Jennifer Anders
Chair
Montana

Bo Downen
Montana

Guy Norman
Washington

Patrick Oshie
Washington

Richard Devlin
Vice Chair
Oregon

Ted Ferrioli
Oregon

Jim Yost
Idaho

Jeffery C. Allen
Idaho

Northwest **Power** and **Conservation** Council

October 8, 2019

MEMORANDUM

TO: **Power Committee**

FROM: **John Ollis**

SUBJECT: Update on GENESYS Redevelopment Progress

BACKGROUND:

Presenter: John Ollis, John Fazio, Dan Hua

Summary: Staff will update the committee on the current state of the stakeholder process and feedback about the redeveloped model. After a brief review of the objectives of the redevelopment, staff will show results of the *second hydro-modeling benchmark*: to reproduce monthly storage and outflow results for all 80 hydro conditions from a study using the current GENESYS model. Staff will also walk through some of the model enhancements that allow staff to control the underlying risks that might create uncertainty about availability of regional imports from the wholesale power market and discuss other model improvements as time permits.

Relevance: The GENESYS model is a key tool that will be used to develop the Council's next power plan. It provides data required by other Council models to forecast electricity prices (AURORA) and to develop resource acquisition strategies (Regional Portfolio Model). GENESYS is also the tool used by the Council and the Resource Adequacy Advisory Committee to assess adequacy of the region's power supply and determine the region's energy and capacity needs. And, in conjunction with other models, it can also provide important information relating to the region's flexibility needs.

Workplan: Action Item ANLYS-21 (review analytical methods), ANLYS-22 (GENESYS model redevelopment) and ANLYS-23 (enhance the GENESYS model to improve the simulation of hourly hydroelectric system operations).

Background: The GENESYS model is one of the major quantitative tools used to develop the Council's regional power plan. GENESYS is primarily used to assess the adequacy of the power supply but it also provides hydroelectric system output to both the AURORA model and the Council's Regional Portfolio Model. In addition, GENESYS is used to validate that the power plan's resource strategy will produce adequate supplies. GENESYS has also become one of Bonneville Power Administration's major tools for assessing federal system adequacy and is being used by other regional entities. Because of the critical role that GENESYS plays in developing the Council's power plan, the model was evaluated and enhanced to improve forecasting reliability as well as to improve its data management capabilities and to make it less cumbersome to use.

More Info: Council website page describing GENESYS and redevelopment process information
https://www.nwcouncil.org/energy/energy-advisory-committees/system-analysis-advisory-committee/genesys-%E2%80%93-generation-evaluation-system-model

Update on the Redeveloped GENESYS

Daniel Hua, John Fazio, John Ollis, Gwen Shearer

10/15/2019

Power Committee
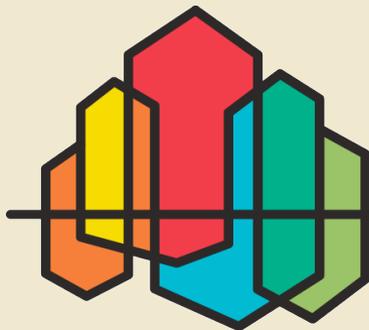
THE 2021
NORTHWEST
POWER PLAN

FOR A SECURE & AFFORDABLE
ENERGY FUTURE

Today's Update

1. Discussion of stakeholder process, timeline and project goals

2. Review simulation stages in redeveloped model

3. Update on validation of weekly model

4. Review of market implementation and operational timeframes enhancement

5. Next steps

THE 2021
NORTHWEST
POWER PLAN

Review Upcoming and Recent Stakeholder Involvement Schedule

August 2019
Present preliminary redeveloped GENESYS results with classic GENESYS results to provide context to adequacy discussion

September 2019
Meet with Bonneville Modeling and Operations SMEs to discuss input data gaps and present preliminary results

November 2019
Meet with broader stakeholder group to discuss modeling issues and show preliminary results

November/December 2019
Meet with SAAC/RAAC to update on progress and discuss preliminary results

December 2019
Begin using redeveloped GENESYS for plan work

THE 2021
NORTHWEST
POWER PLAN

Review: Goals of Redevelopment

1) Serve Needs of Multiple Users and Uses

- Currently used by the Council, BPA and other regional stakeholders.

- Used for annual regional adequacy assessments, regulated hydro flow studies, and analysis of change in revenue due to differing hydro operations.

- Maintain all necessary current functionality.

- Answer new questions that previous model could not answer.
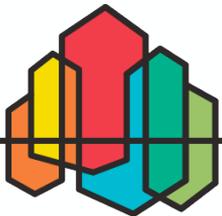
Review: Goals of Redevelopment

2) Improve Model Accuracy

- Co-optimize energy and reserve requirements by cost.

- Better reflect forecast error and market economic effects on regional portfolio dispatch.

- Incorporate future value of resources with storage into scheduling.

- Incorporate emergency resources into dispatch.

- Move from aggregate hydro to plant specific hourly dispatch.
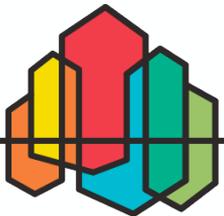
Review: Goals of Redevelopment

3) Improve Model Usability

- Currently, model inputs, execution and output processing all are via FORTRAN.

- Potentially keep FORTRAN for execution of code and structure, but incorporate an easier input and output processing interface.

THE 2021
NORTHWEST
POWER PLAN
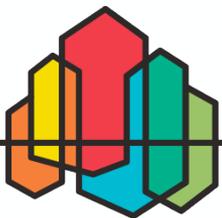
What Does the Redeveloped Model Do Already?

Maintaining current functionality…

- Performs hourly simulation of regional hydro and thermal resource generation under varying stochastic inputs:
    1. Temperature variation (load)
    2. Wind generation
    3. Water supply
    4. Thermal forced outages.
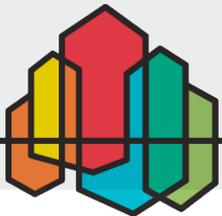
egion with imports

Jun 19, 2021 09:00PM

Balancing area demand	2.310e+4	MW
COI and PDCI Exports	−662.925	MW
PAC East Exports – excludes regional generation	−775.000	MW
Hydro Gen	1.269e+4	MW
Thermal Gen	1200.441	MW
Renewable generation	7519.993	MW

Reset zoom
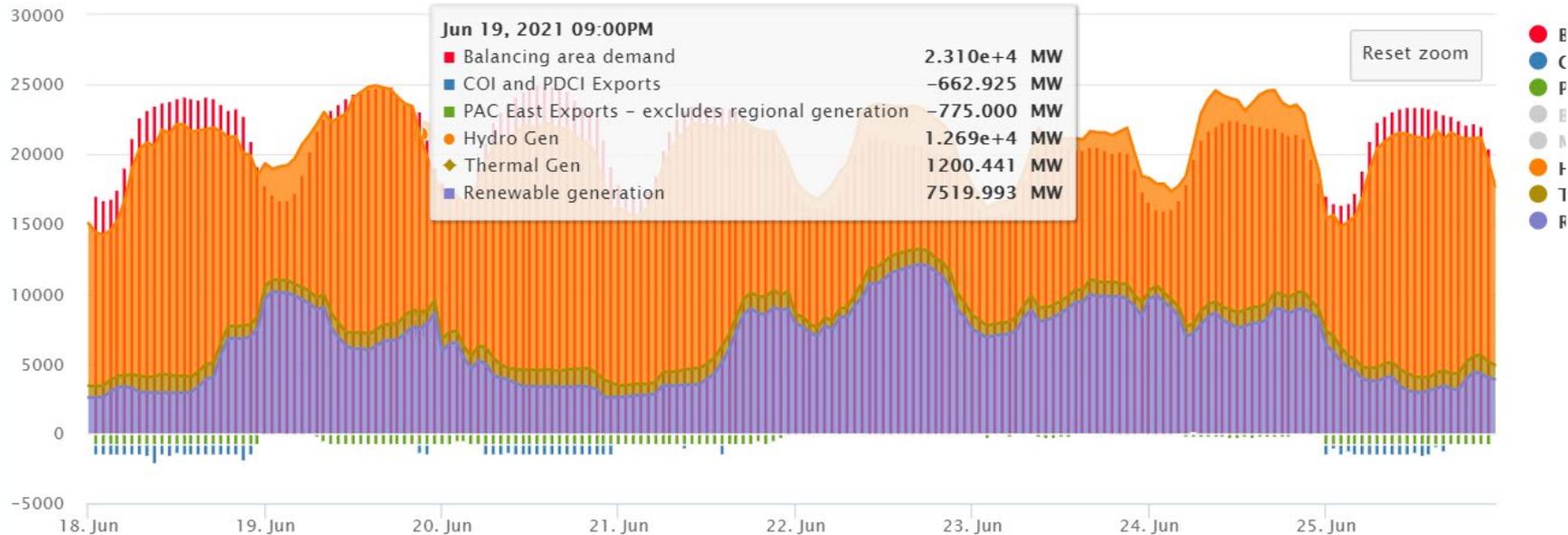
What Does the Redeveloped Model Do Already?

Enhancements from classic GENESYS...

1. Model Usability:
   a. Modern model interface
   b. Easy data input/output transfer via Excel
   c. Internal graphing capability
   d. More automated and faster parallel processing via cloud computing
   e. More capability to output, access and control data via cloud storage
   f. Multiple users able to work on different studies simultaneously and can easily validate study setup differences
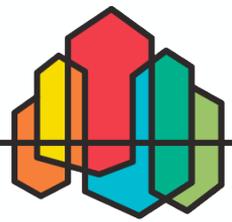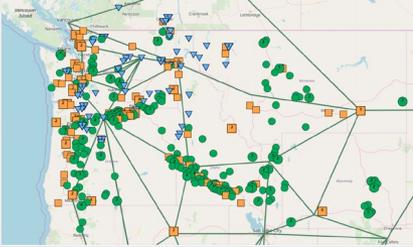
What Does the Redeveloped Model Do Already?

Enhancements from classic GENESYS...

2. Model capability highlights:
   a. More detailed transmission system model between all balancing authorities including seasonal transmission transfer limits.
   b. Models all hydro, wind, solar, and batteries individually,
   c. Co-optimizes energy and reserves
   d. External market supply/demand curve
   e. Represents forecast error using difference commitment timeframes and uncertainty in load/renewable forecast
   f. Incorporates future valuation of resources in dispatch logic
   g. Fuel accounting for gas and hydropower in deployment stage
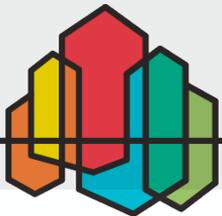
What is left to achieve project goals?

Mostly, just vetting hydro constraints and operations.

- Continue to vet and communicate validated weekly constraints to stakeholders

- Continue to incorporate and validate hourly constraints on the river system.

- Continue to vet hourly river operations with BPA and other stakeholders to ensure reasonable river operation.
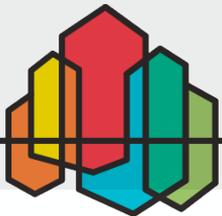
How Does Redeveloped GENESYS Simulate Hourly Operation?

Weekly Forecast

Da... Co...

October

Commit ... Wednesday ... Sunday.

Co... Plan for ... through 23 of next day

Account for energy, reserves, forced outage mitigation, and for fuel usage in Hour 24.

This hourly operational detail is great, but if the monthly and weekly balances are inconsistent with river operations, who cares.

