Projections of power generation sector water withdrawals in the Delaware River Basin

Water Management Advisory Committee

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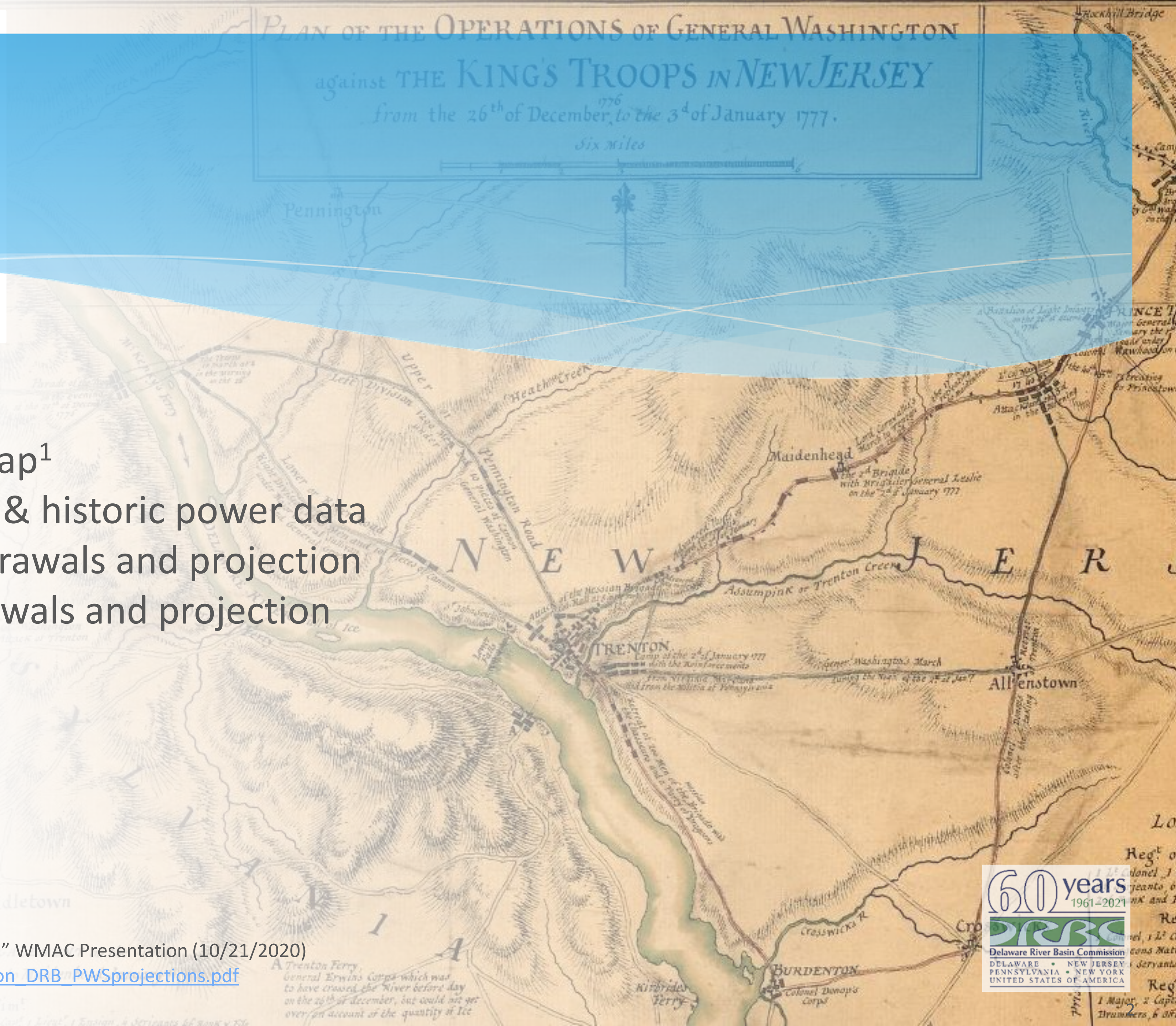
Outline

1. Projection methodology recap[1]
2. Power generation – context & historic power data
3. Thermoelectric water withdrawals and projection
4. Hydroelectric water withdrawals and projection
5. Next Steps



[1] *"Projections of the Public Water Supply Sector in the Delaware River Basin"* WMAC Presentation (10/21/2020)
https://www.state.nj.us/drbc/library/documents/WMAC/102120/thompson_DRB_PWSprojections.pdf

Plan of the operations of General Washington against the King's troops in New Jersey, from the 26th of December to the 3d of January 1777. [1777] Map. https://www.loc.gov/item/gm71000654/.

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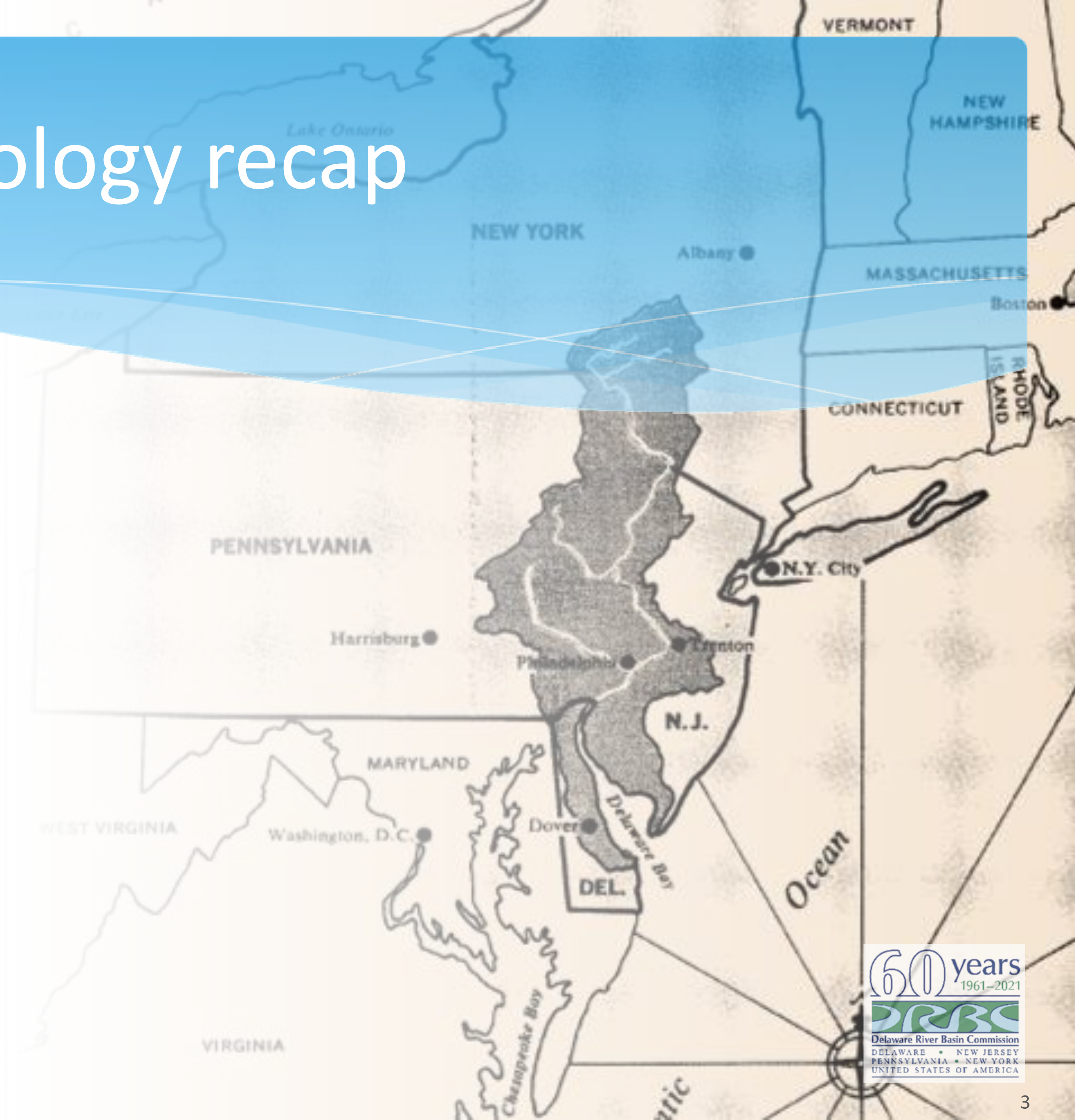
1. Projection methodology recap

