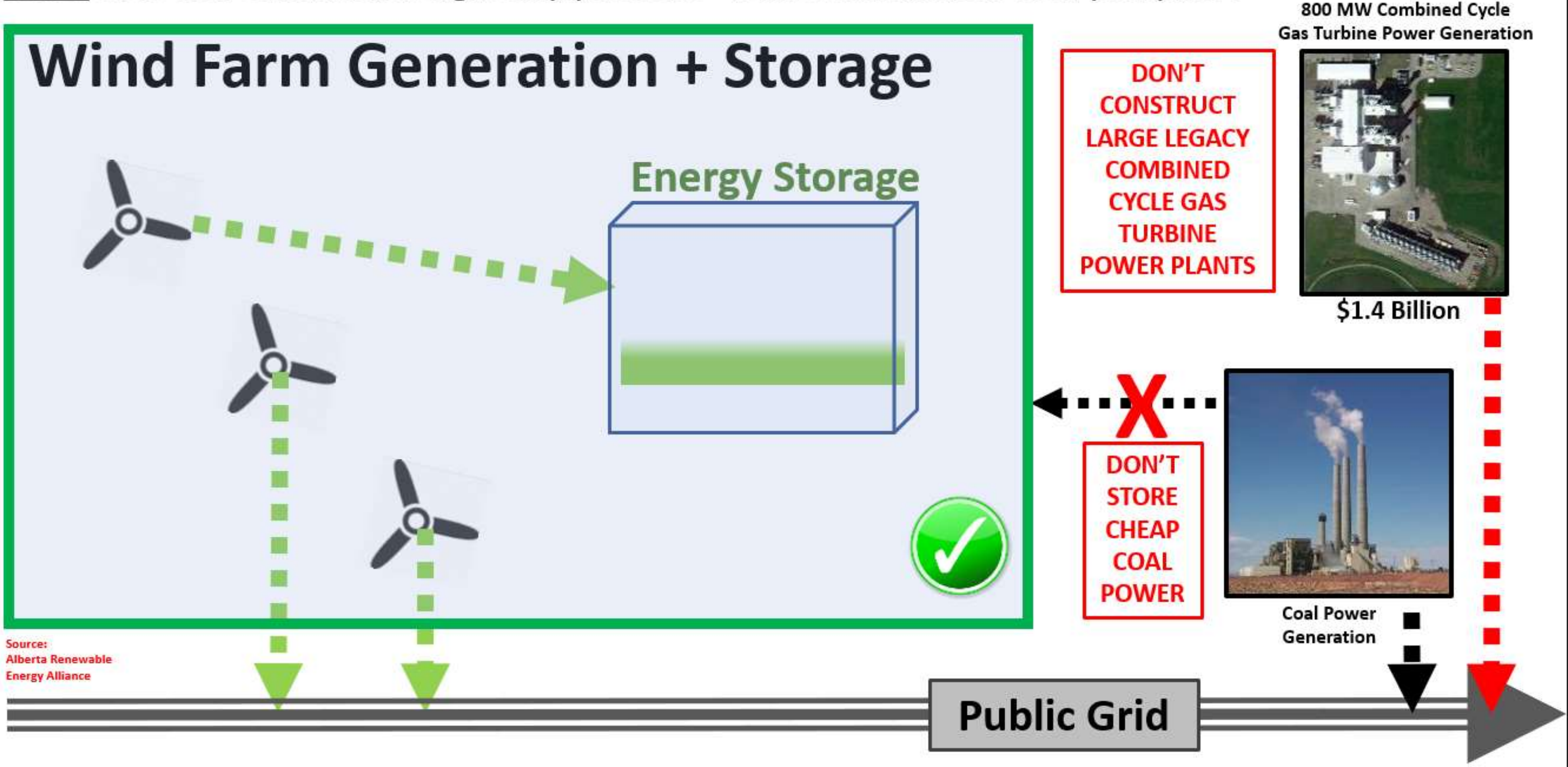
Facts & Figures

- Location: Pincher Creek, AB
- Fuel: Energy Storage
- Capacity (MW): 10 MW / 20 MWh
- Ownership: 100%
- Operator: Yes
- First on-stream: June 2020
- Revenue Source: Merchant
- Builder: Yes
- Contract Expiry: N/A

NEVER CURTAIL WIND GENERATION *animation absent in pdf*

<u>*STORE*</u> a portion of Wind Generation when the wind is blowing.