Cost Optimization

Accounting

THE 2021
NORTHWEST
POWER PLAN
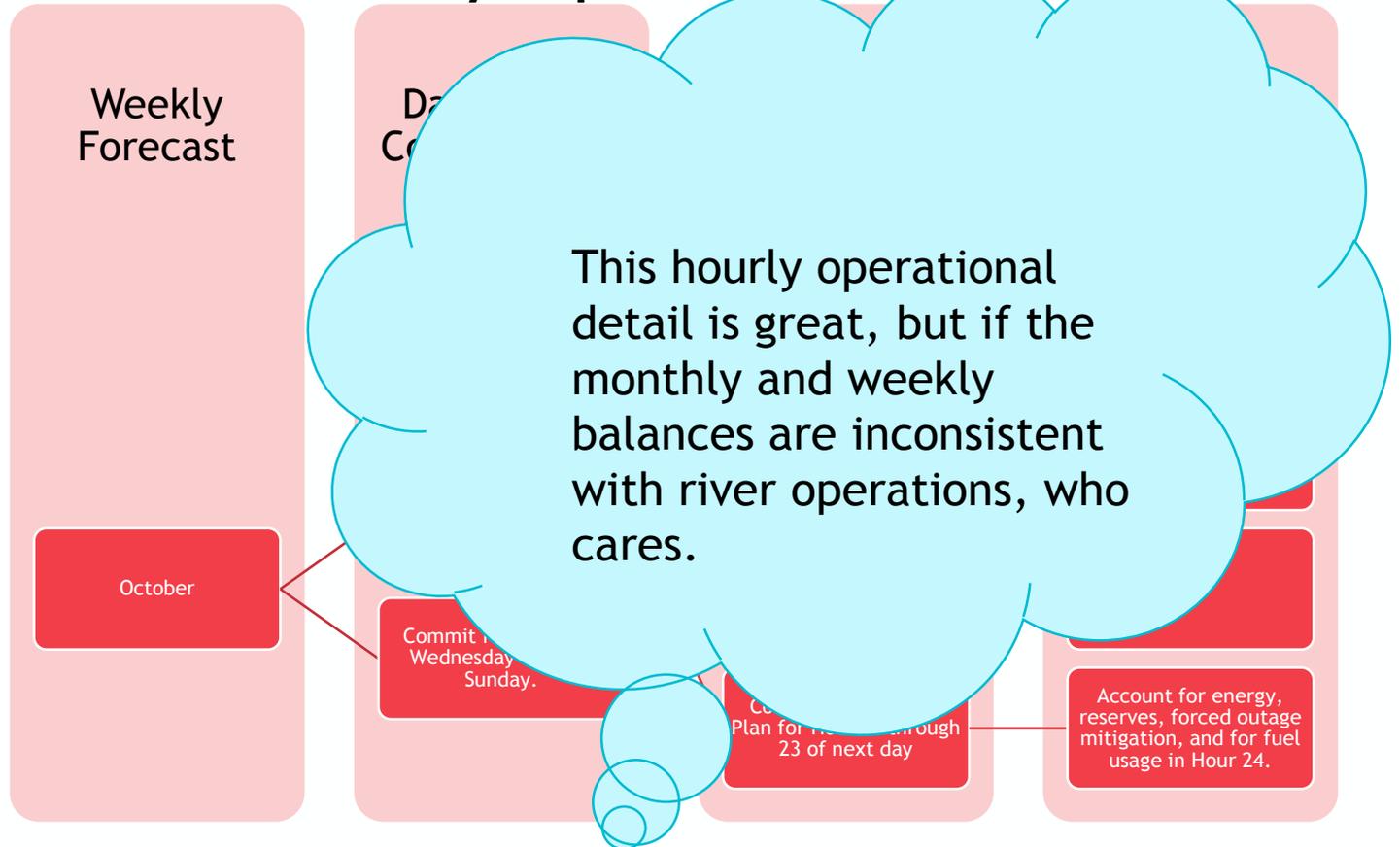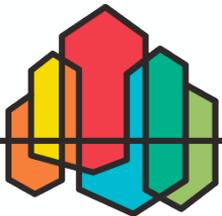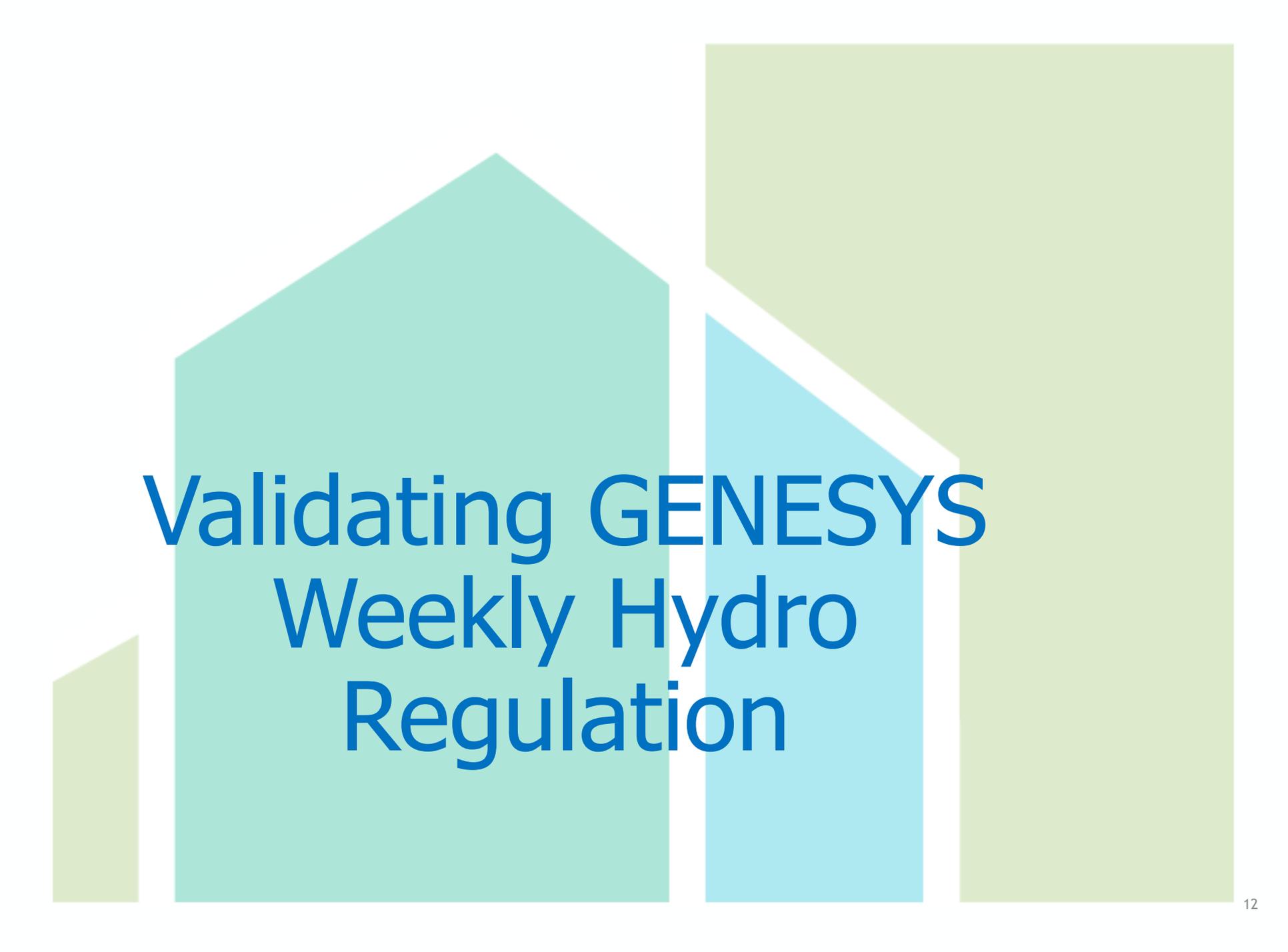
Validating GENESYS Weekly Hydro Regulation

Validating GENESYS Weekly Hydro-Regulation

- Verify that GENESYS could produce realistic *weekly* hydro-regulation: (e.g. storage, outflow and generation at all hydro-projects)

- The HYDSIM model produces *monthly* (*or 14-period*) hydro-regulation that is well understood and satisfies many monthly constraints of varying priorities on storage, outflows, spills, etc.

- <u>For validation</u>: compare GENESYS *weekly* hydro-regulation with HYDSIM *monthly* hydro-regulation. Specifically,

  - ➢ Storage: *run GENESYS storage to match HYDSIM storage*
  - ➢ Outflow: *verify GENESYS water balance is correct*
  - ➢ Generation: *verify with turbine generation input data and turbine flow*
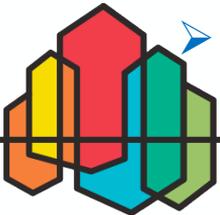
Validation Studies and Data

- HYDSIM is a part of the *classic GENESYS* used in annual Resource Adequacy Assessments

- Use HYDSIM hydro-regulation from the 2022 Resource Adequacy Studies

  - 80 historical hydro conditions (Water Years: 1929 - 2008)
  - Run *80 games for all the historical* water-years

- Data input in GENESYS:

    - HYDSIM plant data from the 2022 Resource Adequacy Studies
    - Daily modified flows for 80 Water Years

THE 2021 NORTHWEST POWER PLAN
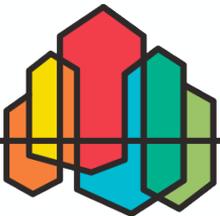
Sample Columbia River Basin Projects

- *Many GENESYS hydro-projects, including the major reservoirs are shown in map*

- *GENESYS model operations of the same 76 HDYSIM hydro-projects in our region (38 reservoirs and 38 run-of-river)*

THE 2021
NORTHWEST
POWER PLAN
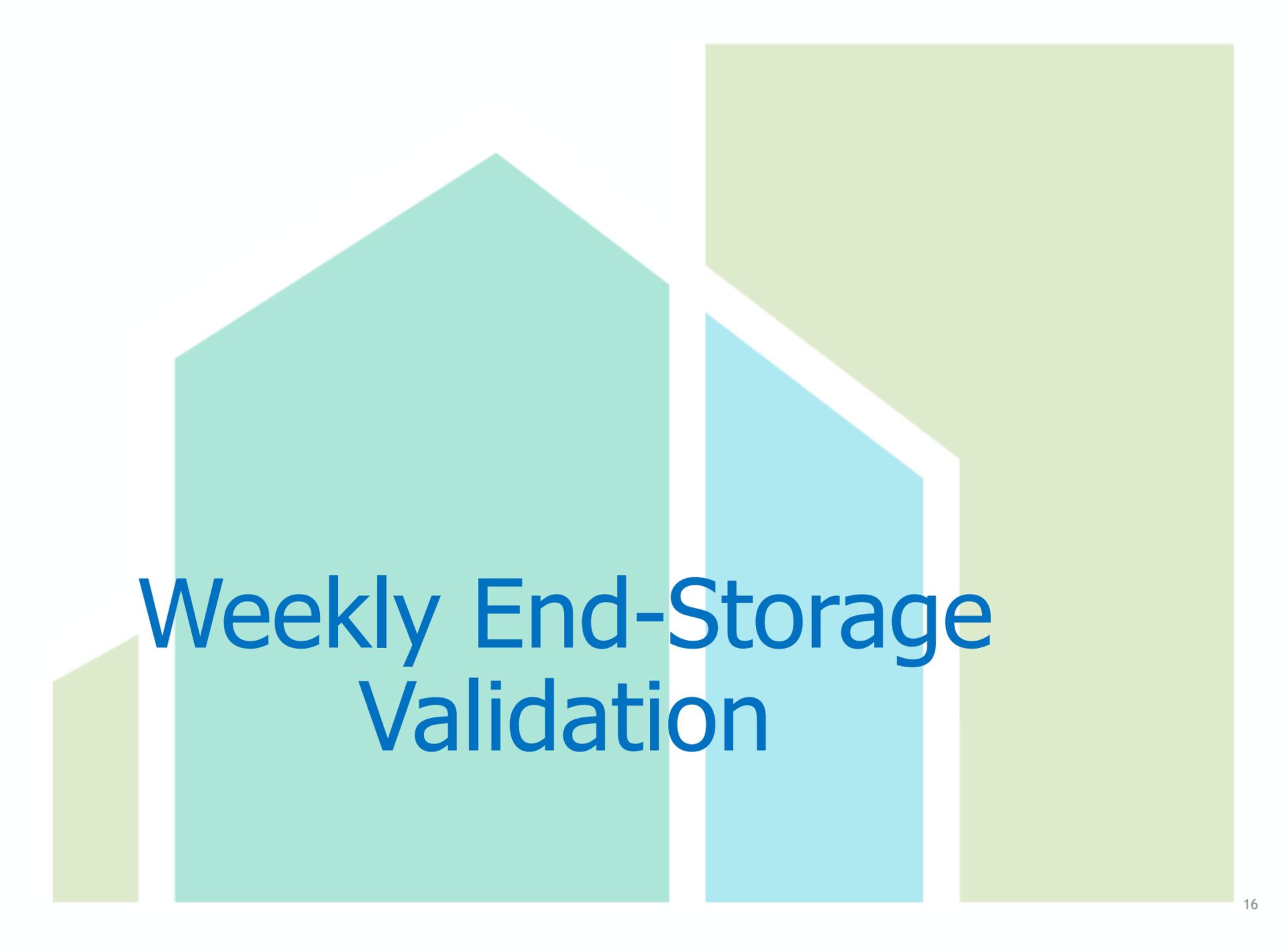
Weekly End-Storage Validation

Validating GENESYS HYDRO-Regulation
Part I – Storage

- From the 80-game HYDSIM hydro-regulation, *interpolate its end-of-month storage* to *end-of-week storage* and used as target storage for GENESYS for the 38 reservoirs

- For the time being, do not impose any other constraint in GENESYS to enable the model to regulate projects to these end-of-week target storages

- Verify that GENESYS could operate the reservoirs to these weekly target storages, and therefore close to the monthly HYDSIM storages