The planning process "…cannot be a grandiose fixed blueprint: rather it is a process involving continuing inputs from diverse programs, agencies, institutions, individuals and groups representative of every conceivable human and natural interest... The end product sought is a dynamic equilibrium serving the public interest."

- DRBC Comprehensive Plan, 1973



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1. Recap: What are the planning objectives?

Provide projections of future average annual water withdrawals in the Delaware River Basin, through the year 2060, to be used in future planning assessments.

Represent each water withdrawal *sector* at the Basin-wide scale.

Apply GW results to the 147 sub-watersheds (Sloto & Buxton, 2006) and the 76 sub-watersheds of SEPA-GWPA.

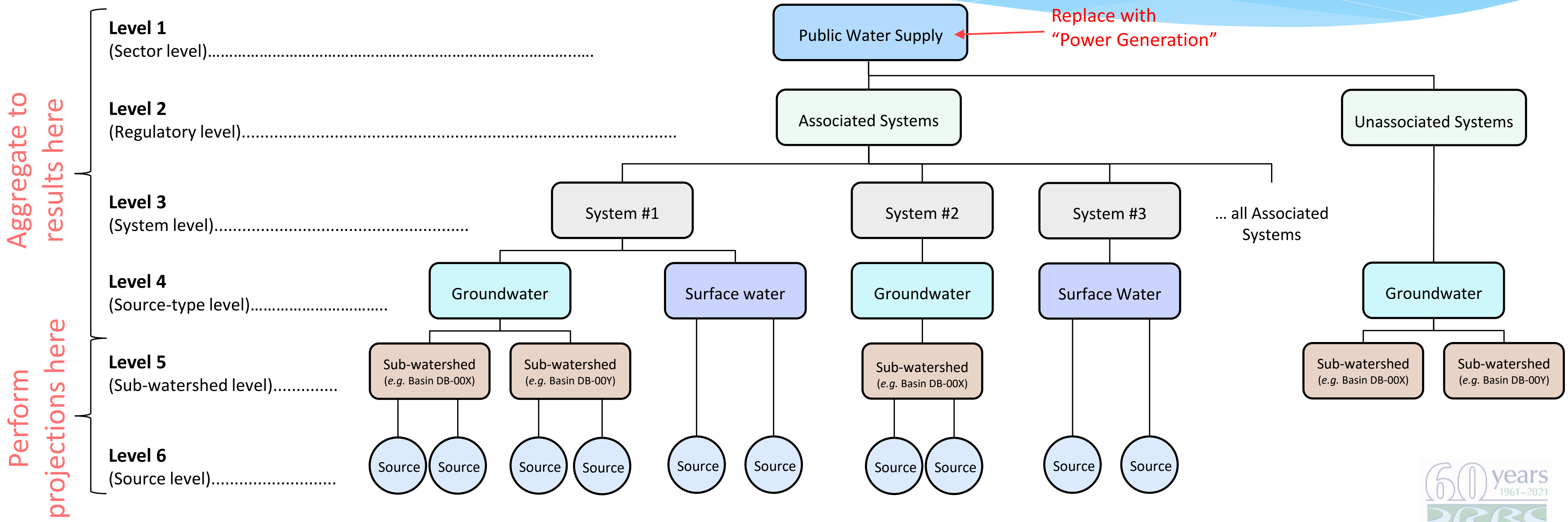
Apply SW results at the source level for future availability analyses.

Relate results to regulatory approvals.

1. Recap: A plan for projecting data?

Where do we start?

Time-series hierarchy



Hyndman, R., & Athanasopoulos, G. (2018). *Forecasting: principles and practice* (2nd ed.). Melbourne, Australia: OTexts. https://otexts.com/fpp2/

