WECC ADS 2034 Hydropower

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Review - 2032 workflow

Selection of Median Year → Weekly Targets → Daily Fluctuations → Evaluation

Data: observed hydrographs, drought monitor, EIA annual generation

Method: required coincidence with Temp and wind/solar, recent year, consensus

2018 water conditions

Data:
Members provided hourly 2018 data.

Where not available, use EIA data downscaled to weekly.

Method: database and PNNL RectifHyd+.
Core Columbia: HYDSIM

From monthly to weekly

Data:
Members provided hourly 2018 data.

Where not available, used statistical approach.

Core Columbia: 2018, 2019, 2021 used

Method: database and PNNL statistical model

Weekly Pmin/Pmax and integration of daily fluctuation in GridView

Scope for WECC ADS 2034 hydropower update

Task 1: Dataset update:

Review fixed/dispatchable and flexible status of power plants

Weekly and monthly values with reproducible code

Over target: Mode of operations (load vs price following)

Re-evaluate available data

Develop the reproducible code

Task 2: Extension to Canada

“Burn” some coincidence

Task 3: Finalize dataset

Documentation and data/code release

Presentation

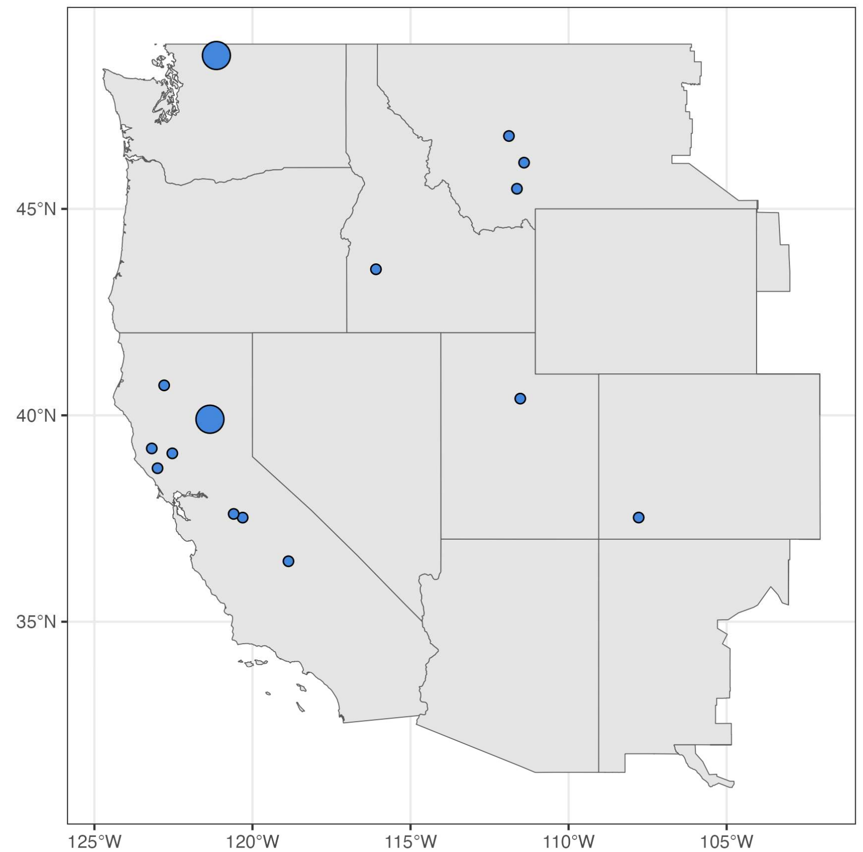
WECC ADS 2032 features maintained:
- 2018 water conditions
- Weekly/monthly datasets
- Post 2018 operations

Task 1: Updating the fixed schedule power plants

- Features of fixed scheduled plants needed to become dispatchable:
    - Have storage
    - Are NOT on canals, transbasin diversions, part of municipal water supply network
    - Have available flow data that allows to go to monthly and weekly resolution
    - Are set as “peaking plant” in EHA (existing hydropower asset) 2022

- **In 2034 ADS database, 16 power plants were identified (380.5MW nameplate capacity) were eligible to be considered dispatchable**.