THE 2021
NORTHWEST
POWER PLAN

Mismatch between Weekly and Monthly Time-steps

1929 Coulee HYDSIM Monthly End Storages

GCL WY 1929 HYDSIM 14-Period End Storages

$ksfd$ = [(thousand cubic foot)/sec] x day
≈ 2 KAF

1929 Coulee HYDSIM and Target End Storages

GCL WY 1929 End Storages

GENESYS weekly target storages: interpolated* between HYDSIM period end storages

Legend: ▲ HYD   □ GEN_tar_stor
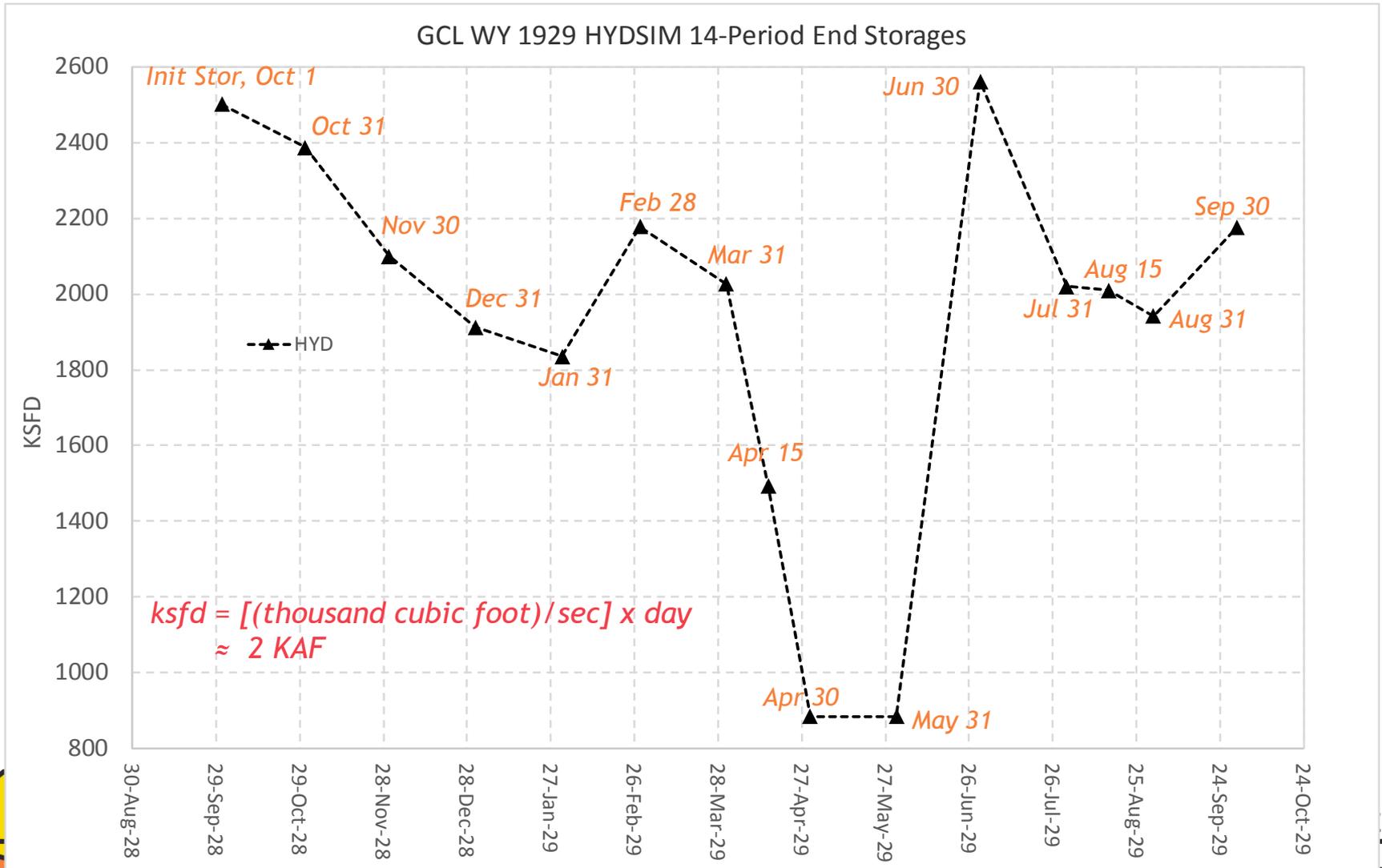
1929 Coulee HYDSIM, Target & Final End Storages

GCL WY 1929 End Storages

GENESYS weekly final storages:
good agreement to weekly target storages

Legend: ▲ HYD   ◇ GEN_end_stor   □ GEN_tar_stor

POWER PLAN
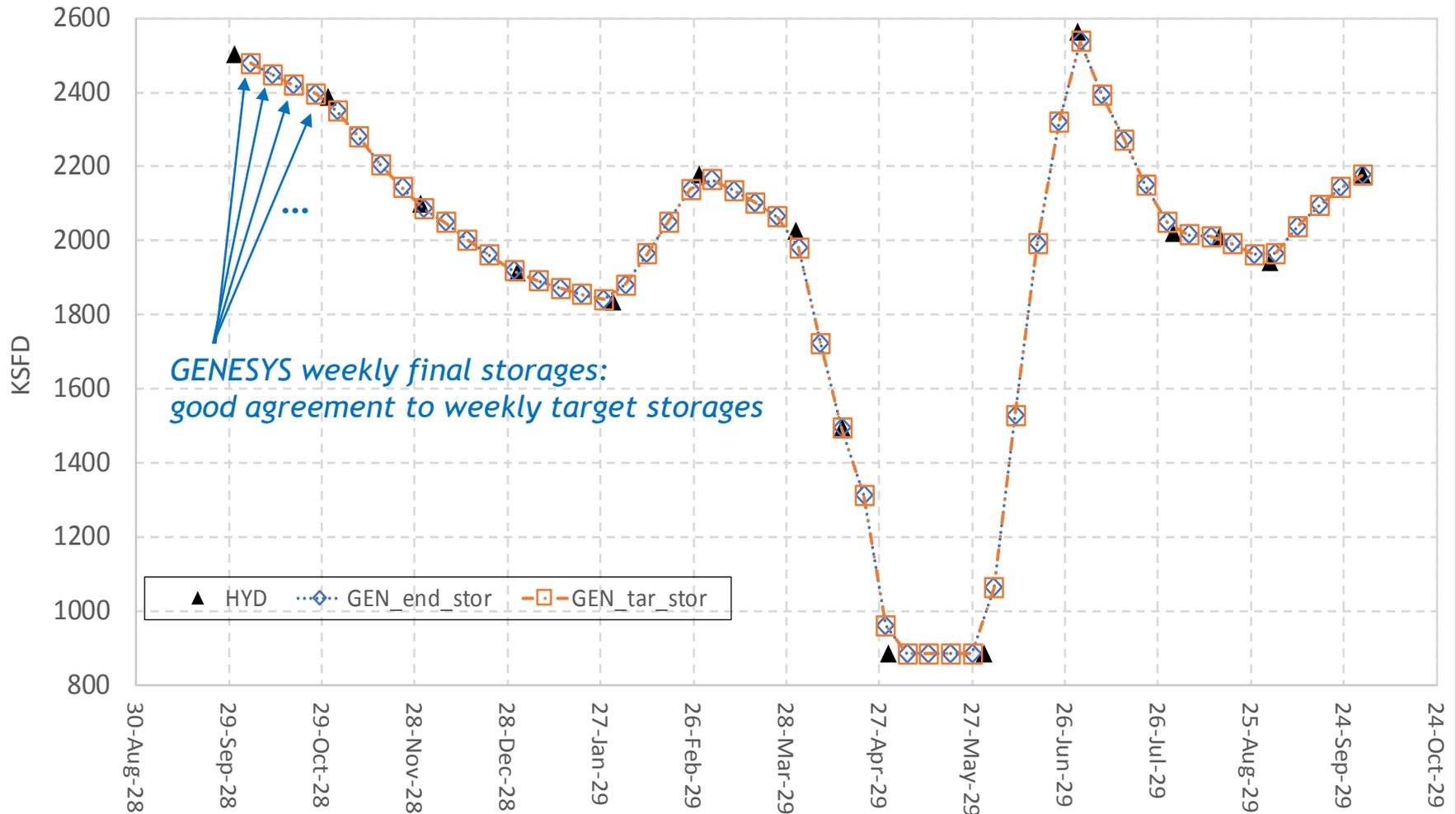
GENESYS and HYDSIM End Storages

- Results: For the 80 water-years, GENESYS could regulate the 38 reservoirs to the weekly end storages *from appropriate interpolation of HYDSIM monthly end storages*

- Due to weekly and monthly time step mismatch, GENESYS weekly end storages are close to, but not exactly the same as HYDSIM monthly end storages at monthly dates *(except at Apr 15 and Sep 30)*
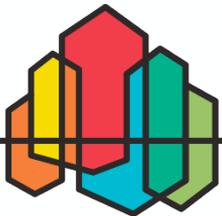
THE 2021
NORTHWEST
POWER PLAN

Weekly Water Balance Validation

Validating GENESYS HYDRO-Regulation
Part II – Outflow

- Since GENESYS could regulate reservoirs to match the target storages *(from interpolating HYDSIM monthly storages) then*

- verify that GENESYS weekly water balance is correct at all hydro-projects
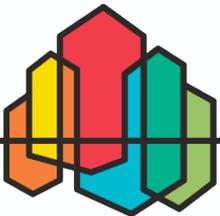
Mismatch between Weekly and Monthly Time-steps

HYDSIM monthly average flow

January 2017 (with q_{jan})

GENESYS weekly average flow

January 2017 (q_1, q_2, q_3, q_4, q_5)

February 2017 (q_5)

❖ *GENESYS Jan average flow (weighted by Jan days) will not exactly match HYDSIM Jan average flow*

25
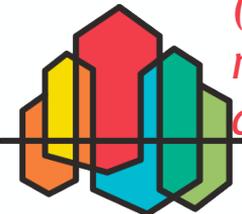
GENESYS and HYDSIM Outflows

- Due to weekly and monthly time-step mismatch,

  - ➢ GENESYS end-of-week storages do not exactly match HYDSIM end-of-month storages at the monthly dates *(except at 4/15 and 9/30)*, leading to different outflow from changes in storage

  - ➢ Also, calculated GENESYS monthly averaged flows will not exactly match HYDSIM monthly average flows

- To validate outflow at hydro-projects, verify GENESYS weekly water balance, *(instead of trying to match HYDSIM monthly average outflow)*

GENESYS Weekly Water-Balance

| Upstream project | Upstream project | ... |

q_u : upstream outflows

q_i : incremental flow

(for headwater projects: q_u = 0)

project

S_i : initial weekly storage

S_f : final weekly storage

q : outflow

$$q = q_u + q_i + \frac{S_i - S_f}{7}$$

THE 2021
NORTHWEST
POWER PLAN
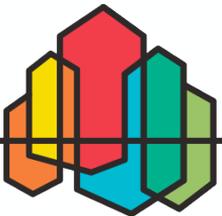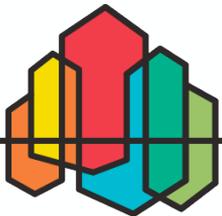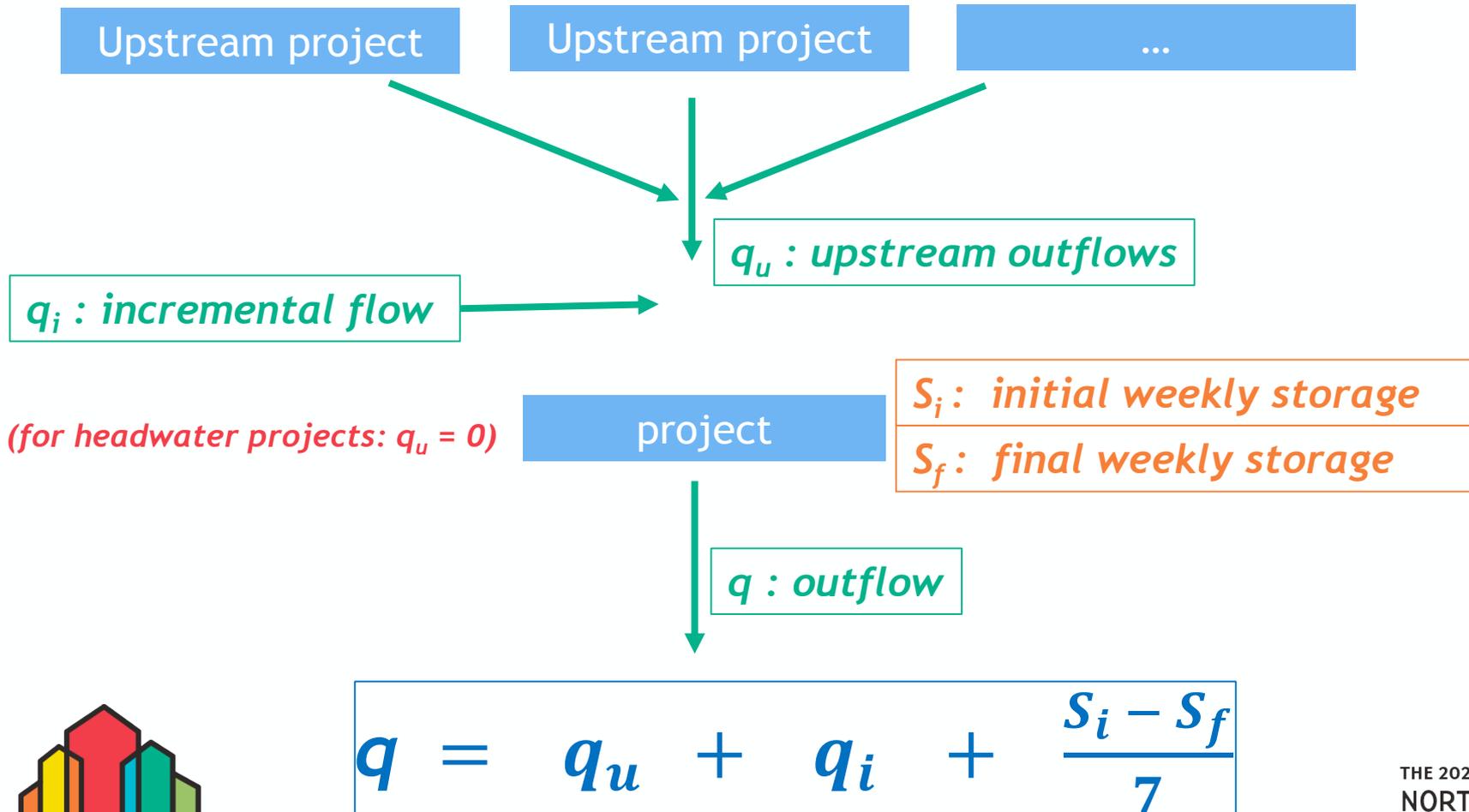
Verify GENESYS Weekly Water Balance