1. Recap: Tools in the toolbox

Prediction interval

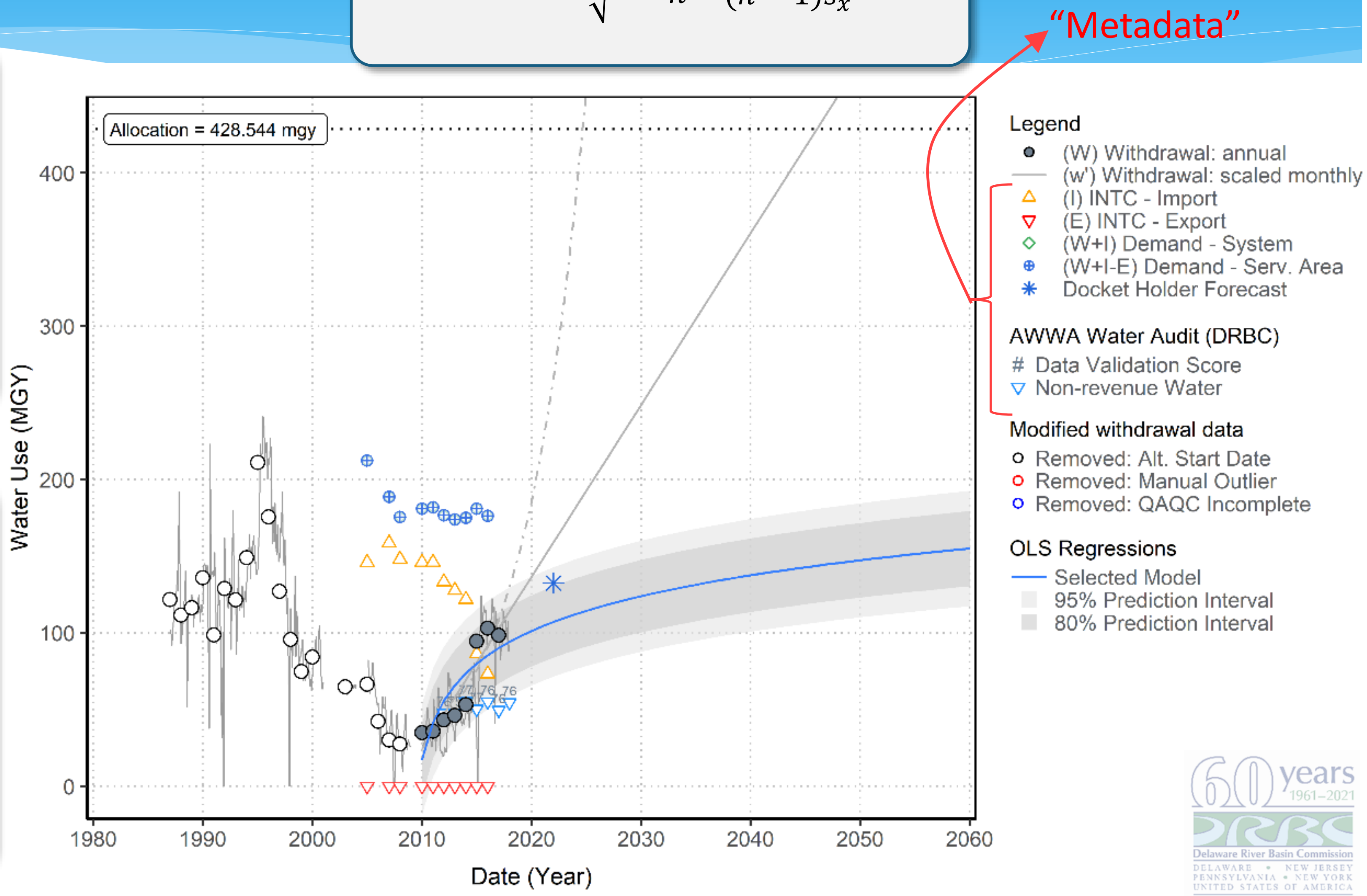
$$\hat{y} \pm t_{\alpha,v} * \hat{\sigma}_e \sqrt{1 + \frac{1}{n} + \frac{(x-\bar{x})^2}{(n-1)s_x^2}}$$

Methods of extrapolation

- Linear ordinary least-squares (OLS)
- Linear and non-linear transformations (i.e. LOG and EXP regressions)
- Mean value (zero-slope linear)
- Top-down equations
- Structural break / offset equations

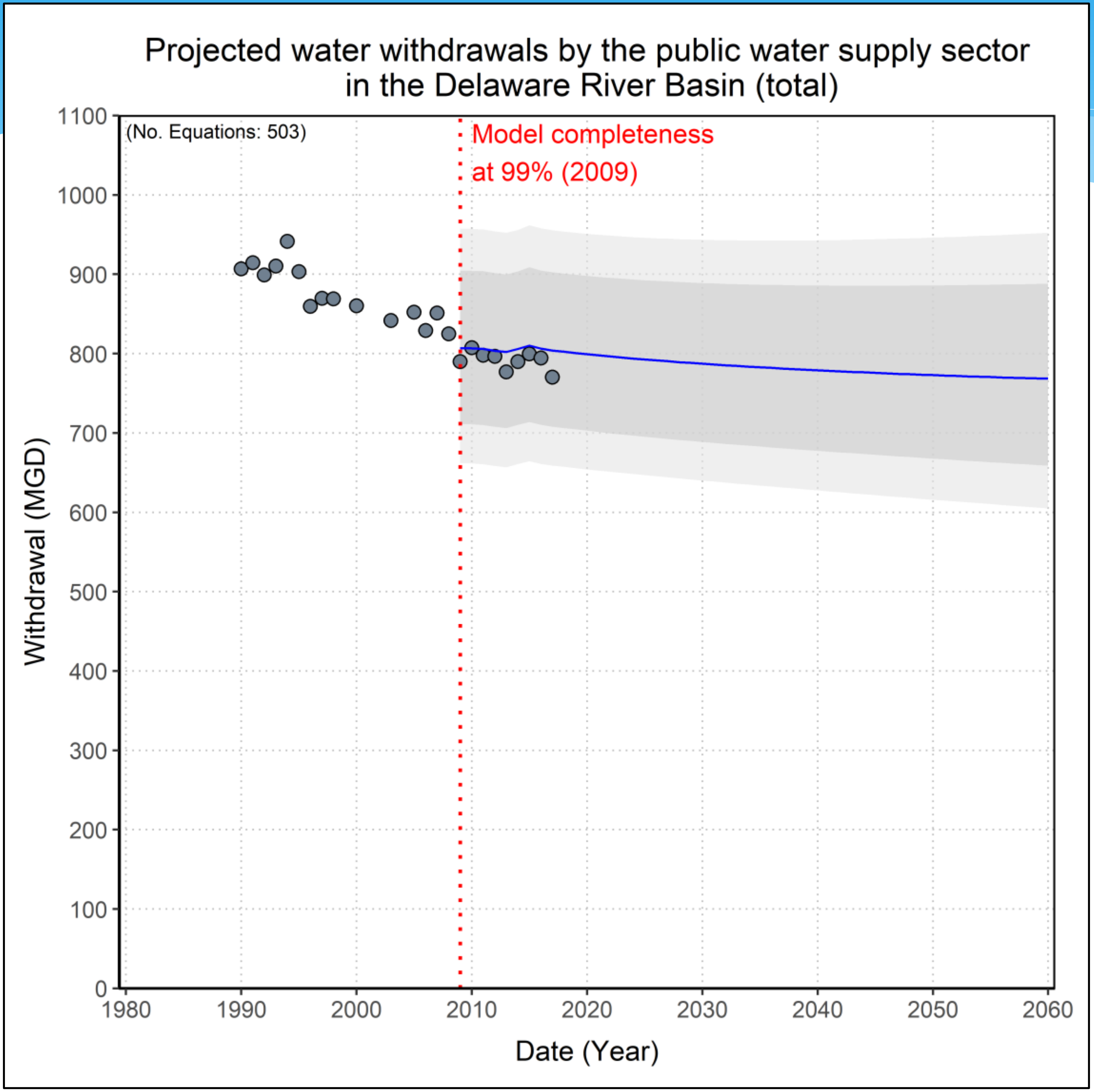
QAQC of data

- **Outlier** – removal of individual point
- **Start date** – alter start of projection
- **Algorithm** checks annual completeness
- **Verifying sources** (in basin, duplicate…)
- **Best professional judgement** (BPJ) to check for capture of trends, metadata, outliers missed in algorithm



1. Recap: **Updated** Basin-wide PWS aggregation

Recall: Withdrawals by the public water supply sector, not residential consumption.