** the mapping between USGS flow and plant locations was also reviewed.*



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Task 1 : New environmental regulation in the Pacific Northwest (EIS 2023)

Previous workflow for 2032 ADS

Observed monthly flow

↓

USACE modified flow (impact of regulation removed)

↓

HYDSIM reservoir model with EIS2020 operations → PNNL HYDSIM emulator trained with 2008-2017 HYDSIM simulations

Jan-Sep 2018 ↓ *Oct-Dec 2018* ↓

Monthly hydropower targets

↓ Observed weekly flow 2018

2018 weekly hydropower targets

Workflow for 2034 ADS

Observed monthly flow

↓

USACE modified flow (impact of regulation removed)

↓

BPA long-term hydromodeling (HYDSIM) with 2020-Level Modified Flows for Water Years 1989-2018 Using FY 2031 expected operations (EIS2023)

↓ *Jan-Sept 2018, Oct-Dec 2007*

Monthly hydropower targets

↓ Observed weekly flow 2018

"emulate moving of water coincident with wind/solar/load" across WECC

2018 weekly hydropower targets

HYDSIM simulations performed by Milli Chennel (BPA)

Task 1: Daily Fluctuations – Flexibility Parameterization

Method 1: 2018 hourly plant-scale data requested, received, and used to developed weekly daily fluctuations

No change from WECC ADS 2032

Method 2: 2018 weekly parameterization received directly

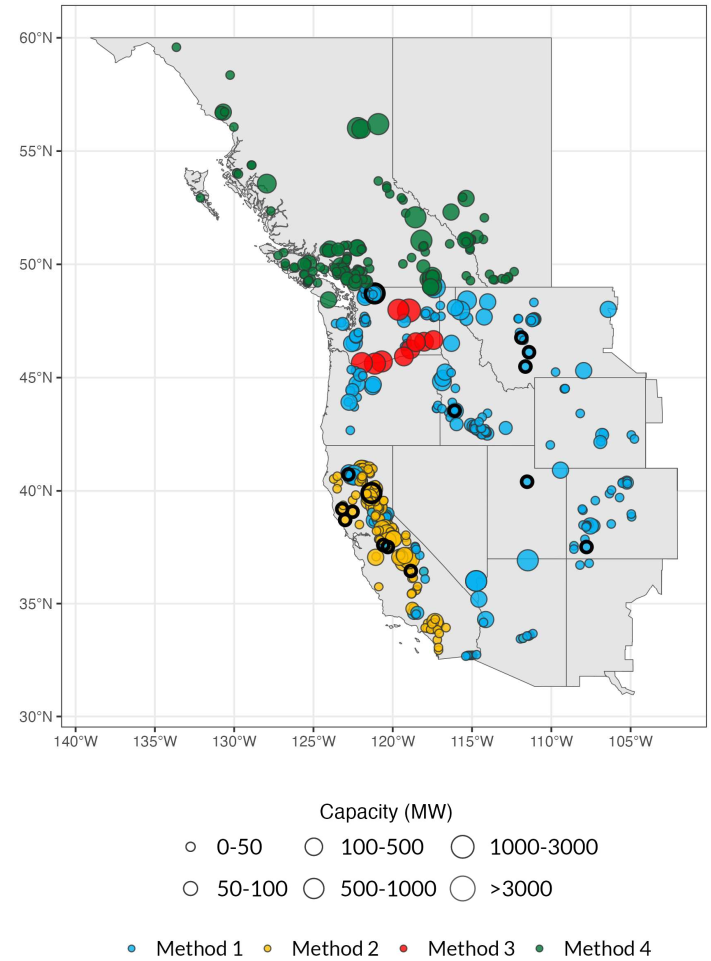
No change from WECC ADS 2032

Method 3: Use 2018 (median-wet), 2019 (median-dry), 2021 (very dry) hourly data to develop quarterly statistical relationship between flow and daily fluctuations, further applied to the HYDSIM 2018 flow.

Shift from Excel table to code.

Method 4: Canadian generators are using the Pacific Northwest standardize flexibility

New for WECC ADS 2034.