- <u>Results:</u> For the 80 water-years, GENESYS hydro-regulation has correct weekly water balance for all 38 reservoirs and 38 run-of-river projects

THE 2021
NORTHWEST
POWER PLAN
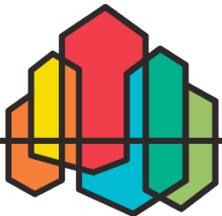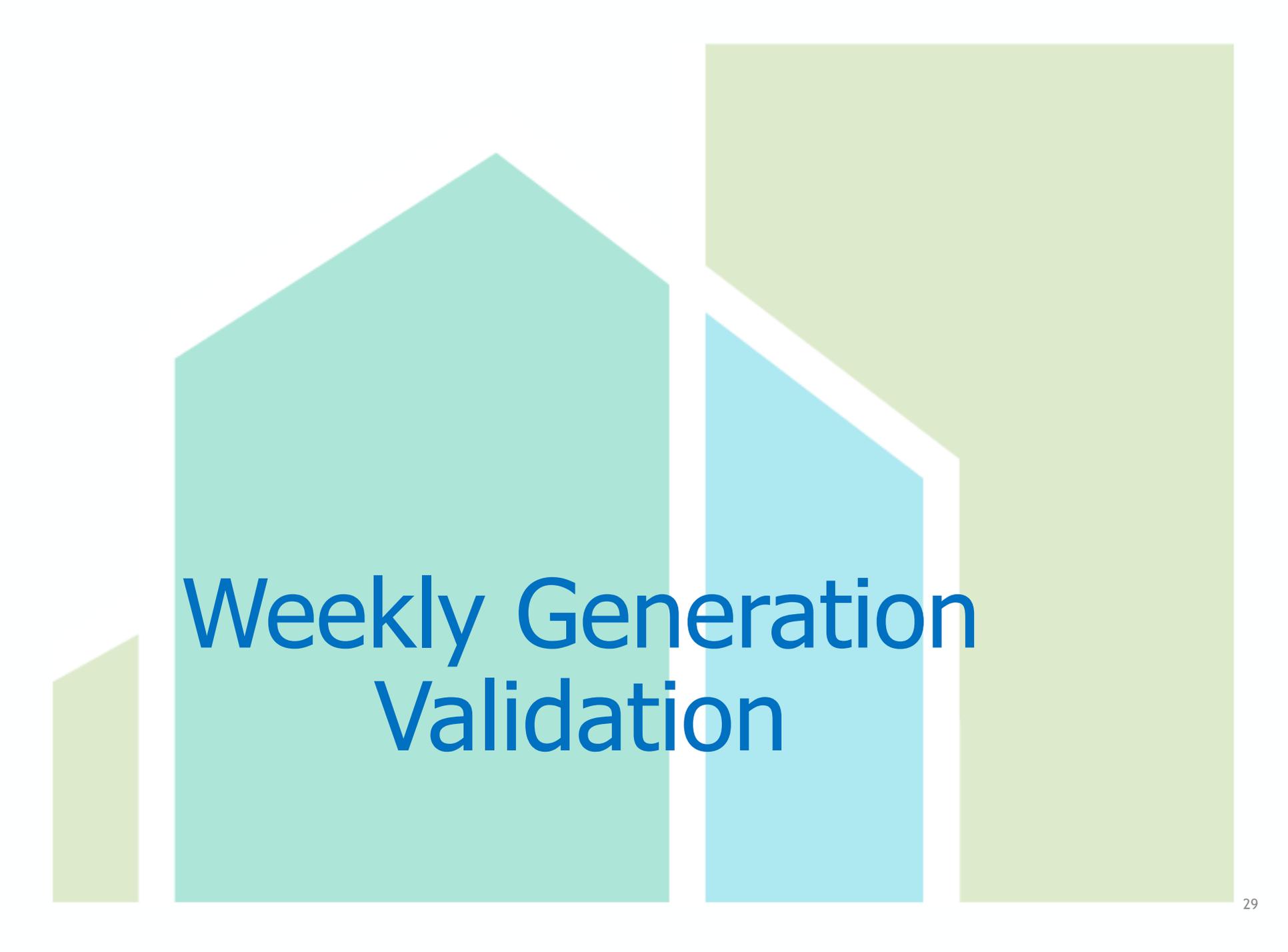
Weekly Generation Validation

Validating GENESYS HYDRO-Regulation
Part III – Generation

- Since the weekly end-storages and water balances are validated for hydro-projects, then

- the next step is to verify that each project's generation is calculated from the turbine generation input data (H/K) and turbine flows

THE 2021
NORTHWEST
POWER PLAN
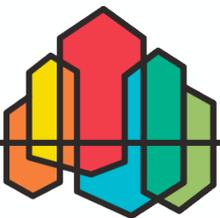
GENESYS Weekly Generation

- To be verified: hydro-project weekly generation =

    (H/K) [MW/kcfs] * turbine flow [kcfs]

THE 2021
NORTHWEST
POWER PLAN
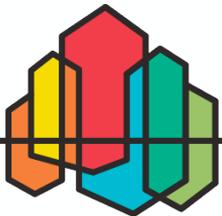
Improving Analysis of Market Operations

- Change Window, Daily and Hourly simulation stages to Week-Ahead, Day-Ahead and Hour-Ahead Unit Commitment stages that optimize on cost based on the best forecasts of renewable generation and load.

  This brings in the reality of forecast error in market decision making and sets up deployment of reserves

- Add in a deployment stage where plants are forced out, actual generation and load simulated, and accounting of fuel (hydro, gas) completed

  This simulates fuel constraints on the hydro and gas generation that limit system response to forecast error after market timeframes.
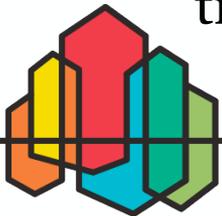
Day-Ahead Unit Commitment

- Optimize regional portfolio operation hourly over 7 day rolling window.

- Commit CCCT, coal and nuclear for day 1 and plan for resource production for following 6 days.

- Plan for the generation and provision of reserves among all other units and conduct day-ahead market purchases/sales

- Use day-ahead forecasts for load, wind, solar
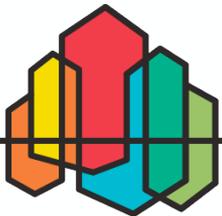
Hour-Ahead Unit Commitment

- Optimize regional portfolio operation over 3 hour rolling window.

- Commit SCCT for hour 1 and plan for unit production for following 3 hours.

- Plan for the generation and provision of reserves among all other units and conduct hour-ahead market purchases/sales

- Use hour-ahead forecasts for load, wind, solar
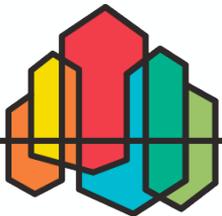
Deployment (True-Up) Stage

- Dispatch plants based on schedule and simulate actual reserve provision.

- Simulate forced outages and portfolio response.

- Simulated load, wind, and solar without forecast error.

- Account for fuel usage of all resources.
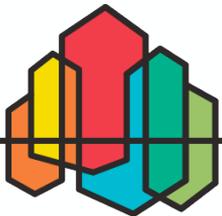
THE 2021
NORTHWEST
POWER PLAN

How Does Redeveloped GENESYS Simulate Hourly Operation?

Period Forecast

Day Com...

October...

Commit... Plan f... throu...

Commit for Hour ? for Hours 2 through Hour 1 of next

Commit for Tuesday, Wednesday through Sunday.

...our 24, Plan for ...ugh 23 of next ...day

Account for energy, ...s, forced ...itigation,

Account for energy, reserves, forced outage mitigation, and for fuel usage in ...

...r energy, ...ced outage ...nd for fuel ...Hour 24.
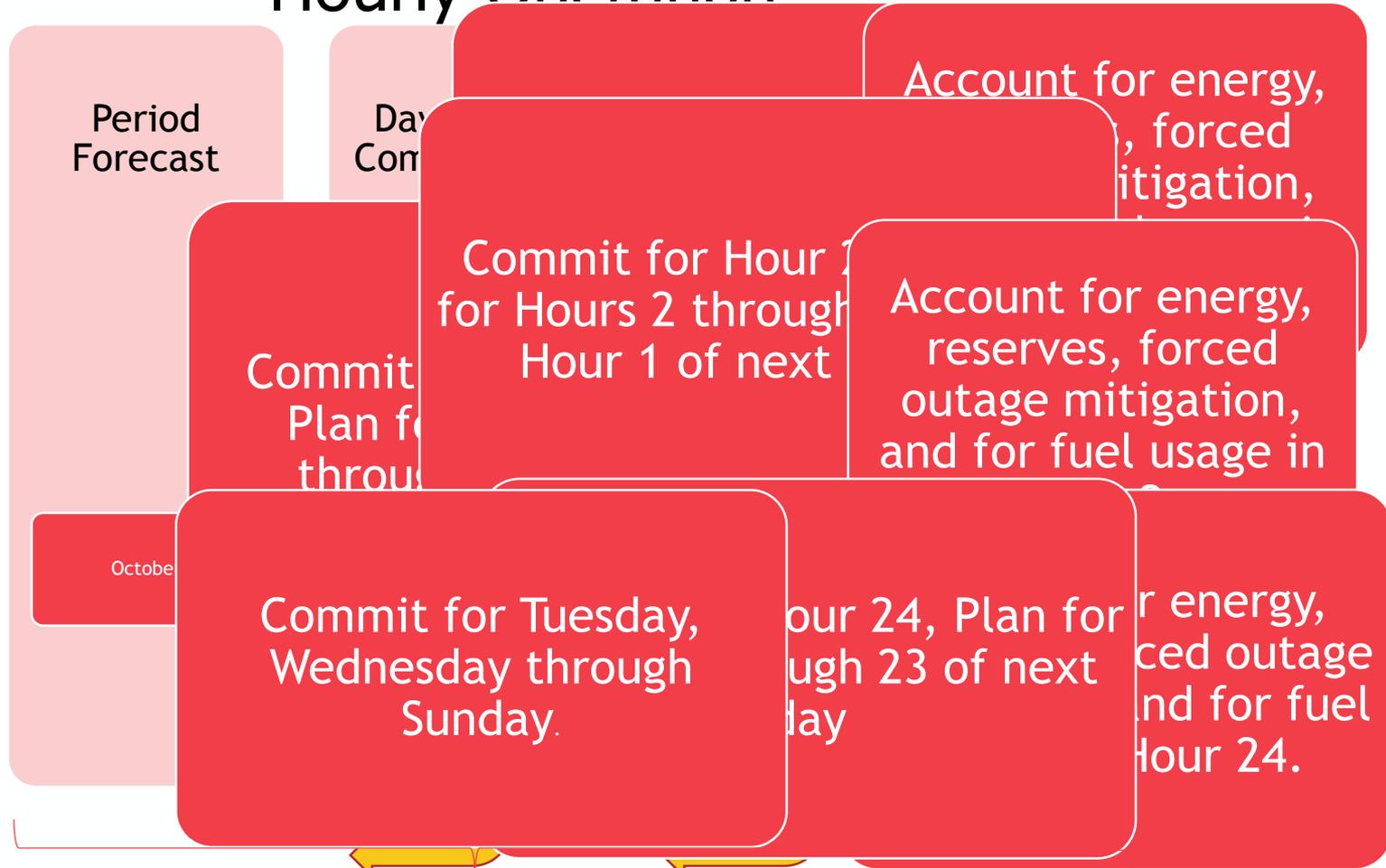
Cost Optimization