Does not include 'unassociated' projections or data.

Preliminary Conclusions

- Basin-wide modelled withdrawal decrease of about 36 MGD (4.4%) from 2017 through 2060
- 95% PI about ±18.6% (2020) to ±22.6% (2060)
- 80% PI about ±12.2% (2020) to ±14.9% (2060)
- Average error against data ≈ 1.8%
- Peak use by PWS has already occurred at the Basin scale

Year	Historic Withdrawal (MGD)	Modelled Withdrawal (MDG)	Percent Error (%)	upr80	upr95	lwr80	lwr95
2010	808	807	0.11	904	957	711	662
2011	798	806	1.01	904	957	710	661
2012	796	804	0.92	901	954	708	658
2013	777	802	3.22	900	952	706	657
2014	790	806	2.04	904	956	710	661
2015	800	810	1.35	909	962	714	664
2016	794	806	1.51	905	958	710	661
2017	770	804	4.36	902	955	708	659
2020	NA	799	NA	898	951	703	654
2030	NA	787	NA	889	943	689	640
2040	NA	779	NA	886	943	678	628
2050	NA	773	NA	886	946	668	616
2060	NA	768	NA	888	952	659	605

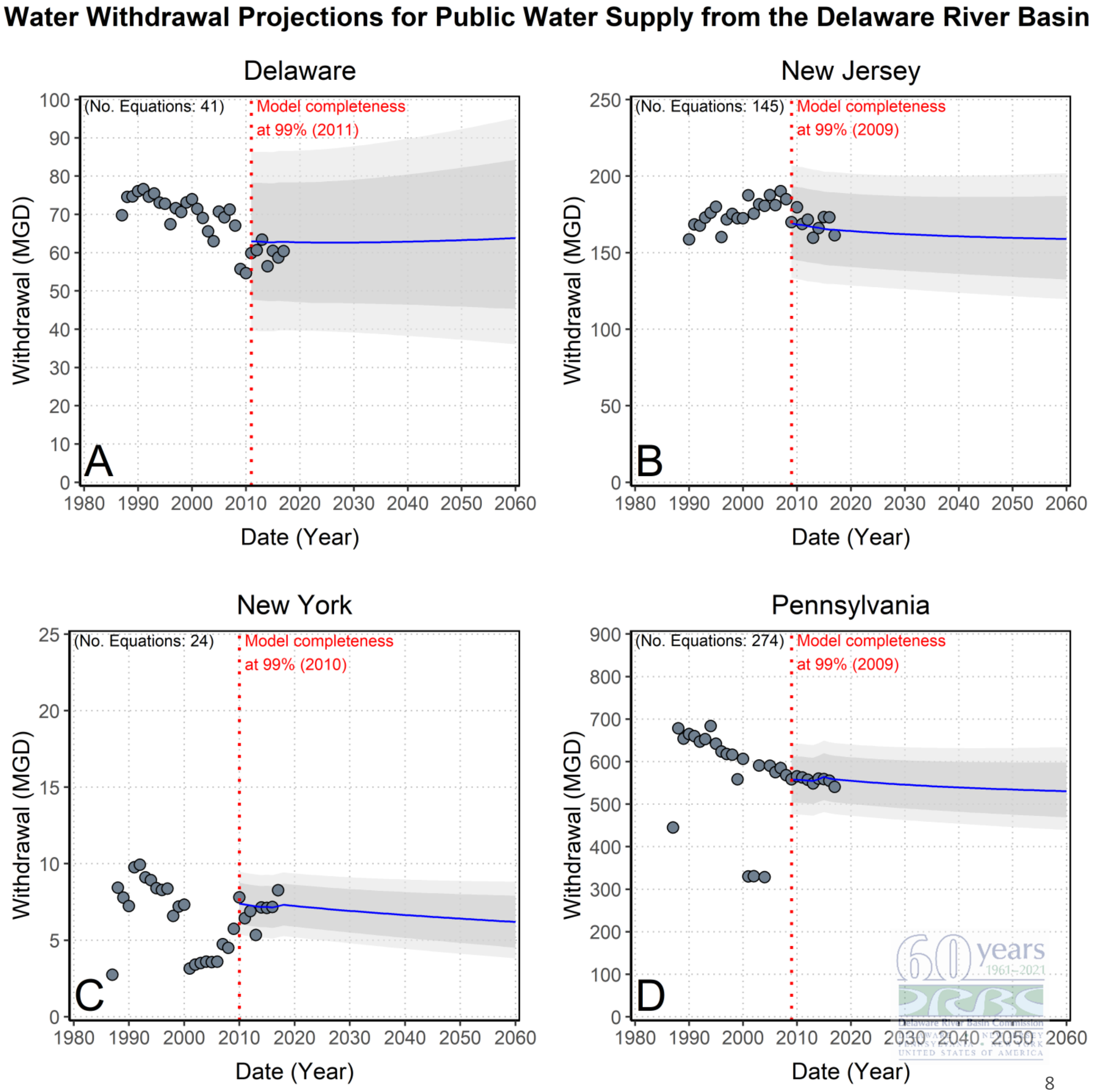
Updates:

- Located and incorporated historic data from Delaware (1990-2000)
- Located and incorporated historic data from New York (1990-2000)
- Filled a few data-gaps in other state datasets (PA, NJ)