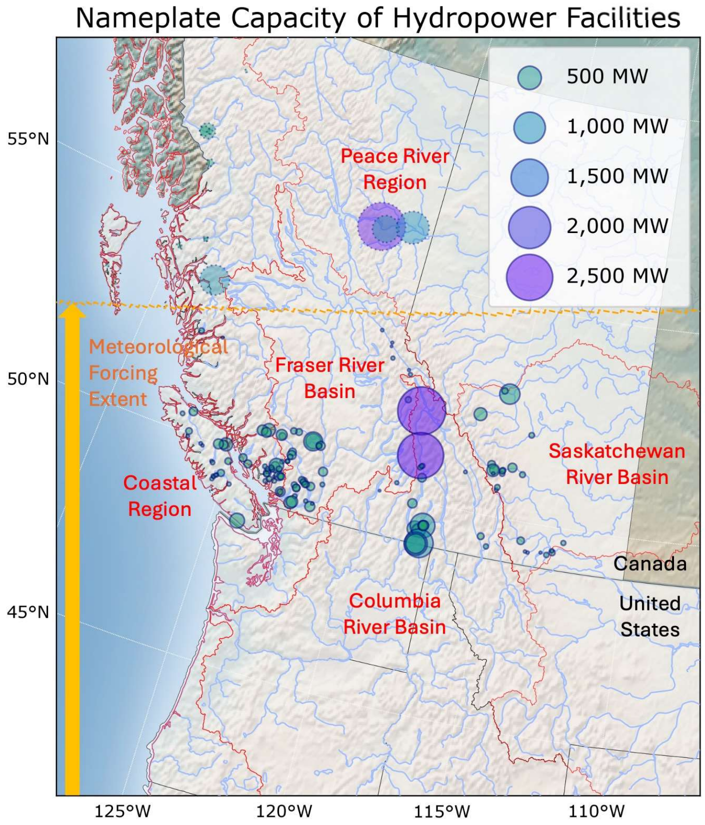


Bold outlined plants moved to load-following in ADS 2034

Task 2 – Extend to Canada

- Monthly Canadian hydro data last shared in 2016 and represent 2008 flow conditions*. No new data were acquired.
- Leverage internal investment on Western US and Canada hydrological and water management/reservoir operations simulations
- 110 facilities updated with monthly generation targets that emulate 2018 flow conditions, and Pacific Northwest flexibility (Pmax, Pmin, daily fluctuation).

** For WECC ADS 2026, 2028, 3020, year 2009 flow conditions were used in the US.*



Son et al. (2025)

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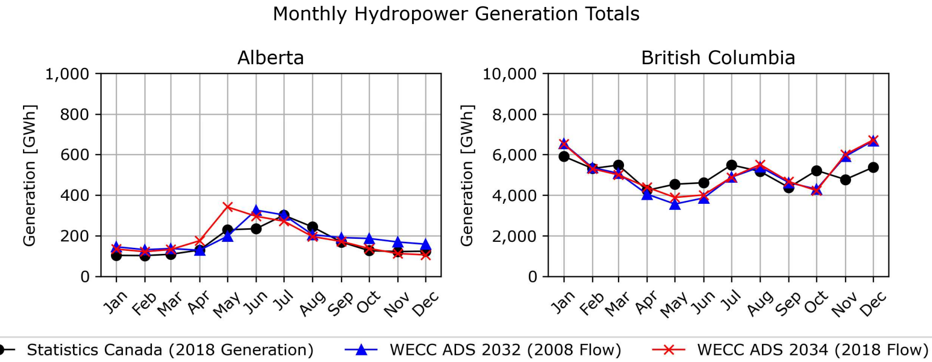
Task 2 – Extend to Canada

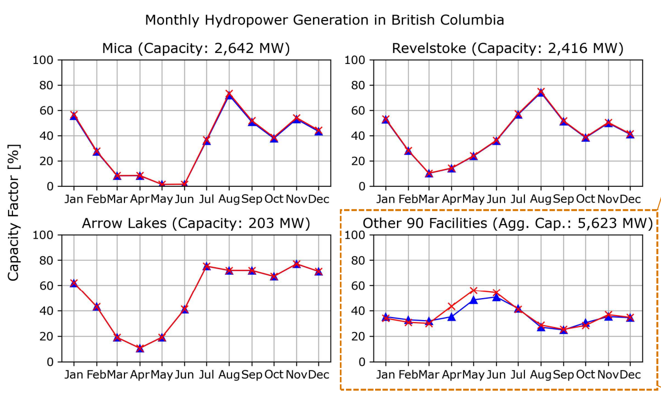
Evaluation at the provincial level:

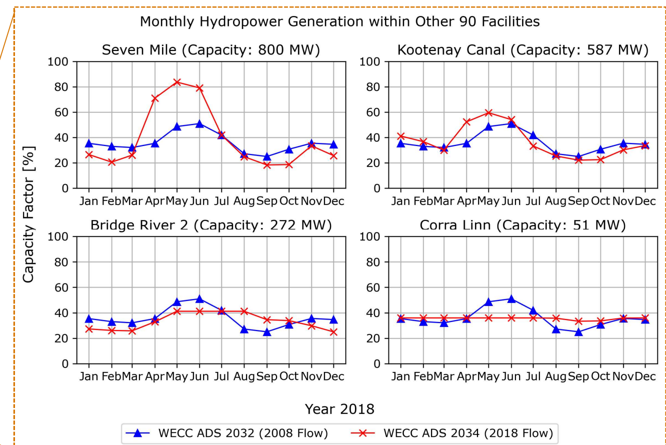
Overall, similar generation patterns (similar flow conditions between 2008 and 2018)



**Keep WECC ADS 2032 for Facilities in Peace River Region*

Evaluation at the facility level





- Negligible change for Mica, Revelstoke, and Arrows Lake facilities, due to strong winter-peaking trends
- In ADS 2032, monthly allocations are identical for other BC facilities. Spatial variability introduced in ADS 2034: monthly allocations vary by facility.

Son et al. (2025)

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Task 3: Reproducible code and documentation

A jupyter notebook that describes step by step the:

- data source (exact file name and the file itself)
- data quality check and curation
- development of weekly targets, Pmin, Pmax, daily fluctuation
  - start the week on a Monday
  - last week has one day – week completed for GridView to solve
  - no leap year
- parameter quality check and evaluation
- formatting for excel ready to translate to GV, include consolidation of data (see next slide)

https://github.com/HydroWIRES-PNNL/weccadshydro

Kerry

Hydropower Processing Mechanics

(***preprocess***)
Extract hourly hydropower generation from Microsoft Access databases

(***preprocess***)
Store hourly generation in Excel workbooks for easier access

(***process***)
Implement methods to transform hourly data into weekly values used by PCM in Python via Jupyter notebooks

Dan. (cam)

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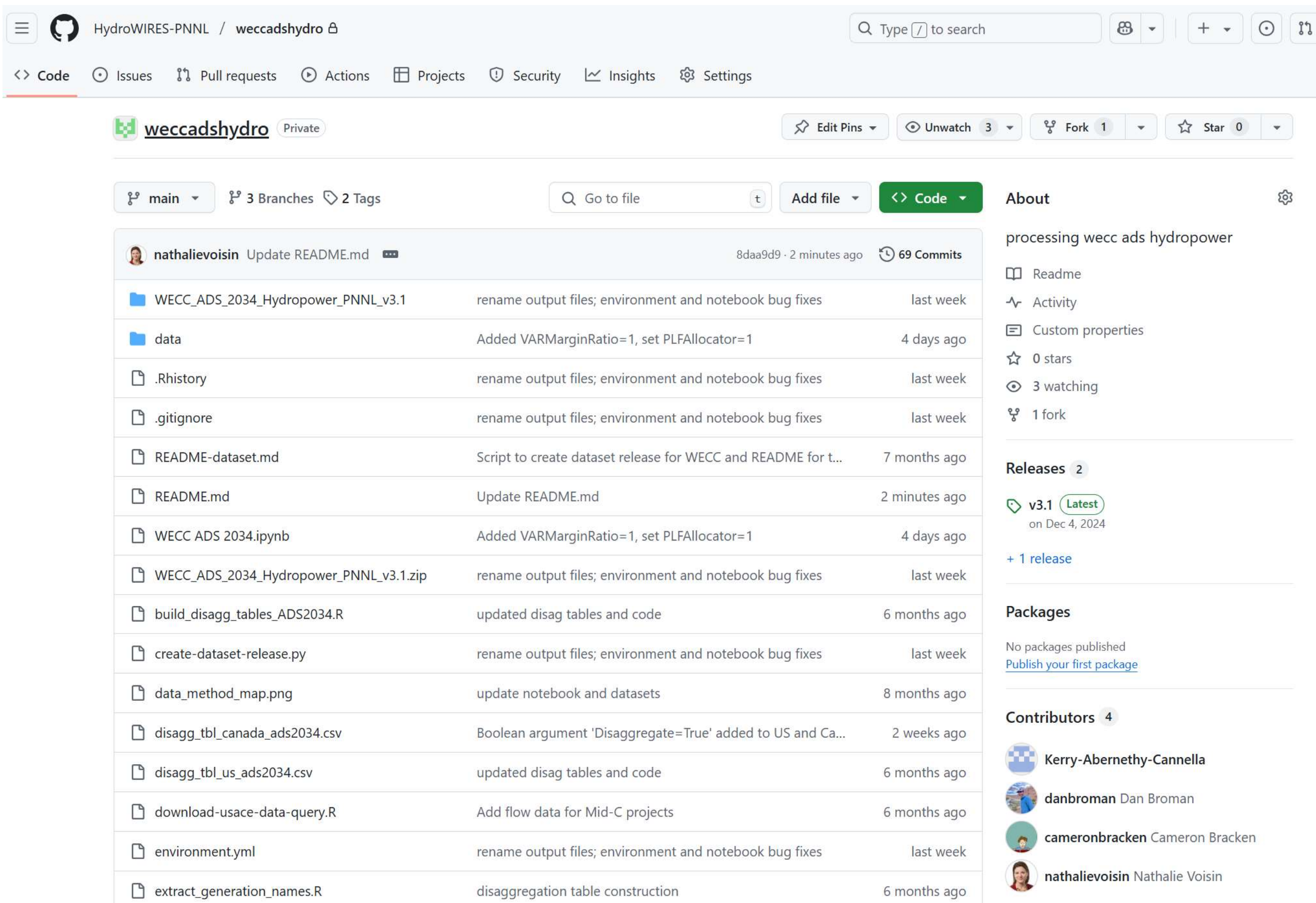
Hydropower Processing Mechanics