Accounting
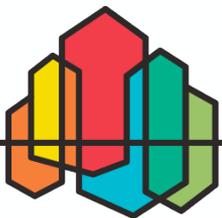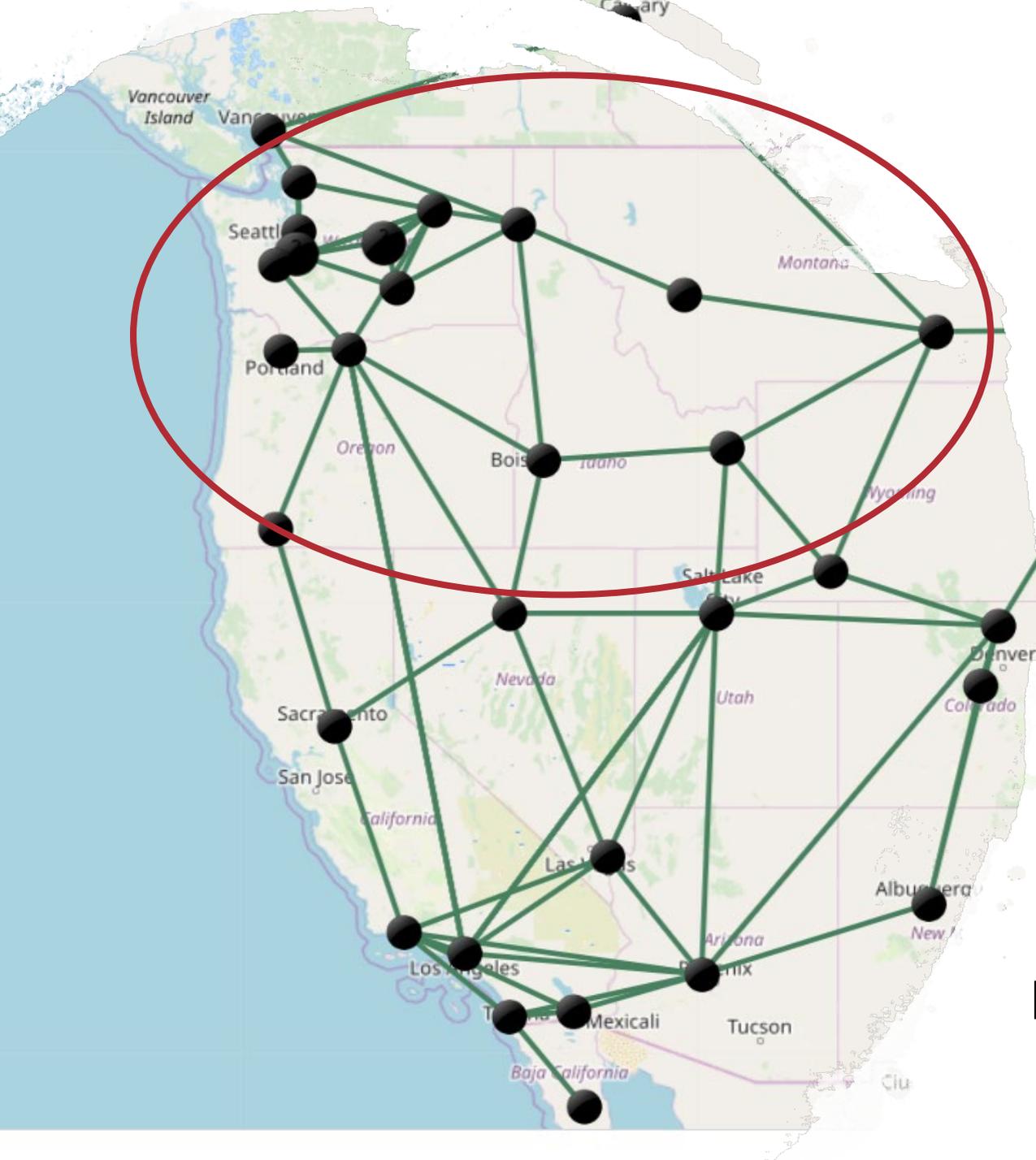
- More detailed transmission topology

- Each "bubble" represents a balancing authority, multiple balancing authorities or part of a balancing authority depending on transmission constraints.

- Hourly loads for each bubble.

- Resources in each bubble represented by bins of the amount of market resource available at a price (hourly) OR as a individually modeled resource.

- Currently, most of the resources in the region are represented as individual resources and most external to the region are represented as bins of market resource.

Expanded External Market Modeling Capability

What can we do with this functionality?

We can use market fundamentals to assess risks that we want to avoid as a region when considering adequacy.

- For example, say we are worried about the adequacy of the region when the California power system is stressed (let's call this *CA Bad Year* scenario for reference).

  1. Simulate a drought year in CA

     Less hydro generation in northern California to the tune approx. 1.2 GW in the winter and 2 GW in the summer.

     AND

  2. Simulate a gas freeze off scenario in the Permian and San Juan basins limiting supply of desert SW gas generation.

     15% of gas generation in AZ and NM offline all winter, since we do not know when the event will happen.
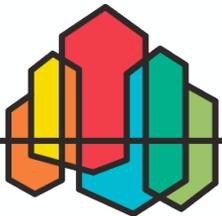
Limiting Market via Fundamentals

- If the regional adequacy looks similar after the *CA Bad Year* scenario, the region's portfolio would seem to be well set up to absorb that market risk.

- On the other hand, if there are certain hours within a day within a season that create issues, then the region is susceptible to that market stressor, and perhaps should not rely so much on the market during that time.

  - Thus, giving stakeholders in the region more granular information about the regional need, and understand which actions would best avoid that market risk.

  - Since significantly more renewable resources will be getting added throughout the WECC, understanding of timing and risk of market exposure will likely require more nuance.
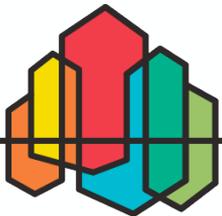
A Few Market Examples in GENESYS

- Daily shape of imports from CA in a bad NW hydro year.

- Daily shape after changes in fundamental assumptions
  1. Base
  2. CA drought year and gas freeze off in Desert Southwest
  3. Retire 8000 MW of out of the money CA gas plants

- Seasonality, daily shape and market dynamics of neighboring regions.

THE 2021
NORTHWEST
POWER PLAN
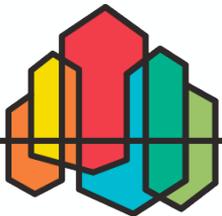
Winter Net Exports to CA in a Bad Hydro Year

Summer Net Exports to CA in a Bad Hydro Year

Importing more during middle of the day when CA is surplus and backing off in evening hours.

NORTHWEST
POWER PLAN
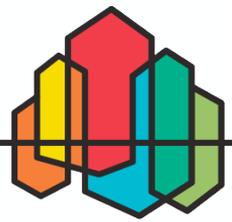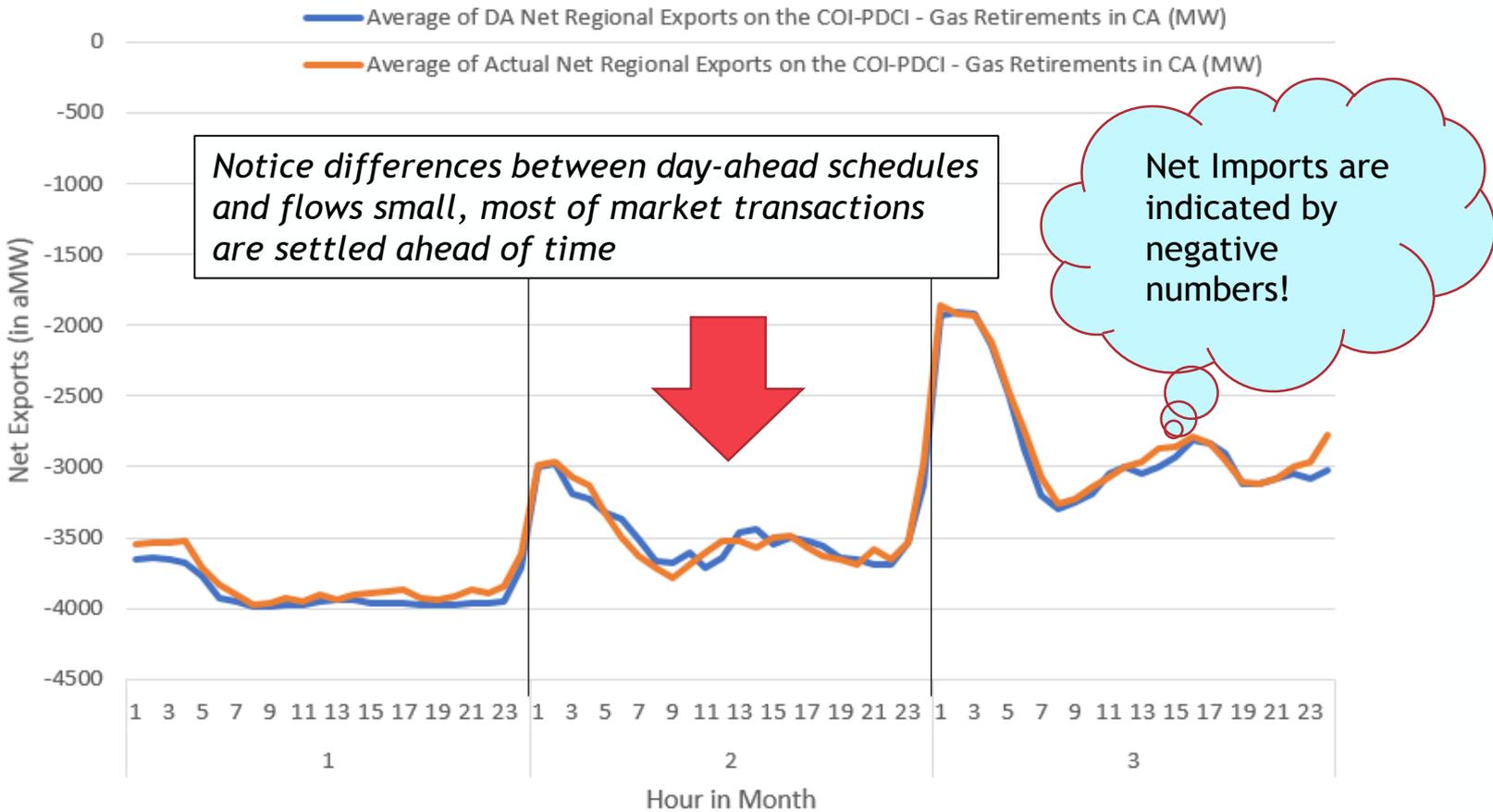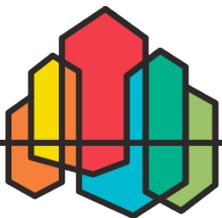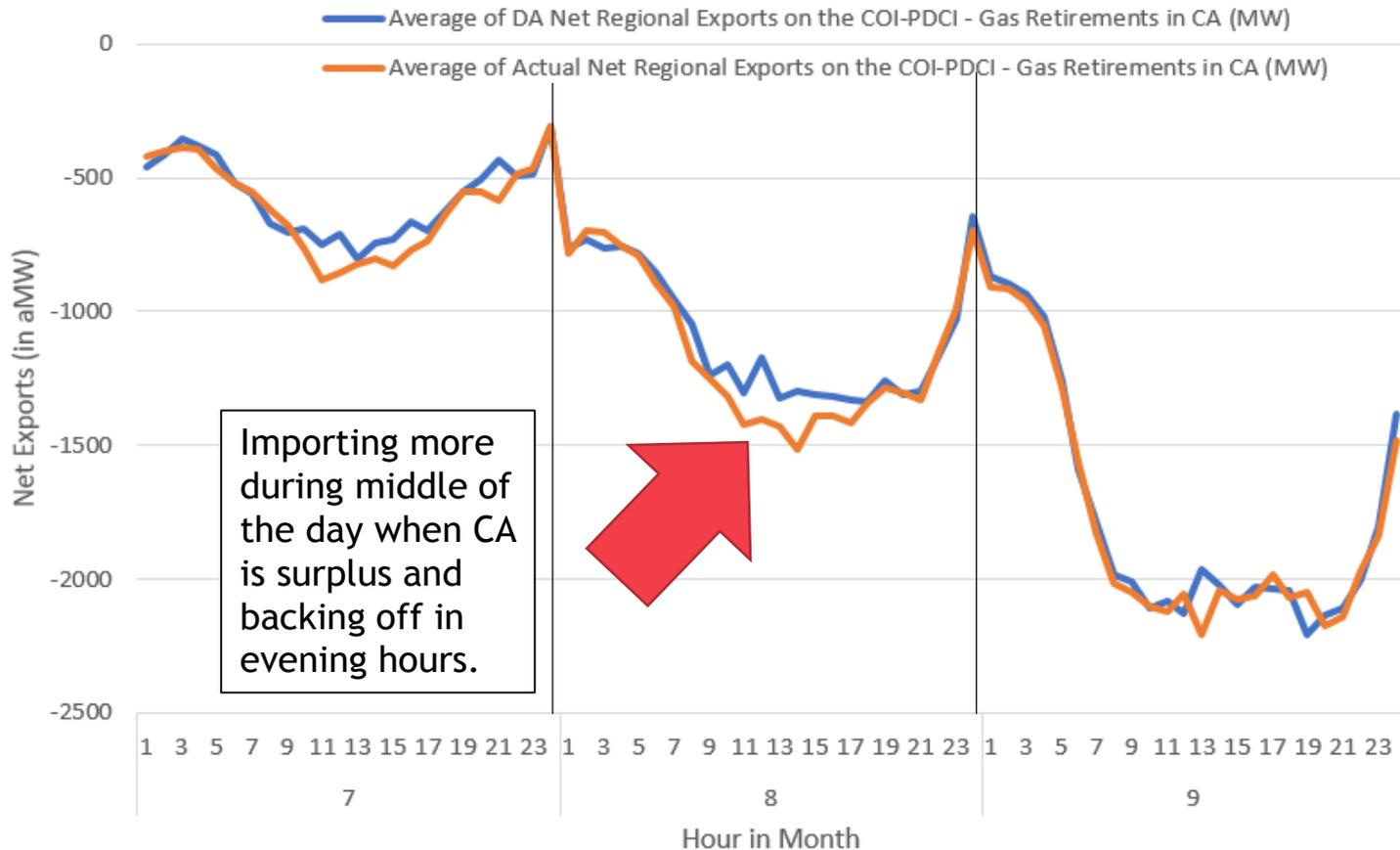
# Market Scenarios in the Winter – Fundamentals Based Stressors
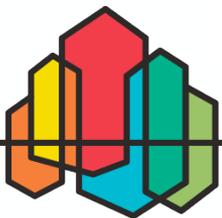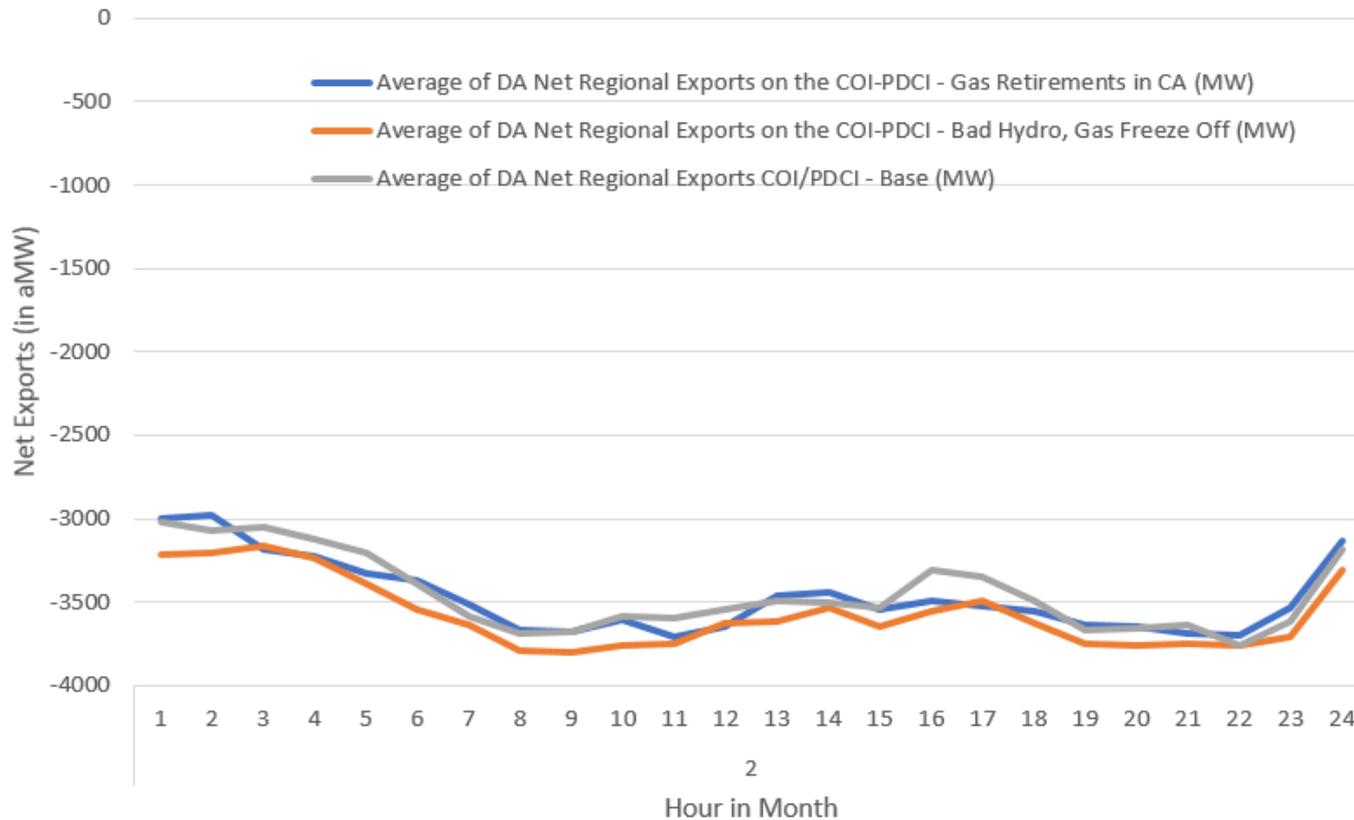
Market Scenarios in the Summer – Fundamentals Based Stressors
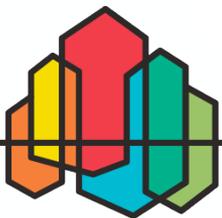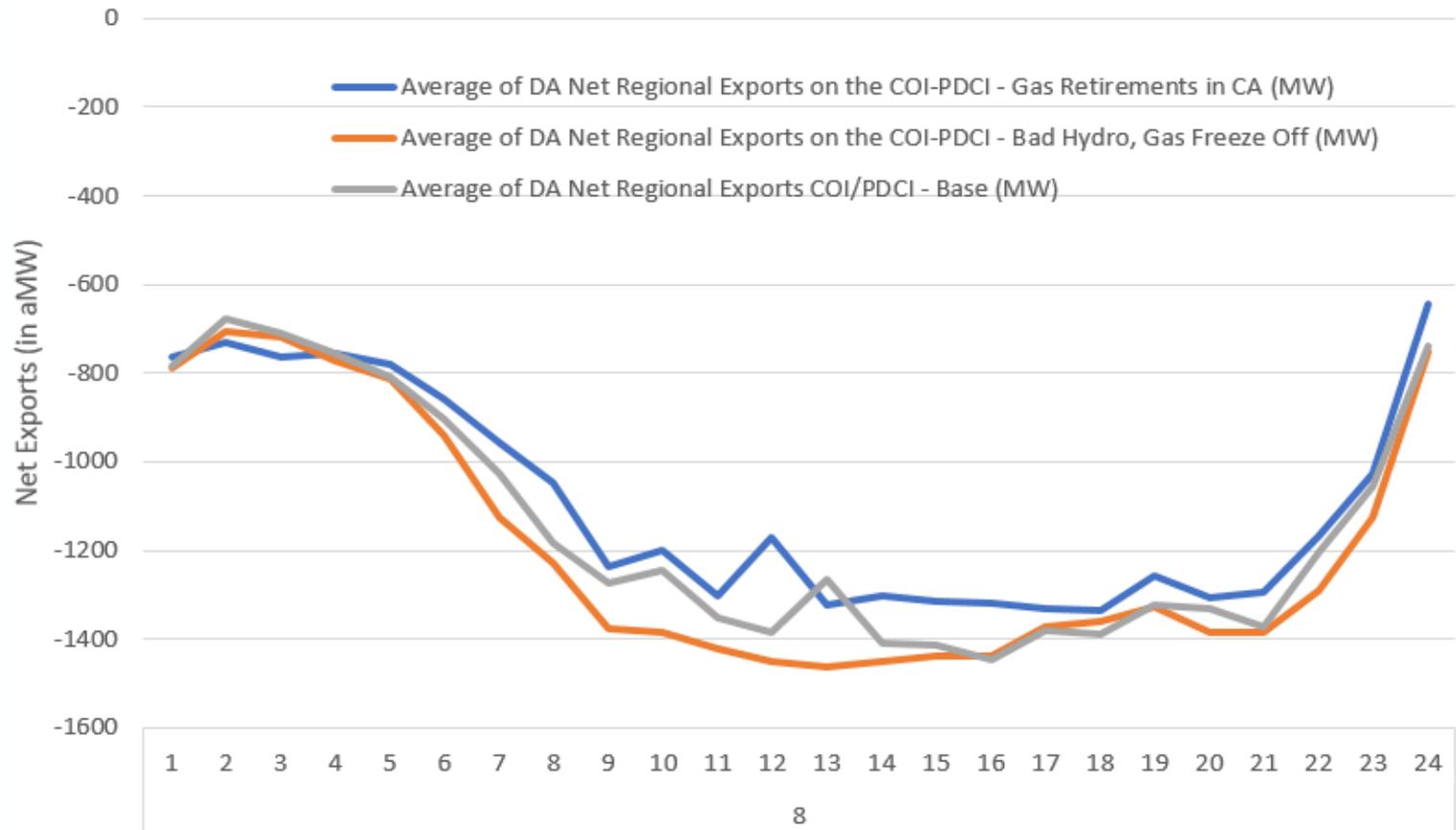
Regional Net Exports – Non-Summer Good Hydro, High Summer Load