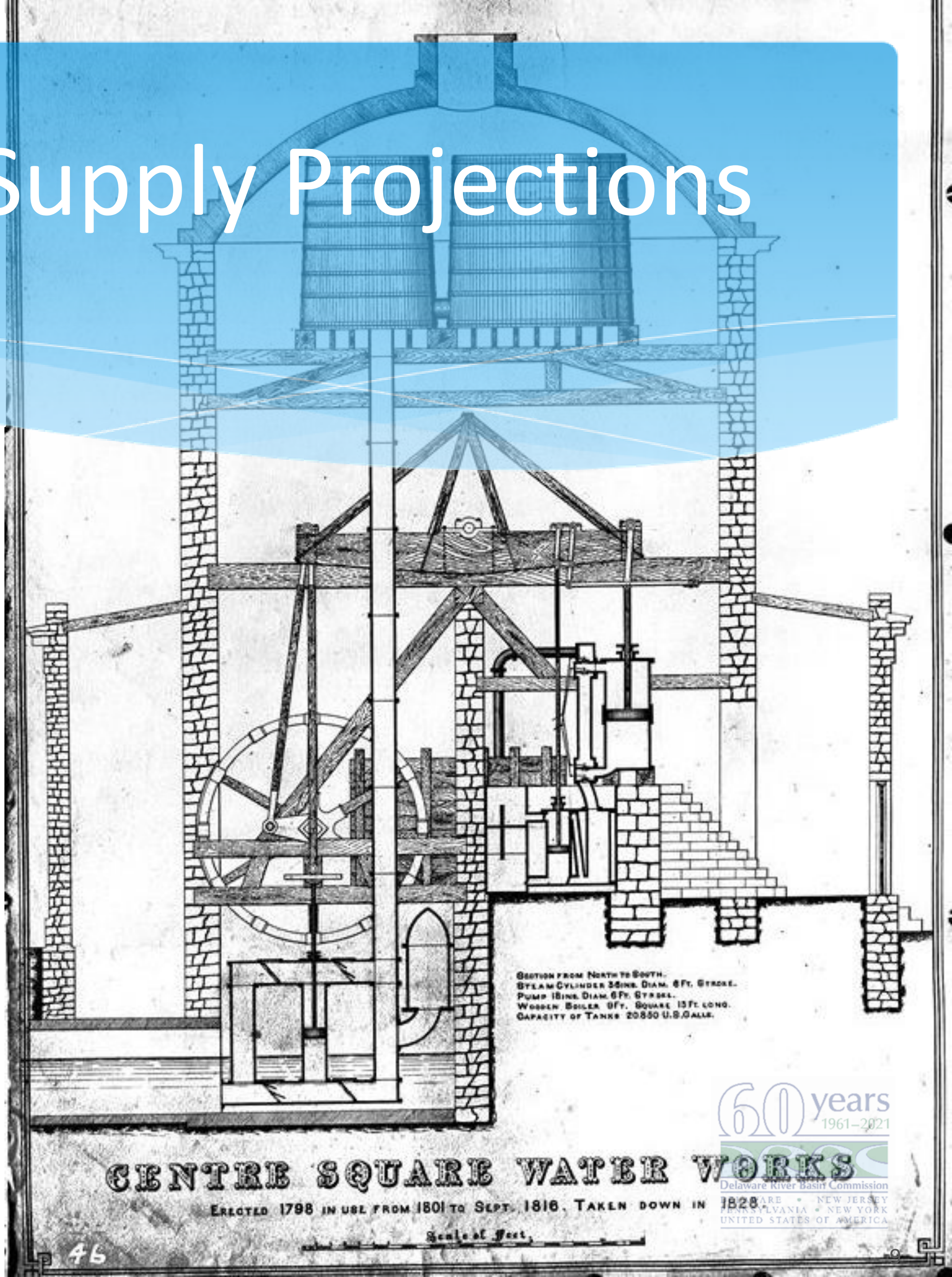
1. Recap: State-wide PWS

Some key notes/observations:

- **On an annual basis, all states withdrawals for public water supply have peaked.**
- **Delaware** had the only aggregated projection resulting in slight increase. Data showed a substantial drop in withdrawals from 2008-2009
- **New Jersey**, withdrawals in public water supply peaked in the mid-2000s
- **New York**, there are known data gaps 2001-2009
- **Pennsylvania**, there are known data gaps in 1999, 2001, 2002 and 2004



Discussion on Public Water Supply Projections



Centre Square Water Works
Philadelphia, PA
(1801-1828)

Image adopted from: http://www.waterworkshistory.us/PA/Philadelphia/

2. Context and historic power data

“After the electric light goes into general use, none but the extravagant will burn tallow candles.”

- Thomas Edison, 1880

Photograph of PECO Chester Generating Station (permanently retired in 1987), obtained from https://ruins.files.wordpress.com/2006/11/chester_generating_station_harrison.jpg on 1/21/2021

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2. Context: water & energy

Thermoelectric power generation typically uses water in the cooling process

Thermoelectric
(once-through non-contact cooling)

Portland Generating Station, photo credit Google Earth

Thermoelectric
(recirculating cooling towers)

Exelon Limerick, photo credit Google Earth

Hydroelectric power generation uses water as the "primary mover"

Hydroelectric (conventional)

Rio (Mongaup System), photo credit Google Earth

Hydroelectric (pumped storage)

Yards Creek Generating Station, photo credit Google Earth

Good reference (and glossary):

Diehl, T. H., Harris, M. A., Murphy, J. C., Hutson, S. S., & Ladd, D. E. (2013). Methods for estimating water consumption for thermoelectric power plants in the United States. Scientific Investigations Report 2013-5188. Reston, Virginia. U.S. Geological Survey. https://doi.org/10.3133/sir20135188

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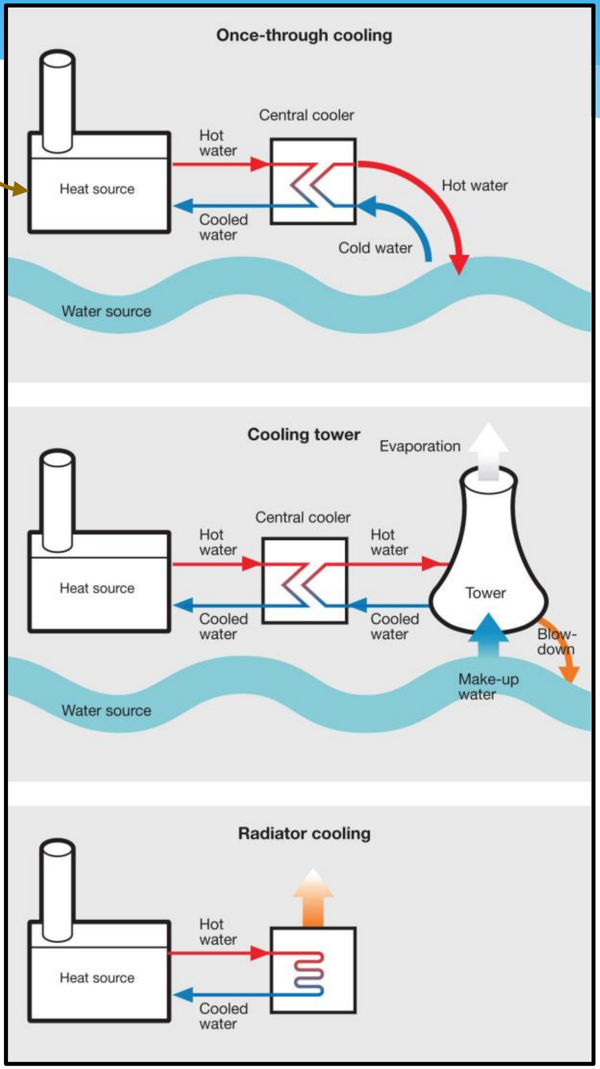
2. Context: water & energy (thermoelectric)

FUEL

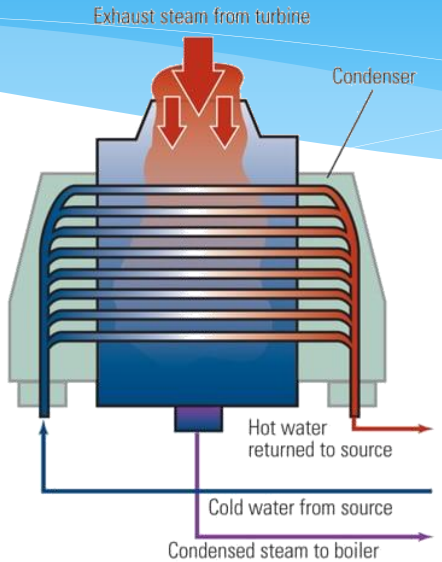
Once through:
Larger withdrawal
Less consumptive