stored the Python code and Jupyter notebooks in a GitHub repository to provide easy access and for version control

Dan (cam)

WECC ADS 2034 hydropower dataset

Funding:

In Kind:

Jon Jensen, Enoch Davies, Anuj Patil, Kellen Romero, Andrew Fay

Resources

Dataset

Voisin, N., Broman, D., Abernethy-Cannella, K., Bracken, C., Son, Y., & Harris, K. (2025). WECC ADS 2034 Hydropower Generation Datasets (3.2) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.12617457

Code

https://github.com/HydroWIRES-PNNL/weccadshydro : private for protection of WECC-member hydropower data

Canada (full dataset and method)

Son, Y., Bracken, C., Broman, D., & Voisin, N. (2025). Monthly Hydropower Generation Dataset for Western Canada (1.1.0) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.14984725

Procedure for Putting Hydropower in the ADS

Function: Period_Statistics_Tables()

- Arguments:
  - Hourly_Generation_Table: xlsx (string)
  - Plant_ID_Col: The name of the column with the plant ID (string)
  - Date_Col: The name of the column with the datetime (pandas format) information (string)
  - Generation_Col: The name of the column with the generation in MW (string)
  - Period: Specify “Month” or “Week” (string)

Source.Name	Unit_ID	Unit_Name	iDate	iHr_End	HyGen
generator_GENERATION_1.xlsx	851	Albeni Falls	1/1/2018 0:00	1	14
generator_GENERATION_1.xlsx	851	Albeni Falls	1/1/2018 0:00	2	14
generator_GENERATION_1.xlsx	851	Albeni Falls	1/1/2018 0:00	3	14
generator_GENERATION_1.xlsx	851	Albeni Falls	1/1/2018 0:00	4	14

Note: This sample has extra columns; the only necessary columns are Plant ID, Date, and Generation (these are specified by the other arguments)

Function: Period_Statistics_Tables()

- Output:
  - List of pandas dataframes:
    - If Period == ‘Month’:

	Source	PlantID	MinGen	MaxCap	PeriodEnergy	DailyOpRange
0	PNNL	851	13	30	15552	2.741935
1	PNNL	851	18	29	16355	2.821429
2	PNNL	851	11	23	13330	2.790323
3	PNNL	851	0	19	7476	2.533333
4	PNNL	851	0	0	0	0.000000
5	PNNL	851	0	39	13437	3.883333
6	PNNL	851	13	42	23464	5.387097
7	PNNL	851	16	30	15807	3.064516
8	PNNL	851	16	29	15590	3.100000
9	PNNL	851	20	40	23756	3.870968
10	PNNL	851	10	24	12141	3.200000
11	PNNL	851	12	21	12208	3.016129