<u>*DON'T*</u> store Coal Generation at night simply because "it must run, and is at a low pool price".



Source:
Alberta Renewable
Energy Alliance

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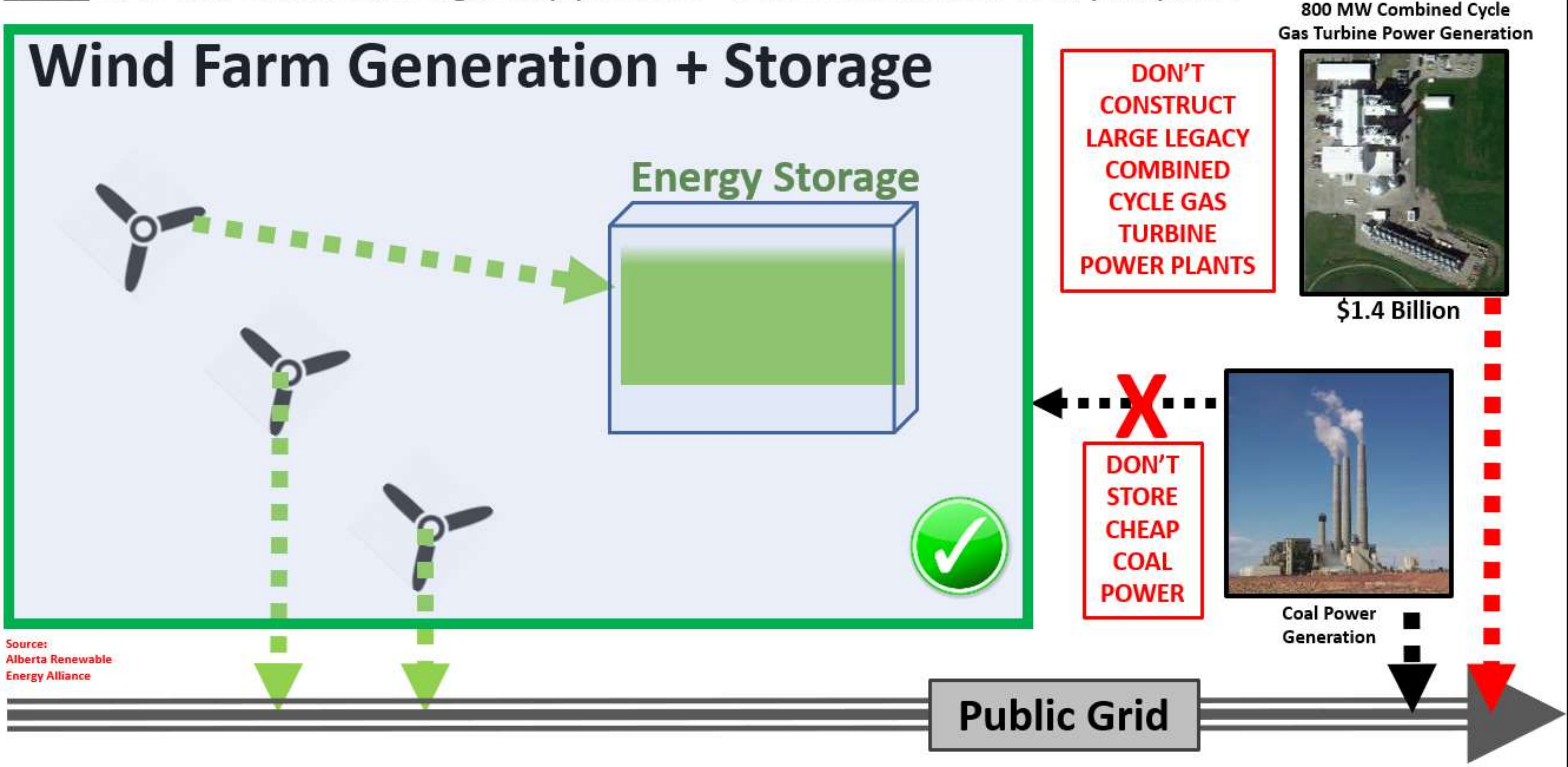