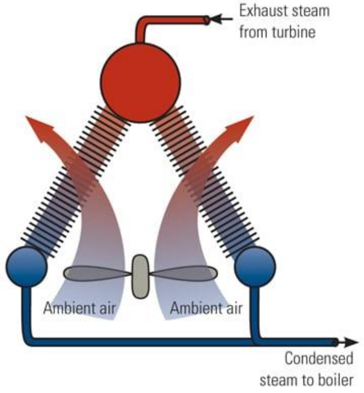
Recirculating tower:
Smaller withdrawal
More consumptive
(evaporation)

Dry cooling:
No cooling withdrawal
(boiler water make-up)

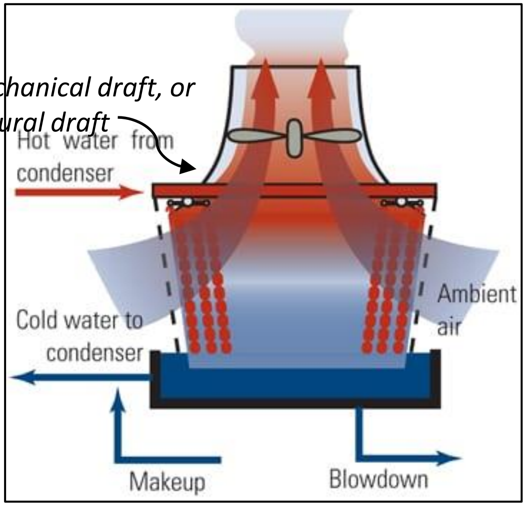


Rantanen, Mikko. 2008. Efficient use and consumption of water in power generation. WÄRTSILÄ TECHNICAL JOURNAL. Online: https://cdn.wartsila.com/docs/default-source/Power-Plants-documents/reference-documents/power-plants-articles/efficient-use-and-consumption-of-water-in-power-generation.pdf?sfvrsn=2





Mechanical draft, or
Natural draft



Three cooling system graphics obtained from: https://www.powermag.com/water-conservation-options-for-power-generation-facilities/

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2. Context: some quick terms

EIA Glossary:
https://www.eia.gov/tools/glossary/

Electric utility

Delivers electric energy for use primarily by the public. Included are investor-owned electric utilities, municipal and State utilities, Federal electric utilities, and rural electric cooperatives.

Electric non-utility

Costs are not established and recovered by regulatory authority (e.g. independent power producers, power marketers and aggregators, merchant transmission service providers, self-generation entities, and cogeneration firms with Qualifying Facility Status)

Installed capacity

Delivers electric energy for use primarily by the public. Included are investor-owned electric utilities, municipal and State utilities, Federal electric utilities, and rural electric cooperatives.

Net Generation

The amount of gross generation less the electrical energy consumed at the generating station(s) for station service or auxiliaries.

AER Fuel Type

A description of the fuel used to generate the electricity. This represents a partial aggregation of the reported fuel type codes into larger categories used by EIA in, for example, the Annual Energy Review (AER).

Primary Mover Type

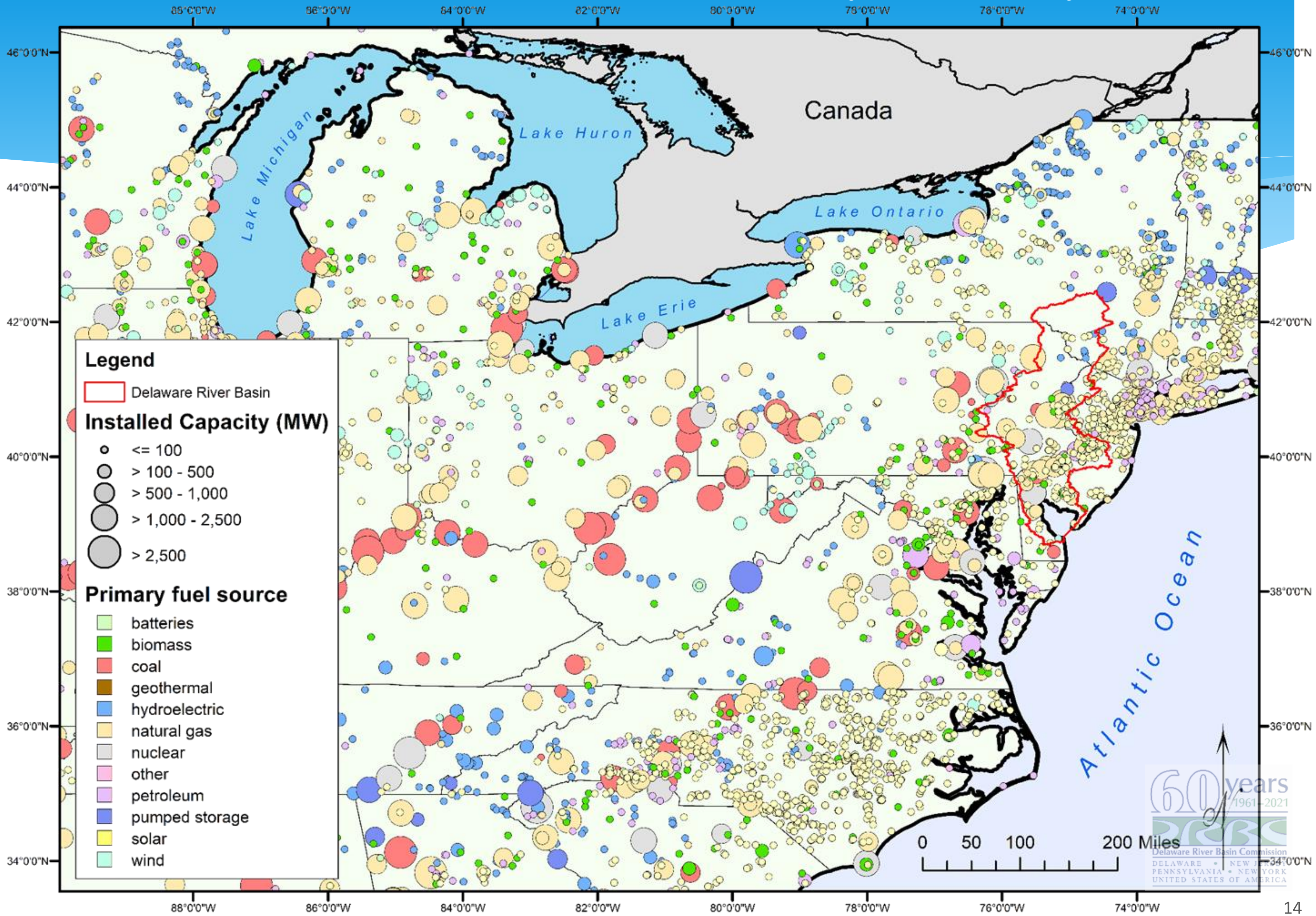
The engine, turbine, water wheel, or similar machine that drives an electric generator; or, for reporting purposes, a device that converts energy to electricity directly (e.g. steam turbine [ST]).