    - If Period == ‘Week’:

	Source	PlantID	MinGen	MaxCap	PeriodEnergy	DailyOpRange
0	PNNL	851	13	24	3168	3.214286
1	PNNL	851	13	24	3189	2.785714
2	PNNL	851	14	23	3258	2.285714
3	PNNL	851	21	30	4122	2.714286
4	PNNL	851	24	28	4316	2.642857
48	PNNL	851	12	21	2924	3.714286
49	PNNL	851	12	20	2935	3.428571
50	PNNL	851	12	21	2666	3.071429
51	PNNL	851	12	19	2640	2.285714
52	PNNL	851	12	19	2733	2.357143

This can be run several times to produce multiple lists, which can then be combined.

Function: BPA_Period_Statistics_Tables()

- This produces an output similar to Period_Statistics_Tables(), but for the BPA Plants. A separate function is needed because we don't have hourly generation data for the BPA plants.
- Arguments:
  - Gen_Avg_Table: xlsx (string)
  - Gen_Min_Table: xlsx (string)
  - Gen_Max_Table: xlsx (string)
  - Flow_Table: (Next Slide)
  - Year: integer
  - Period: Specify "Month" or "Week" (string)

Note: The example below is of Gen_Avg_Table, but Gen_Min_Table and Gen_Max_Table should have the exact same structure, but with min and max values instead of avg values in the cells.

Note: While the Plant Name column is not necessary for the code to run, the function assumes that there are two columns before Jan.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Plant Name	Plant ID	Jan	Feb	Mar	Apr A	Apr B	May	Jun	Jul	Aug A	Aug B	Sep	Oct	Nov	Dec
2	Grand Coulee	6163	3159.108	3400.429	2503.365	2312.191	2898.309	3475.562	3852.542	2673.032	2236.46	2635.978	1400.761	1349.858	1582.915	2306.99
3	Chief Joseph	3921	1718.92	1892.929	1484.118	1451.934	1897.89	1988.805	1869.67	1447.605	1219.628	1443.405	799.149	732.1259	855.3189	1247.368
4	Lower Granite	6175	397.4846	427.7394	415.5319	150.8143	123.0221	339.7112	203.9637	163.6289	132.8678	100.7104	157.4023	143.0959	173.1995	211.5038
5	Little Goose	3926	395.5723	425.2557	419.4666	160.4979	152.3861	484.9409	258.1832	200.6664	148.5833	113.8728	157.6774	144.4252	172.3814	209.3685
6	Lower Monumental	3927	437.0196	465.7995	456.1928	159.2601	83.50554	239.1626	215.2273	177.8179	147.9193	109.4283	163.5398	149.4956	183.012	227.3832
7	Ice Harbor	3925	434.3177	451.9247	438.2155	140.6129	63.82476	224.441	181.6683	212.4267	148.651	120.6726	156.7358	143.992	179.4546	222.0158
8	McNary	3084	969.076	957.2581	957.2581	744.534	254.7055	706.9159	436.0362	387.2657	594.6209	638.1721	454.4733	428.7137	539.8441	718.2515
9	John Day	3082	1618.453	1789.73	1472.944	1370.769	941.2451	1671.833	1200.276	818.5355	762.4718	910.3582	670.1474	634.0286	801.9803	1083.112
10	The Dalles	3895	1310.889	1441.749	1188.426	1180.538	936.8679	1333.593	985.1674	586.6094	500.2991	582.2942	538.2542	514.384	654.8964	891.546
11	Bonneville	3075	901.0009	952.692	807.5035	692.0344	451.3238	709.6777	604.774	293.7409	306.1756	384.9144	396.8961	406.9337	510.3442	642.618

Function: BPA_Period_Statistics_Tables()

Flow_Table:

- Hourly flow data used to disaggregate Monthly data into weekly data
- Necessary columns:
  - “value” (the flow value)
  - “EIA_ID” (the EIA ID)
  - All other columns shown are not necessary.
- This argument is not needed if Period == “Month”.