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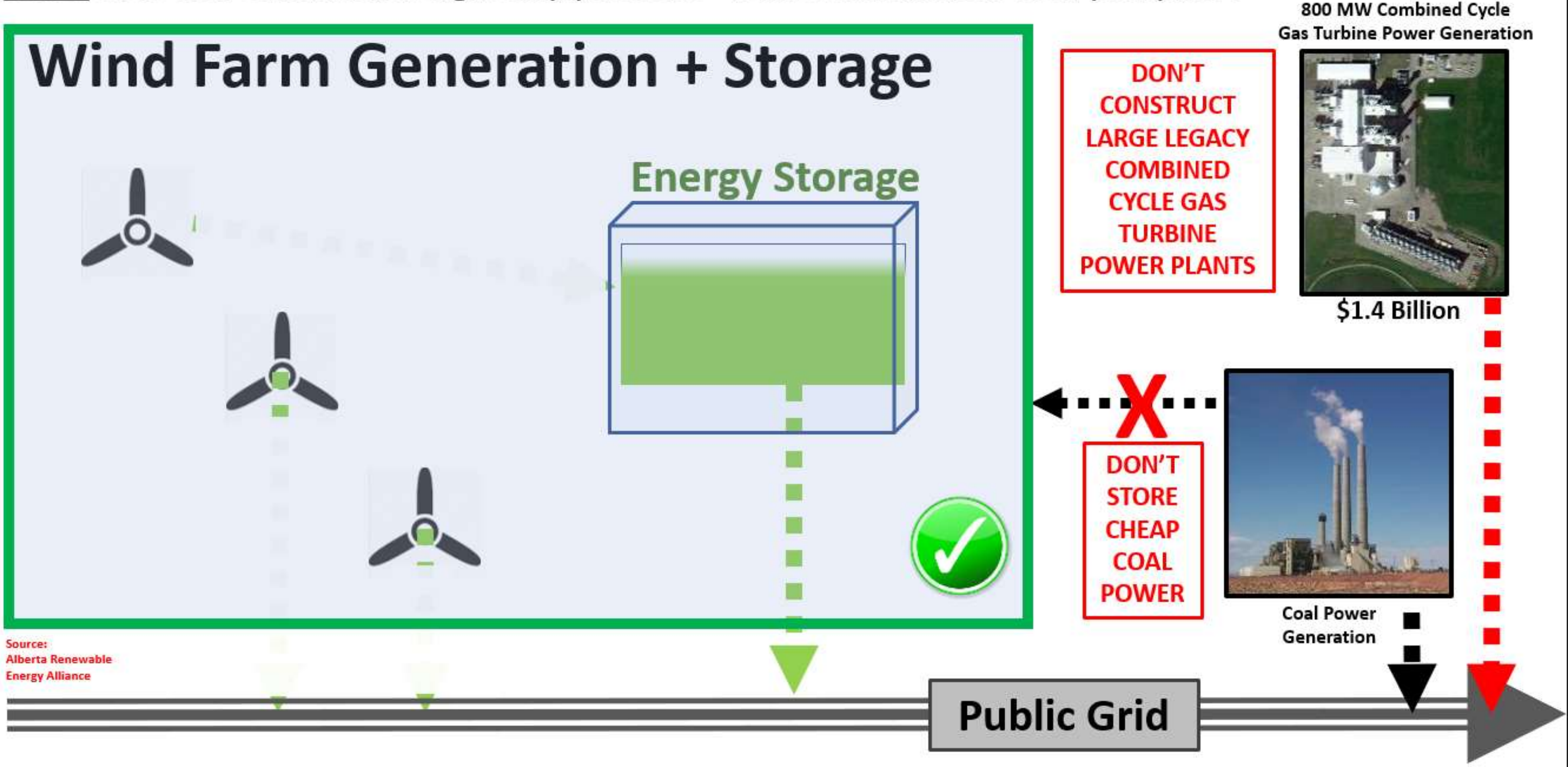