1997 Hydro Regional Net Exports/Imports - Fall/Spring/Winter
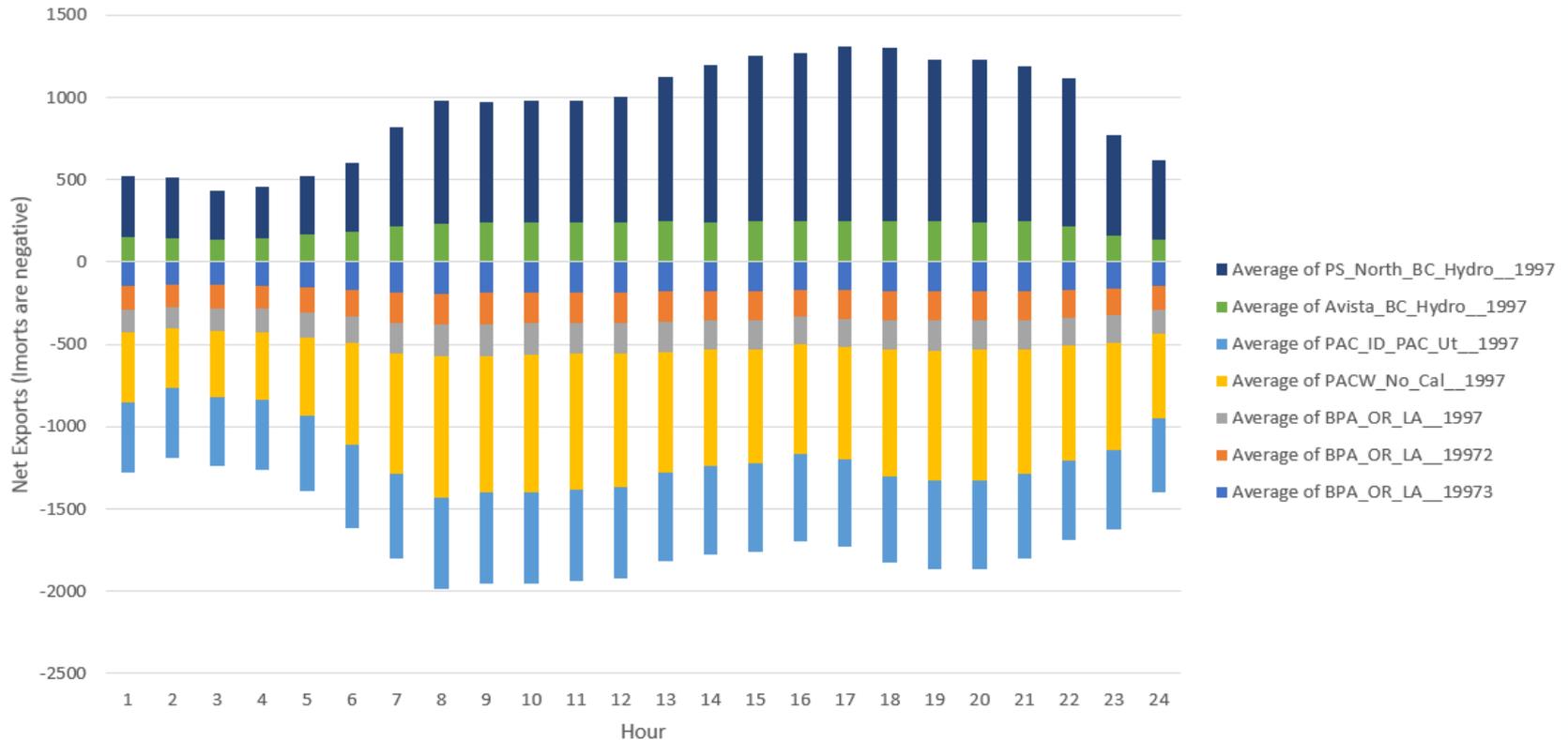
Much of the imports from Southwest and Mountain West heading north to BC

THE 2021
NORTHWEST
POWER PLAN
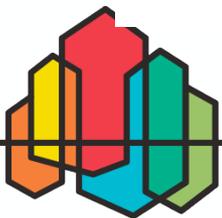
Regional Net Exports – Non-Summer Bad Hydro, High Summer Load