	A	B	C	D	E	F	G
1	year	month	day	dam	variable	value	EIA_ID
2	2018	1	1	BON	outflow_kc	167.4875	3075
3	2018	1	2	BON	outflow_kc	181.6917	3075
4	2018	1	3	BON	outflow_kc	192.4667	3075
5	2018	1	4	BON	outflow_kc	186.7292	3075
6	2018	1	5	BON	outflow_kc	192.4958	3075
7	2018	1	6	BON	outflow_kc	174.9292	3075
8	2018	1	7	BON	outflow_kc	149.8667	3075

Note: This function does not read datetime information from this table, so (within each plant) all flow values should be in order.

Function: BPA_Period_Statistics_Tables()

- Output:
  - List of pandas dataframes:
    - If Period == 'Month':

	Source	PlantID	MinGen	MaxCap	PeriodEnergy	DailyOpRange
0	BPA	6163	412.896	5124.740953	2.350376e+06	NaN
1	BPA	6163	399.653	4960.372821	2.285089e+06	NaN
2	BPA	6163	381.939	4750.002496	1.862504e+06	NaN
3	BPA	6163	464.071	4408.800611	1.875780e+06	NaN
4	BPA	6163	484.978	4520.379736	2.585818e+06	NaN
5	BPA	6163	539.833	5026.714546	2.773831e+06	NaN
6	BPA	6163	439.524	5141.856152	1.988736e+06	NaN
7	BPA	6163	432.918	4927.243039	1.817341e+06	NaN
8	BPA	6163	413.372	4478.404264	1.008548e+06	NaN
9	BPA	6163	416.211	5160.714679	1.004294e+06	NaN
10	BPA	6163	419.135	5170.933235	1.139699e+06	NaN
11	BPA	6163	419.526	5160.120334	1.716401e+06	NaN

- If Period == 'Week':

	Source	PlantID	MinGen	MaxCap	PeriodEnergy	DailyOpRange
0	BPA	6163	412.896000	5124.740953	500895.626188	NaN
1	BPA	6163	412.896000	5124.740953	546255.860073	NaN
2	BPA	6163	412.896000	5124.740953	542074.099381	NaN
3	BPA	6163	412.896000	5124.740953	534383.624945	NaN
4	BPA	6163	405.328571	5030.816306	507829.097624	NaN
48	BPA	6163	419.526000	5160.120334	485642.643137	NaN
49	BPA	6163	419.526000	5160.120334	373257.302987	NaN
50	BPA	6163	419.526000	5160.120334	334303.098390	NaN
51	BPA	6163	419.526000	5160.120334	350637.314006	NaN
52	BPA	6163	419.526000	5160.120334	366699.430118	NaN

The Column "DailyOpRange" is left blank for BPA plants.

Get CAISO data in the right format

One cell of code is used to convert CAISO data from one format:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Plant_ID	Plant_Name	iYr	iMo	Mo_Min	Mo_Max	_AvgDailyN	_AvgDailyN	_AvgDailyC	Mo2Hr_Mi	Mo2Hr_Ma	Hr_AvgDail	Hr_AvgDail	Hr_AvgDail	oGen_aM	oGen_MW	s_wZero_(	s_wZero_G	DayCount
2	1	APLHIL .SL	2018	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31	744	31
3	1	APLHIL .SL	2018	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28	672	28
4	1	APLHIL .SL	2018	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31	744	31
5	1	APLHIL .SL	2018	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30	720	30
6	1	APLHIL .SL	2018	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31	744	31
7	1	APLHIL .SL	2018	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30	720	30
8	1	APLHIL .SL	2018	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31	744	31

…into a format that is of the right structure:

	Source	PlantID	MinGen	MaxCap	PeriodEnergy	DailyOpRange
12	CAISO	2	0.00	0.00	0.000000	0.000000
13	CAISO	2	0.00	0.00	0.000000	0.000000
14	CAISO	2	0.00	1.00	313.054694	0.017011
15	CAISO	2	0.19	1.00	644.472737	0.026260
16	CAISO	2	0.00	0.72	386.795570	0.043481
17	CAISO	2	0.40	0.63	389.033591	0.028993
18	CAISO	2	0.00	0.72	480.941049	0.029515
19	CAISO	2	0.00	0.71	355.414624	0.046842
20	CAISO	2	0.00	0.47	202.049964	0.055219
21	CAISO	2	0.00	0.46	266.071397	0.057216
22	CAISO	2	0.00	0.36	117.182997	0.014591
23	CAISO	2	0.00	0.00	0.000000	0.000000