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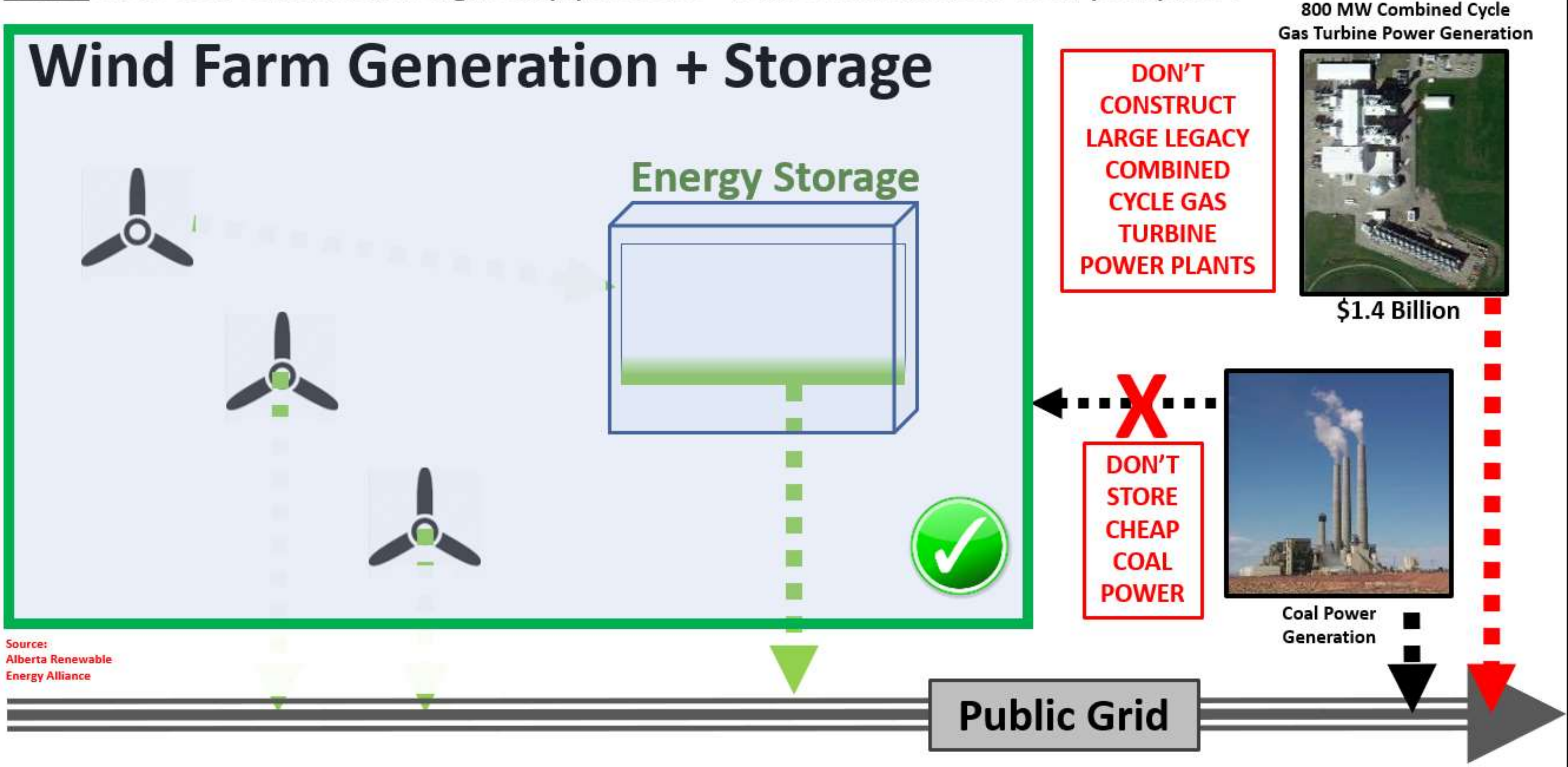