2. Context: power in the Delaware River Basin, comparatively

<u>Data sources</u>:
EIA: *PowerPlants_US_202004.shp*
https://www.eia.gov/maps/layer_info-m.php

"Operable electric generating plants in the United States by energy source. This includes all plants that are operating, on standby, or short- or long-term out of service with a combined nameplate capacity of 1 MW or more."

Represents "current" facility conditions as of April 2020. <u>Does not</u> represent net generation, or historic fuels primary fuel types.



2. Context: power in the Delaware River Basin, comparatively

Data sources:

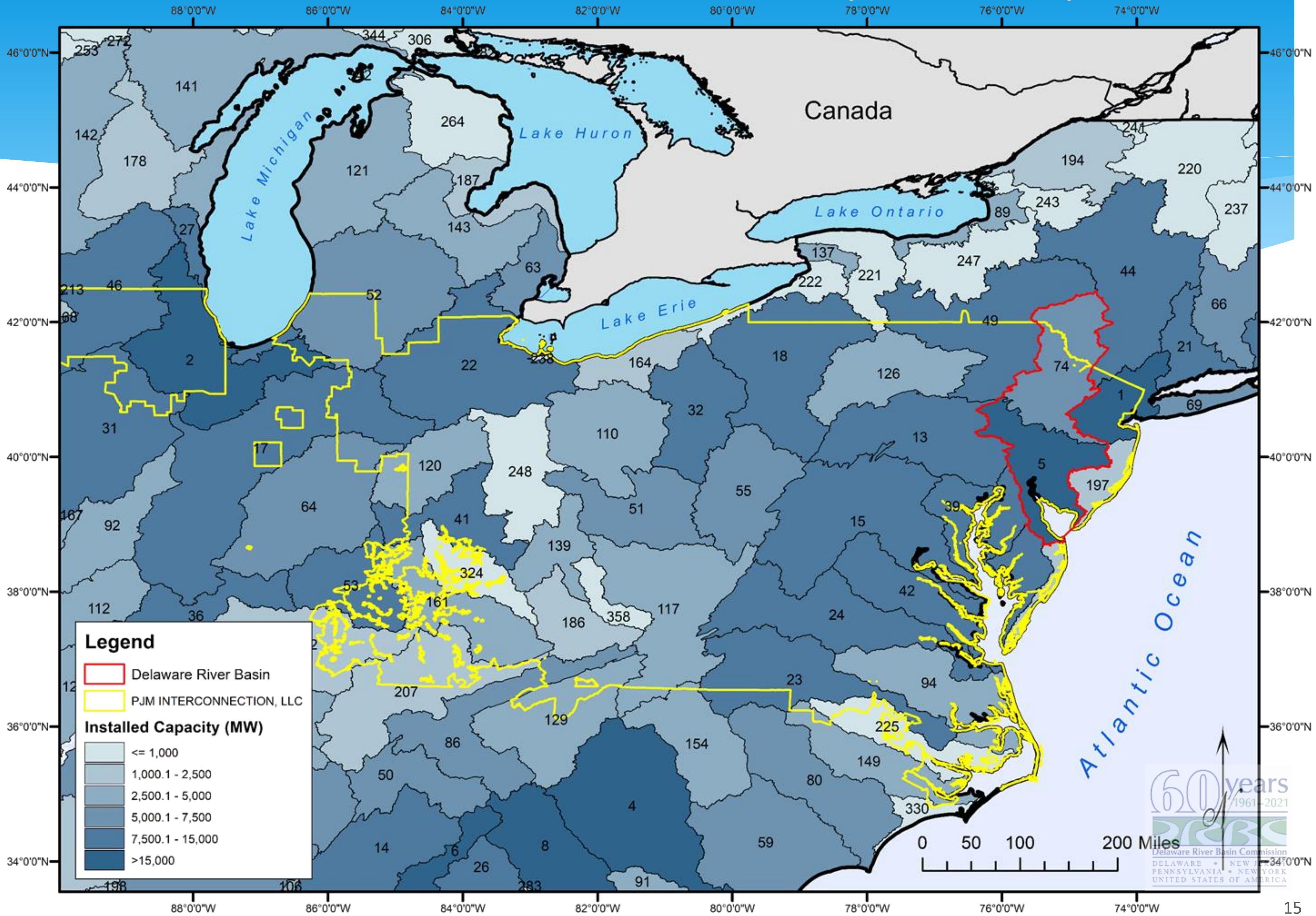
EIA: *PowerPlants_US_202004.shp*
https://www.eia.gov/maps/layer_info-m.php

USGS: *WBD_National_GDB.gdb*
http://prd-tnm.s3-website-us-west-2.amazonaws.com/?prefix=StagedProducts/Hydrography/WBD/National/GDB/

Some notes:

- Aggregate the installed capacity by HUC-6 code.
- 388 HUC-6 codes
  (excludes CN, GU, PR, MX, VI)
- 360 have installed capacity
- (020402) LDRW = 5th / 360
- (020401) UDRW = 74th / 360

Power in the DRB is comparably significant.