Function: Combined_Statistics_Table()

- Every function so far has produced a list of DataFrames with limited information. These lists can be combined into a new list and fed into Combined_Statistics_Table(). This function does 3 important things:
  - Combines all the statistics into one table
  - Disaggregates plant-level data into generator-level data
  - Checks for errors: MaxCap >= 0.001; 0.99 < sum(Disaggregation) < 0.01; remove duplicates
- Arguments:
  - Period_Plant_Stats_Table_List: That big combined list we just made (list)
  - Choose_Output_Name: The name of the .csv file this saves (string)
  - Period: Specify "Month" or "Week" (string)
  - DT
  - DT_Plant_ID_Col
  - DT_Generator_Name_Col
  - DT_Generator_Allocation_Col

Next Slide

Function: Combined_Statistics_Table()

Disaggregation Table

- Used to disaggregate plant-level data into generator-level data
- Arguments:
  - DT: xlsx (string)
  - DT_Plant_ID_Col: The name of the column with the plant ID (string)
  - DT_Generator_Name_Col: The name of the column with the Generator Name (string)
  - DT_Generator_Allocation_Col (string)

Note: If the Plant ID does not appear in the disaggregation table, it will not be included in the output.

	A	B	C
1	Plant ID	Generator Name	Generator Allocation
2	149	Roosevelt	1.000
3	340	KernRiver1_1	0.250
4	342	Lundy1	1.000

Function: Combined_Statistics_Table()

- Output: (this example is from monthly data)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Source	Generator Name	DataTypeN	DatatypeID	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	PNNL	AlbeniFalls1	VOMCost	1	0												
3	PNNL	AlbeniFalls1	FixedCost	2	0												
4	PNNL	AlbeniFalls1	MinGen	3	0	4.33	6	3.67	0	0	0	4.33	5.33	5.33	6.67	3.33	4
5	PNNL	AlbeniFalls1	MaxCap	4	0	10	9.67	7.67	6.33	0.001	13	14	10	9.67	13.33	8	7
6	PNNL	AlbeniFalls1	MonthlyEn	5	0	5184	5451.67	4443.33	2492	0	4479	7821.33	5269	5196.67	7918.67	4047	4069.33
7	PNNL	AlbeniFalls1	KLoadFollo	6	0	0	0	0	0	0	0	0	0	0	0	0	0
8	PNNL	AlbeniFalls1	DispatchCc	9	0												
9	PNNL	AlbeniFalls1	Pvalue	10	0	0	0	0	0	0	0	0	0	0	0	0	0
10	PNNL	AlbeniFalls1	DailyOpRa	11	0	0.91	0.94	0.93	0.84	0	1.29	1.8	1.02	1.03	1.29	1.07	1.01
11	PNNL	AlbeniFalls1	PLFAllocat	12	0												
12	PNNL	AlbeniFalls2	VOMCost	1	0												
13	PNNL	AlbeniFalls2	FixedCost	2	0												
14	PNNL	AlbeniFalls2	MinGen	3	0	4.33	6	3.67	0	0	0	4.33	5.33	5.33	6.67	3.33	4
15	PNNL	AlbeniFalls2	MaxCap	4	0	10	9.67	7.67	6.33	0.001	13	14	10	9.67	13.33	8	7
16	PNNL	AlbeniFalls2	MonthlyEn	5	0	5184	5451.67	4443.33	2492	0	4479	7821.33	5269	5196.67	7918.67	4047	4069.33
17	PNNL	AlbeniFalls2	KLoadFollo	6	0	0	0	0	0	0	0	0	0	0	0	0	0
18	PNNL	AlbeniFalls2	DispatchCc	9	0												
19	PNNL	AlbeniFalls2	Pvalue	10	0	0	0	0	0	0	0	0	0	0	0	0	0
20	PNNL	AlbeniFalls2	DailyOpRa	11	0	0.91	0.94	0.93	0.84	0	1.29	1.8	1.02	1.03	1.29	1.07	1.01
21	PNNL	AlbeniFalls2	PLFAllocat	12	0												