Source:
Alberta Renewable
Energy Alliance

Proposed Canyon Creek Pumped Hydro Energy Storage Project - Alberta

- https://www.hydroworld.com/articles/2019/01/first-pumped-storage-project-in-alberta-canada-approved-by-legislature.html

Turning Point Generation reports that Alberta Legislature has approved the construction and operation of the Canyon Creek Pumped Hydro Energy Storage Project.

The *Canyon Creek Hydro Development Act* passed unanimously in late 2018. Turning Point says Canyon Creek is "the first hydro project to be approved by the legislature in 10 years as well as both the first ever pumped hydro and first ever large-scale energy storage project to be approved in Alberta."

The Canyon Creek project will be located about 13 km from Hinton, Alberta, Canada, and is designed to incorporate two small off-stream water reservoirs, one atop a hill by Obed mine and the other at the bottom not far from the Athabasca River, Turning Point said. The company says the project will have capacity to store 75 MW for 37 hours of full-capacity generation.

"This is an important milestone for the project, for TPG and for Alberta's electricity sector," said Kipp Horton, president and chief executive officer of Turning Point's parent company, WindRiver Power Corporation. "We are excited to now engage with financing partners to move the project to the construction phase."

According to Horton, pumped hydro energy storage will be a critical feature of Alberta's electricity grid as the grid accommodates increasing production from renewable energy, particularly large-scale wind. "The project addresses a key hurdle to integrating renewable generation by absorbing its intermittent output and delivering stable, reliable, carbon-free electricity back to the grid. Pumped hydro is a proven storage technology, deployed globally for decades, and the project's closed-loop, off-stream design significantly reduces any potential adverse environmental impacts to Alberta's natural river courses," he said.

WindRiver is engaged in the development, ownership and operation of renewable energy projects in western Canada and internationally, with a focus on run-of-river hydro, wind generation and now, through Turning Point, pumped hydro energy storage.