2001 Hydro Regional Net Exports/Imports - Fall/Spring/Summer

Legend:
- Average of PS_North_BC_Hydro__2001
- Average of Avista_BC_Hydro__2001
- Average of PAC_ID_PAC_Ut__2001
- Average of PACW_No_Cal__2001
- Average of BPA_OR_LA__2001
- Average of BPA_OR_LA__20012
- Average of BPA_OR_LA__20013
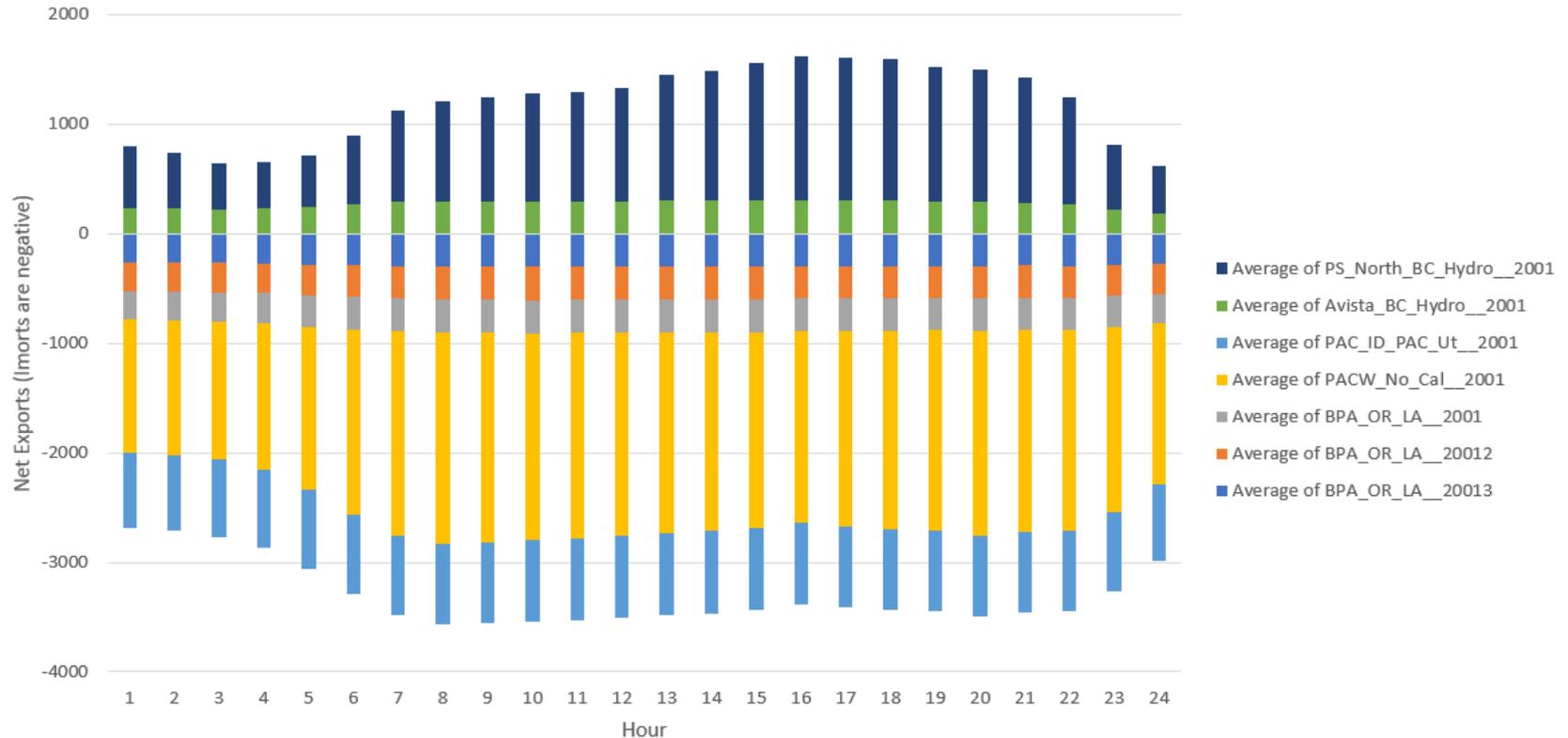
Even more imports from Southwest and Mountain West heading north to BC because of bad hydro in NW and BC

THE 2021 NORTHWEST POWER PLAN
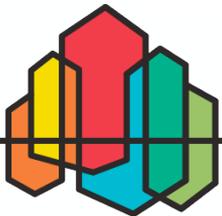
Regional Net Exports – Summer Good Hydro, High Summer Load

1997 Hydro Regional Net Exports/Imports - Summer

Legend:
- Average of PS_North_BC_Hydro__1997
- Average of Avista_BC_Hydro__1997
- Average of PAC_ID_PAC_Ut__1997
- Average of PACW_No_Cal__1997
- Average of BPA_OR_LA__1997
- Average of BPA_OR_LA__19972
- Average of BPA_OR_LA__19973
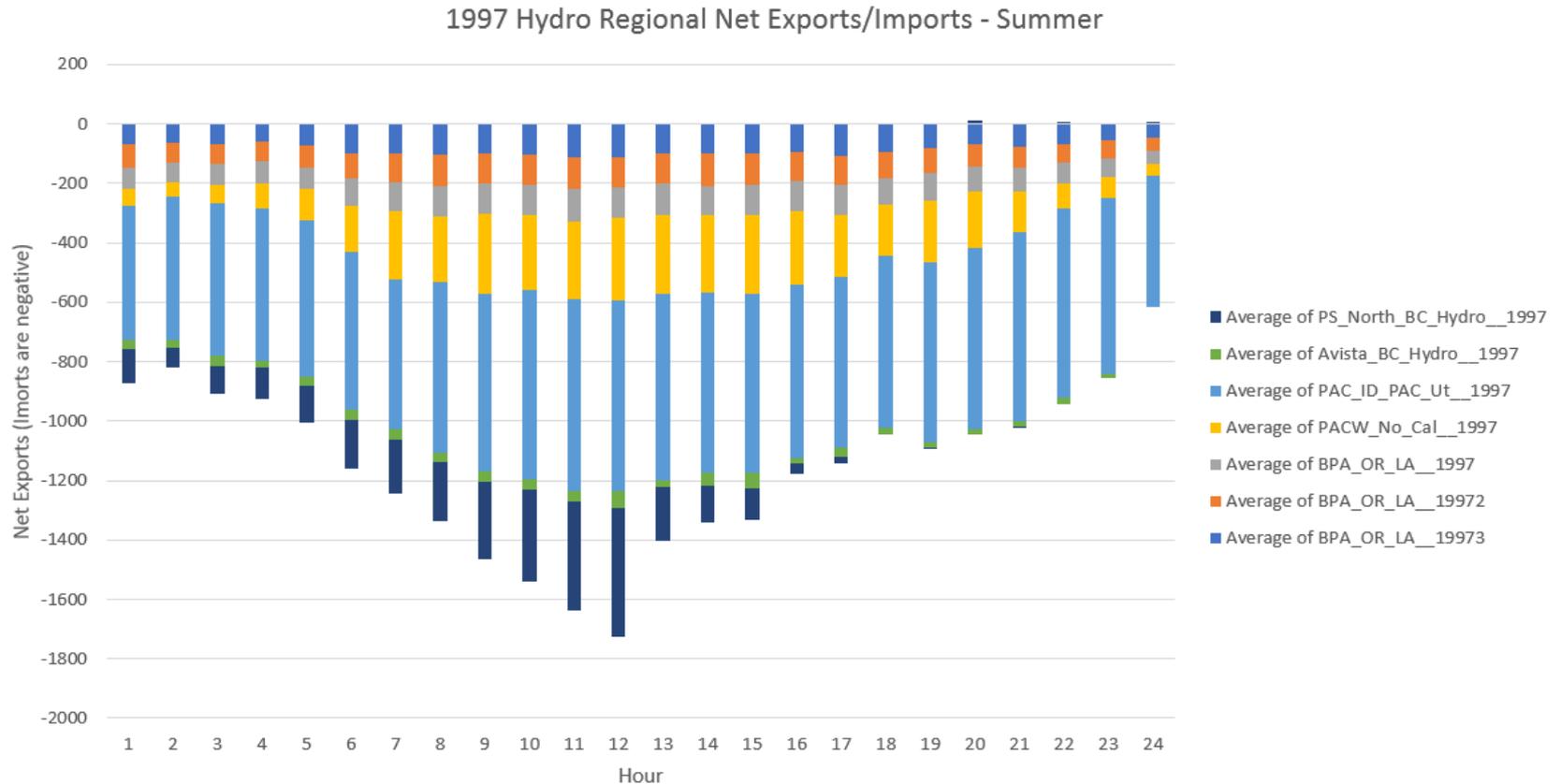
NW importing a little bit in the summer but mostly during peak solar hours.

THE 2021
NORTHWEST
POWER PLAN
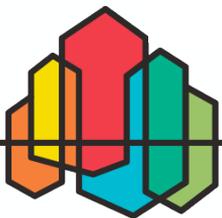
Regional Net Exports –Summer Bad Hydro, High Summer Load

2001 Hydro Regional Net Exports/Imports - Summer
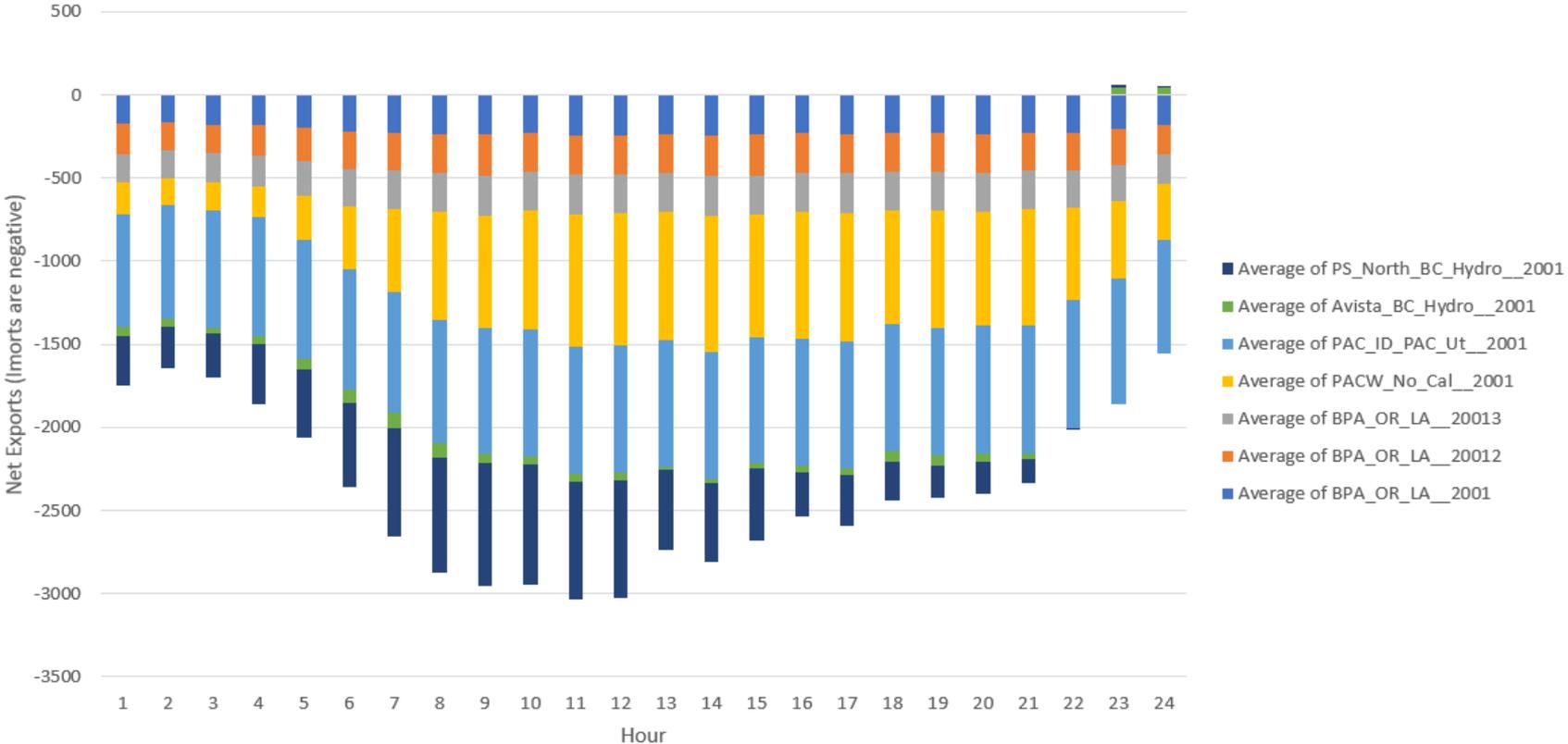
NW importing more in the summer because of bad hydro but still more so during peak solar hours.

THE 2021
NORTHWEST
POWER PLAN
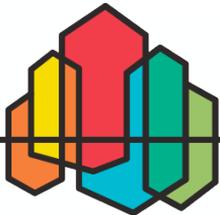
Next Steps

1. Continued validation of hourly hydro operations
   a. Collaborate with BPA to ensure implementation of hourly constraints.
   b. Collaborate with stakeholders to ensure operations are appropriate.

2. Continued validation of market and transmission system implementation
   a. Collaborate with BPA to ensure implementation of transmission constraints appropriate
   b. Work with regional stakeholders to tune market assumptions for adequacy studies.
   c. Work with regional stakeholders to verify general input assumptions for plan work.