Canyon Creek PHES primer - 2017-12-15.pdf - Adobe Reader

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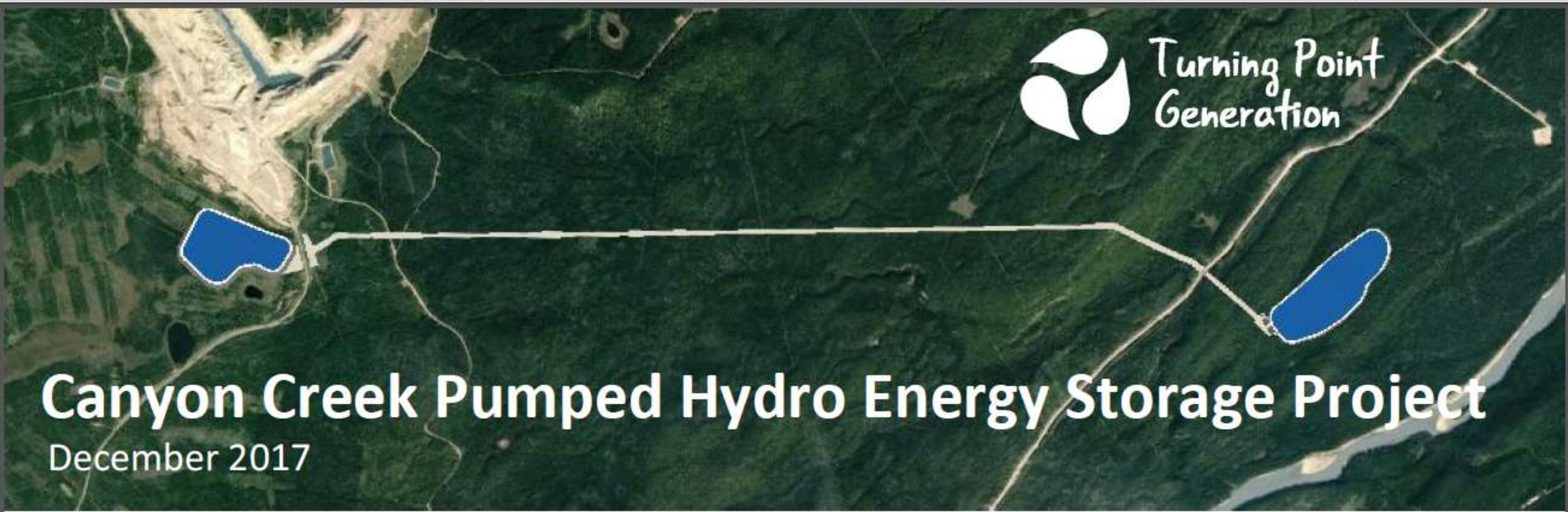

Canyon Creek Pumped Hydro Energy Storage Project

December 2017

INTRODUCTION

This document is intended as introduction for partners and supporters interested in more information regarding the Canyon Creek Pumped Hydro Energy Storage project

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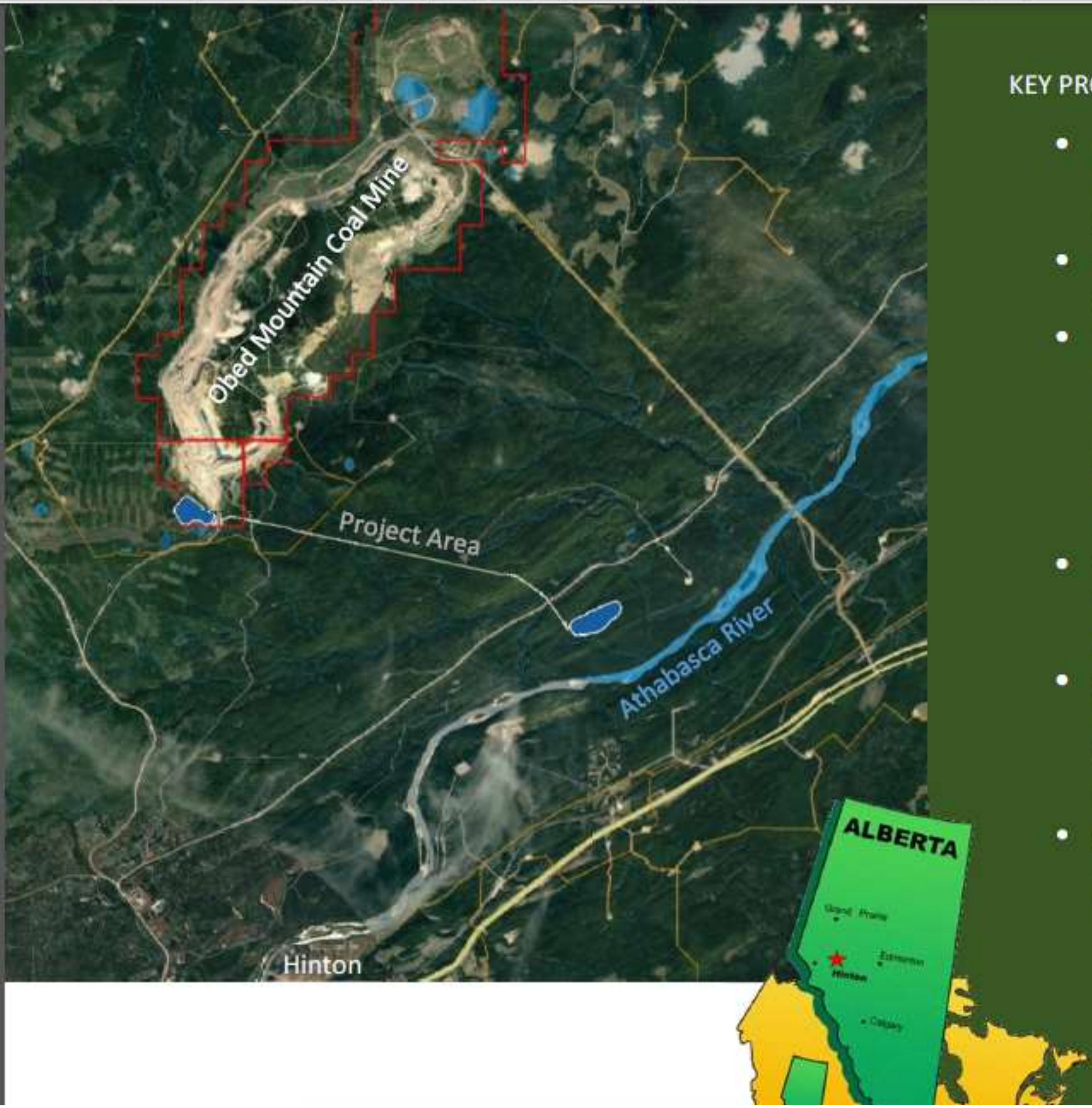