THE 2021
NORTHWEST
POWER PLAN
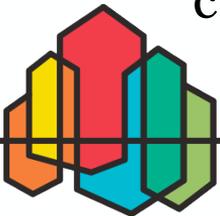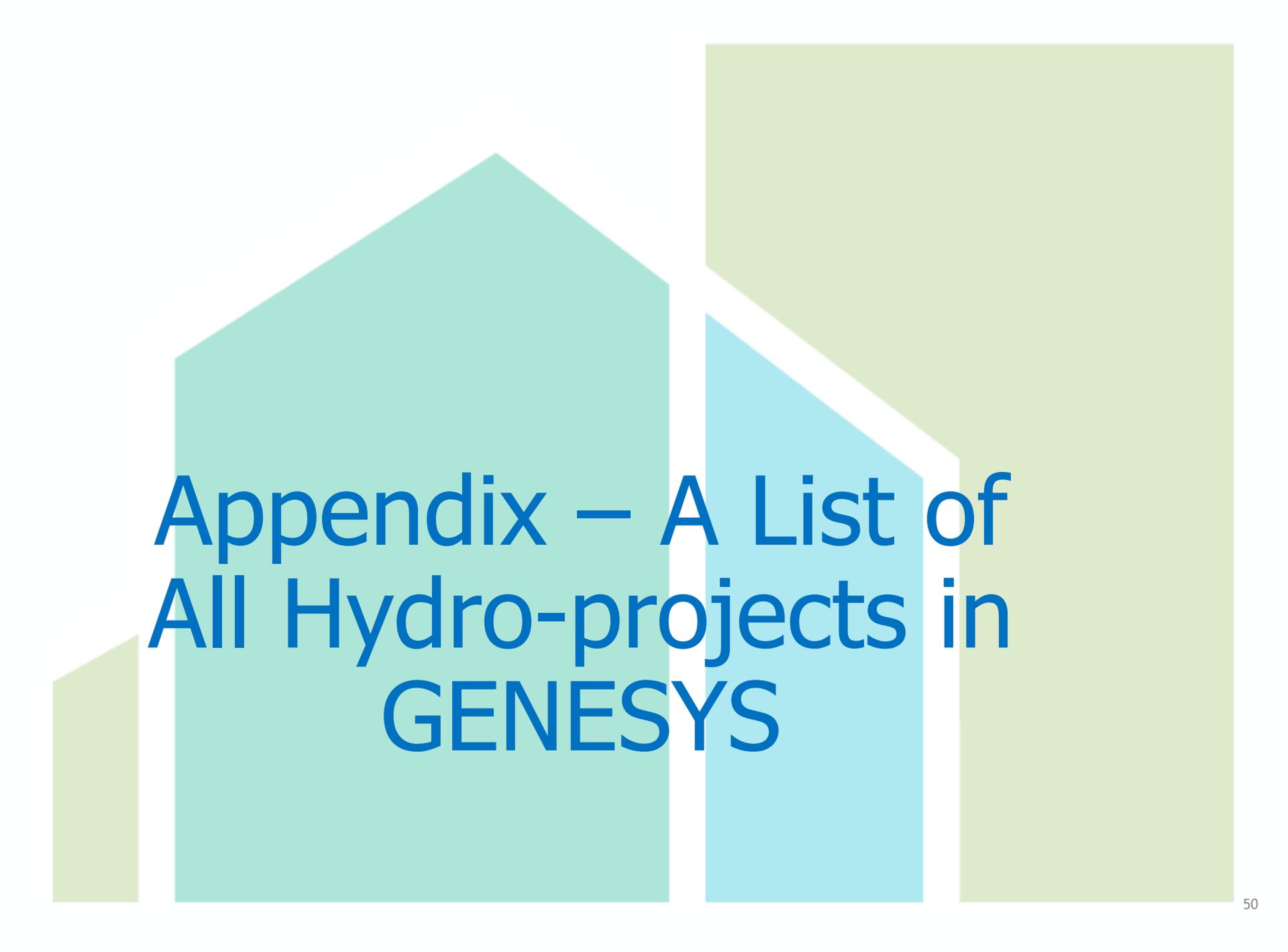
Appendix – A List of All Hydro-projects in GENESYS

Complete GENESYS Hydro Projects (I)
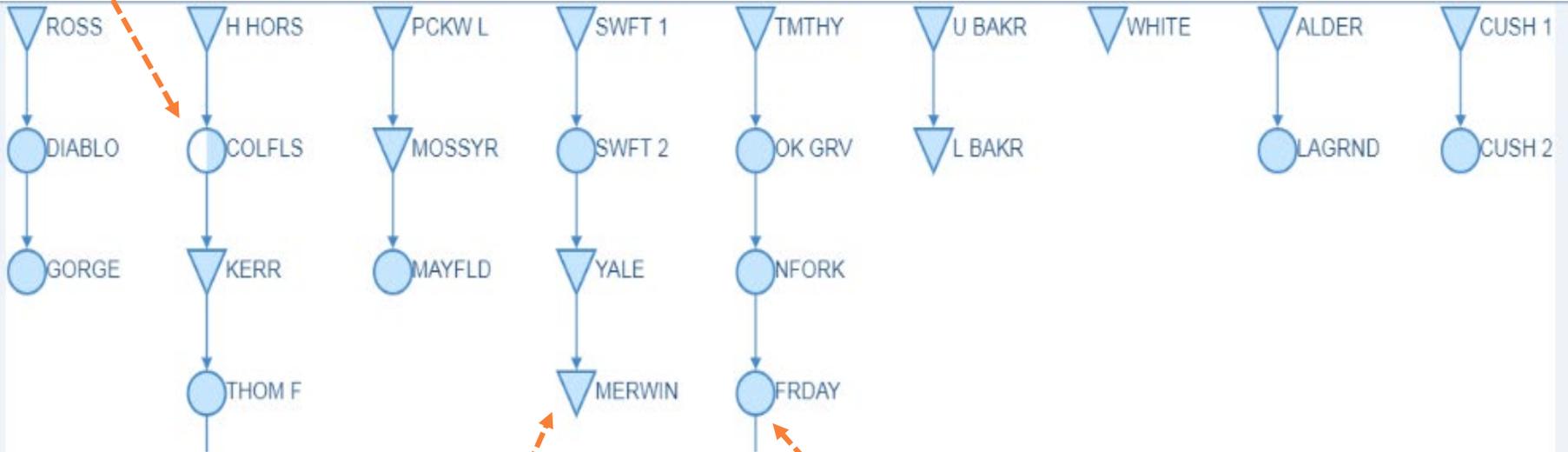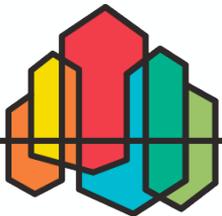
# Complete GENESYS Hydro Projects (II)
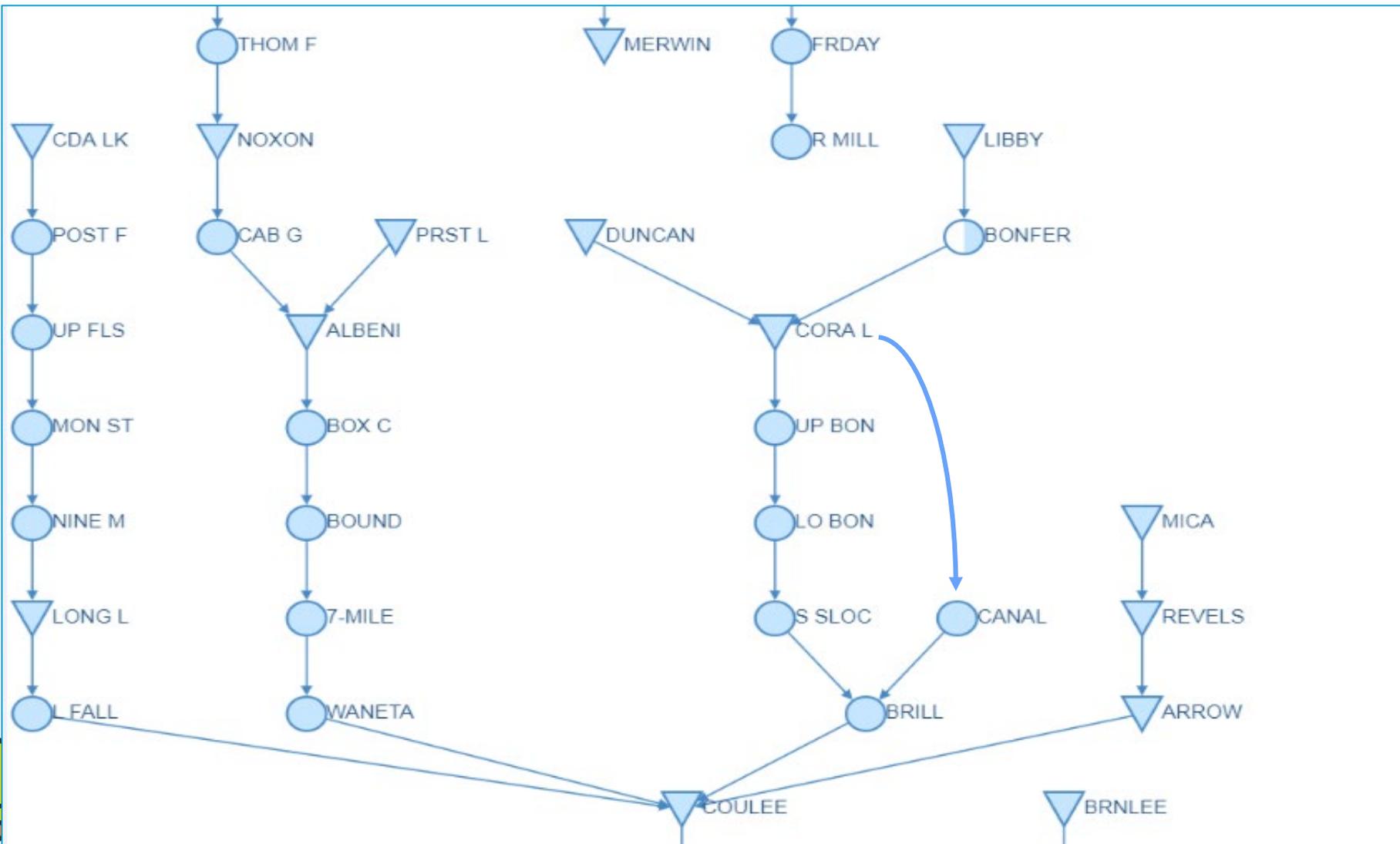
Complete GENESYS Hydro Projects (III)
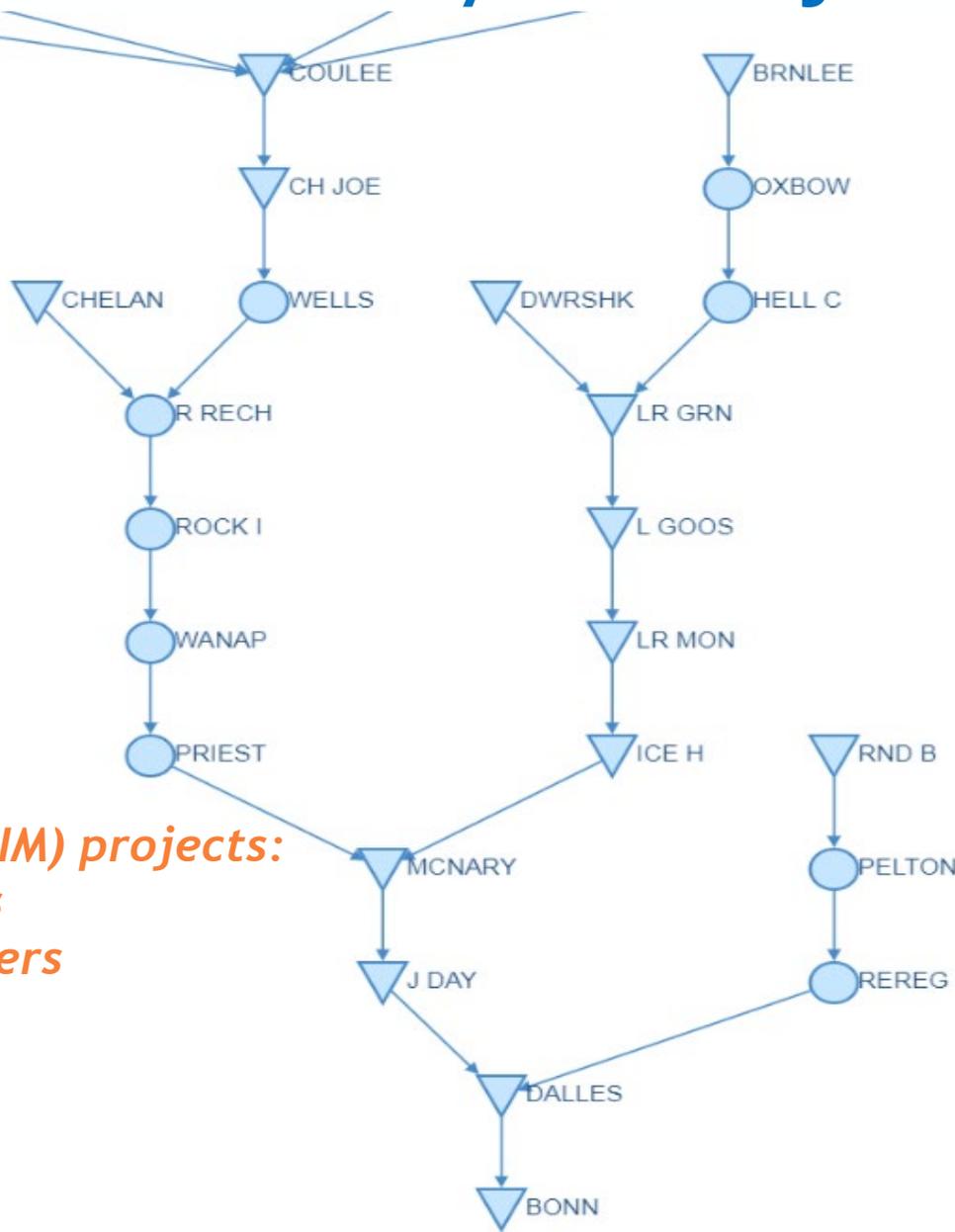
- *Total GENESYS (HYDSIM) projects:*
  - *38 reservoirs*
  - *38 run-of-rivers*