KEY PROJECT ATTRIBUTES

- Considered the overall best pumped hydro site in Alberta according to TPG research
- 75 MW capacity with 37 hour storage at full capacity.
- Purpose built reservoirs and closed loop system resulting in low environmental impact. Project is adjacent to the old Obed coal mine enabling efficiencies in development.
- Cost effective site and design resulting in low cost project (relative to industry typicals)
- Strategic location on the AIES. Interconnection point within 3 km with confirmed capacity reserved.
- Supportive community. Convenient, constructible location

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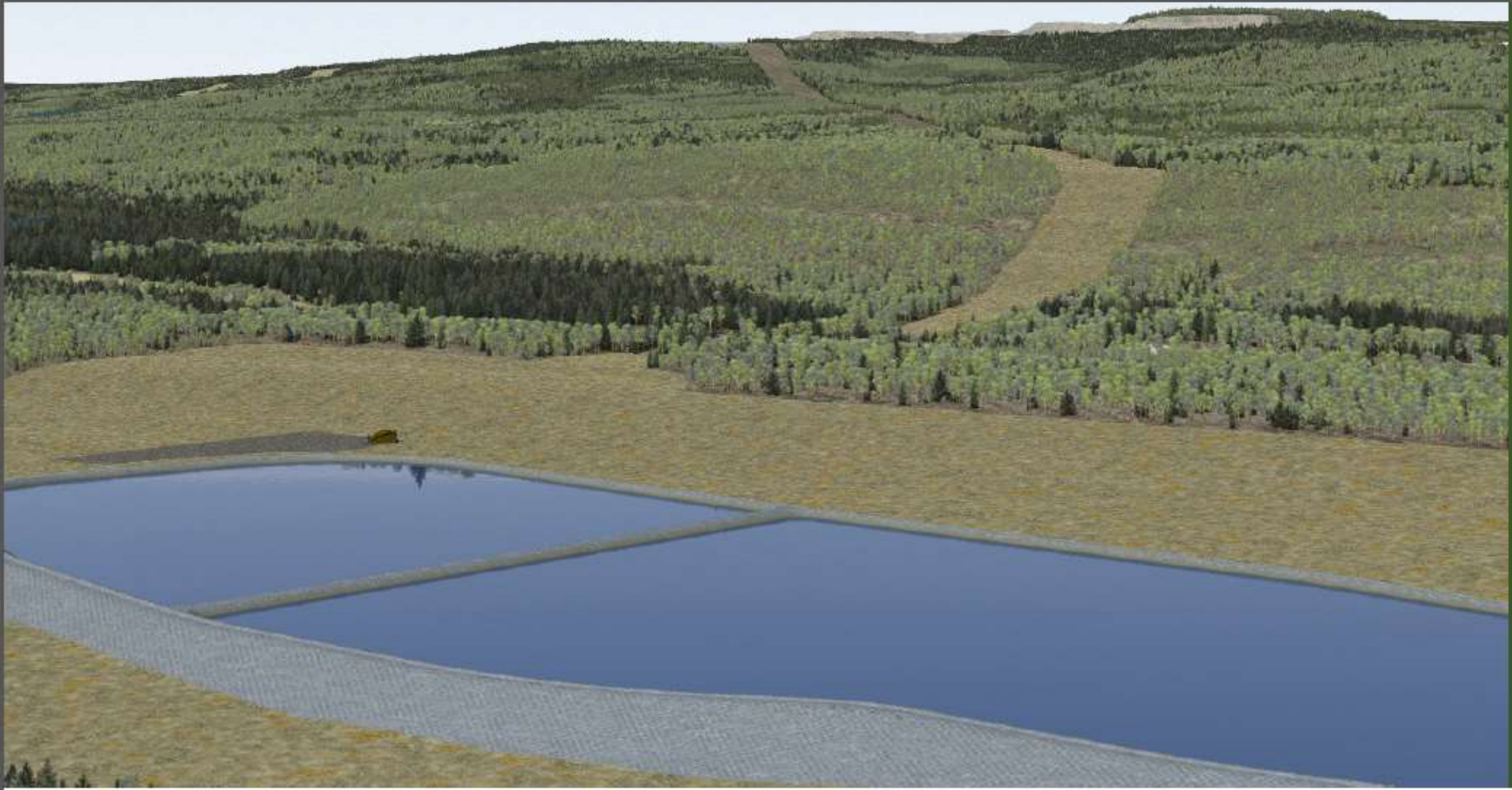

Visualization of Lower Reservoir together with penstock right-of-way.

Note the penstock right-of-way going uphill and to the left. Part of Obed mine can be seen on the very top of the horizon.


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Camera: LowerDam
Bearing: 77.0 - 1032.00m
Latitude: 53.50976 N
Longitude: 117.42321 W
Computer generated visualization of Lower Reservoir.

DESIGN

The project layout was designed to fit effectively within the existing topography. With 482m of nominal gross head the stored water represents a relatively high amount of energy and reservoir and penstock sizes are highly efficient.

With two purpose built reservoirs the entire project is completely off-stream. The closed loop system will be initially charged with water from the Athabasca River. A naturally well-balanced evapotranspiration rate at the project site results in very minor make-up water requirements.

Of particular value is the fact that the reservoirs can be built in a modular fashion to accommodate various operating strategies of storage up to 37hours (75MW).

Upper Reservoir:
Type: Earth-filled berm, liner

Area: up to 30ha
Maximum berm height: <15m

Lower Reservoir:
Type: Earth-filled berm, liner
Area: up to 41.7ha
Maximum berm height: <15m

Powerhouse:
3x 25 MW Pelton turbines,

Pump House:
4x 16MW Horizontal 2 stage HPDM type pump

Penstock:
Type: Shallow buried, steel pipe
Length: 7km
Diameter: 2 – 2.5m
Static head: 482m
Number of creek crossings: 1

Interconnection:
Voltage: 138kV
Distance to nearest transmission line: 3.7km

Discussion ?