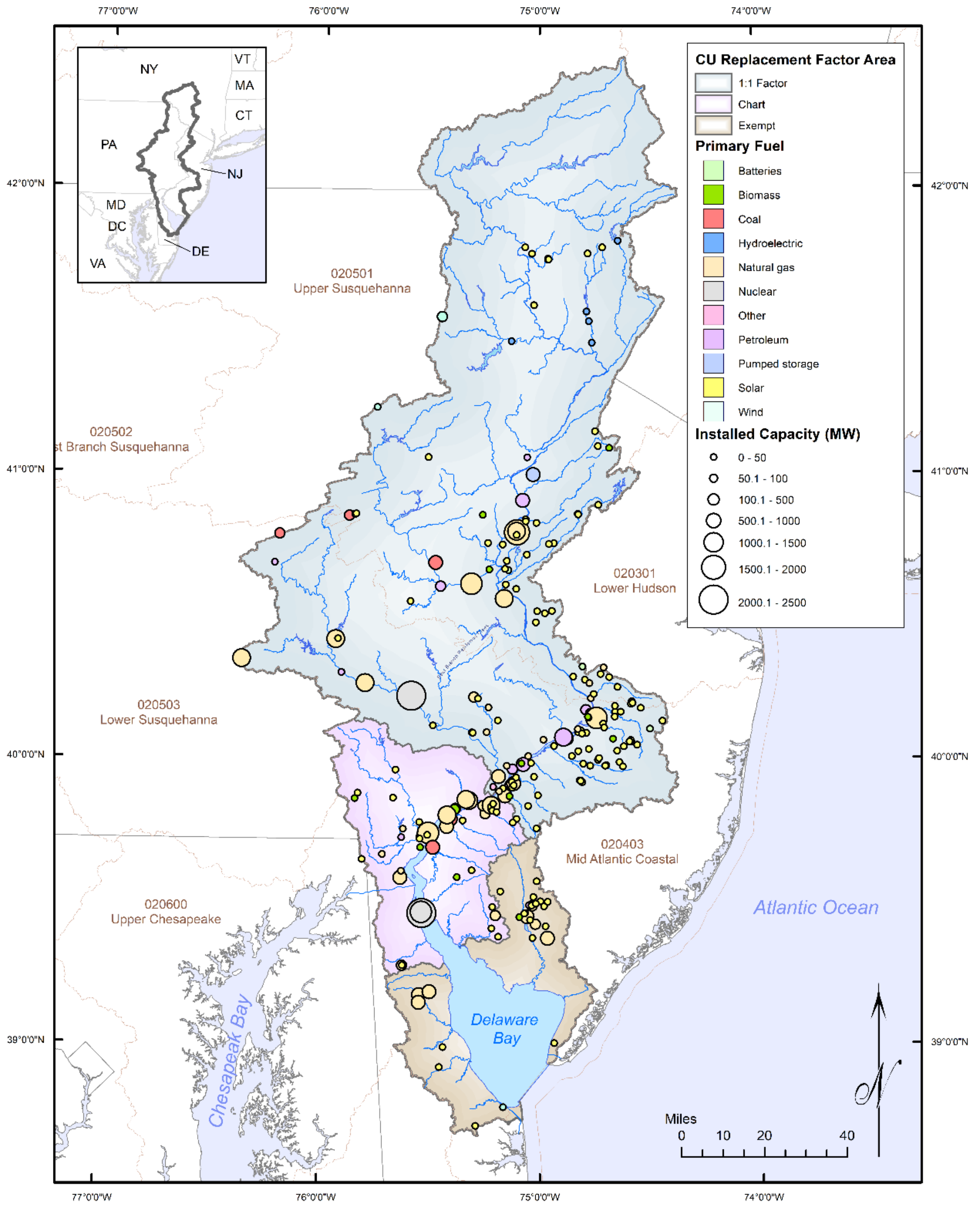


2. Context: a closer look at the DRB

Key notes:

1. There were 234 facilities identified in this shapefile ("active")
   - Need to consider retired facilities in order to provide a complete time-series of net generation
2. Historic **Form EIA-860** annual reports from 2012-2019 allowed identification of 27 more facilities
3. Of the fuel types for power generation, there are two general categories which use water in the DRB:
   - Thermoelectric
   - Hydroelectric
4. Consumptive use is attributed to thermoelectric generation
   - Consumptive use is not considered "equal" in regard to repelling the salt front ("Relative Effect Factor")
   - **Resolution 2018-5**
   - https://www.state.nj.us/drbc/library/documents/WMAC/06212018/pindar_power_consumptive-use_policy.pdf

On to discussing net-generation…



2. Historic power data: Where'd the data come from?

(2001-2019) Utility & Non-utility: ……Monthly data from Forms EIA-906/920/923
(1990-2000) Utility: ……………………………Monthly data from Form EIA-759
(1999-2000) Non-utility: …………………… Monthly data from Form EIA-906 (format differs from 2001)
(1990-1998) Non-utility: …………………… Annual data from Form EIA-867

For the entire county…
(2019 is still "preliminary")

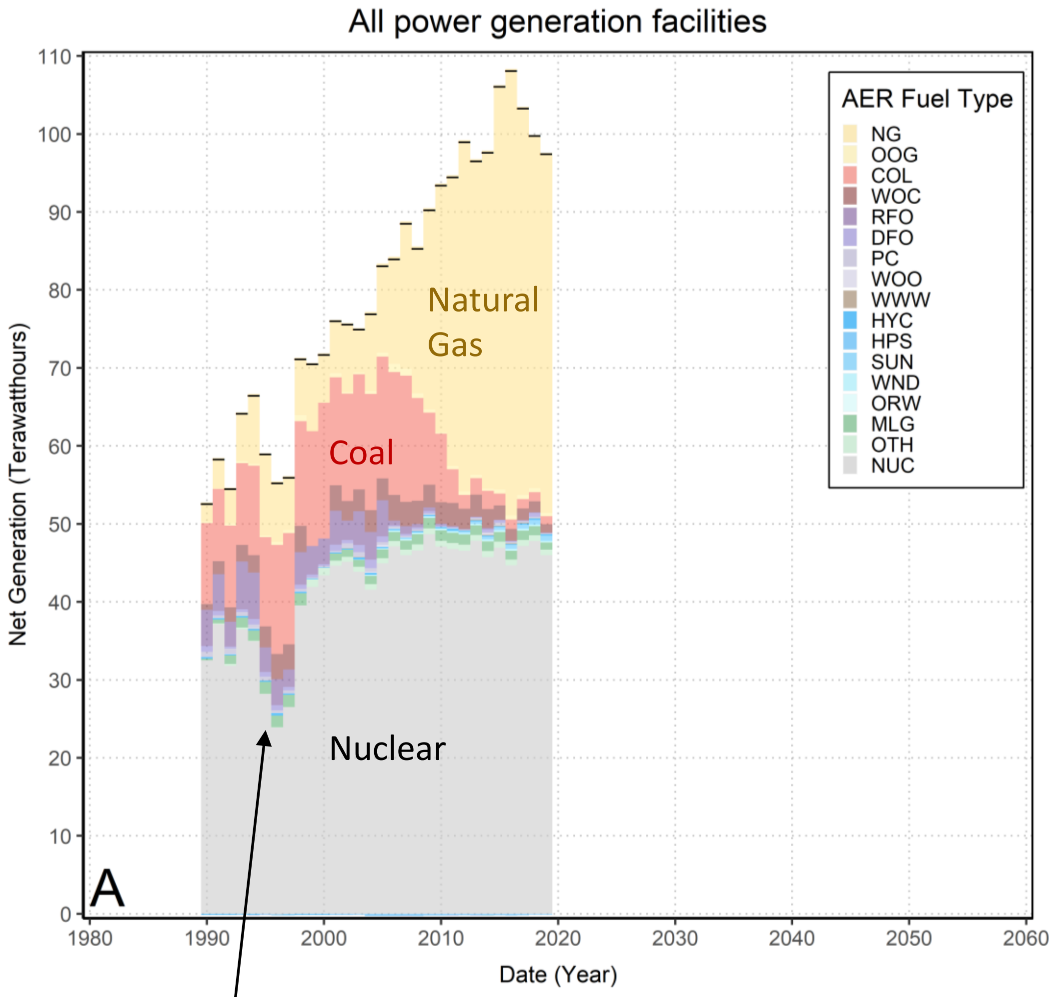
Some additional data prepping needed:

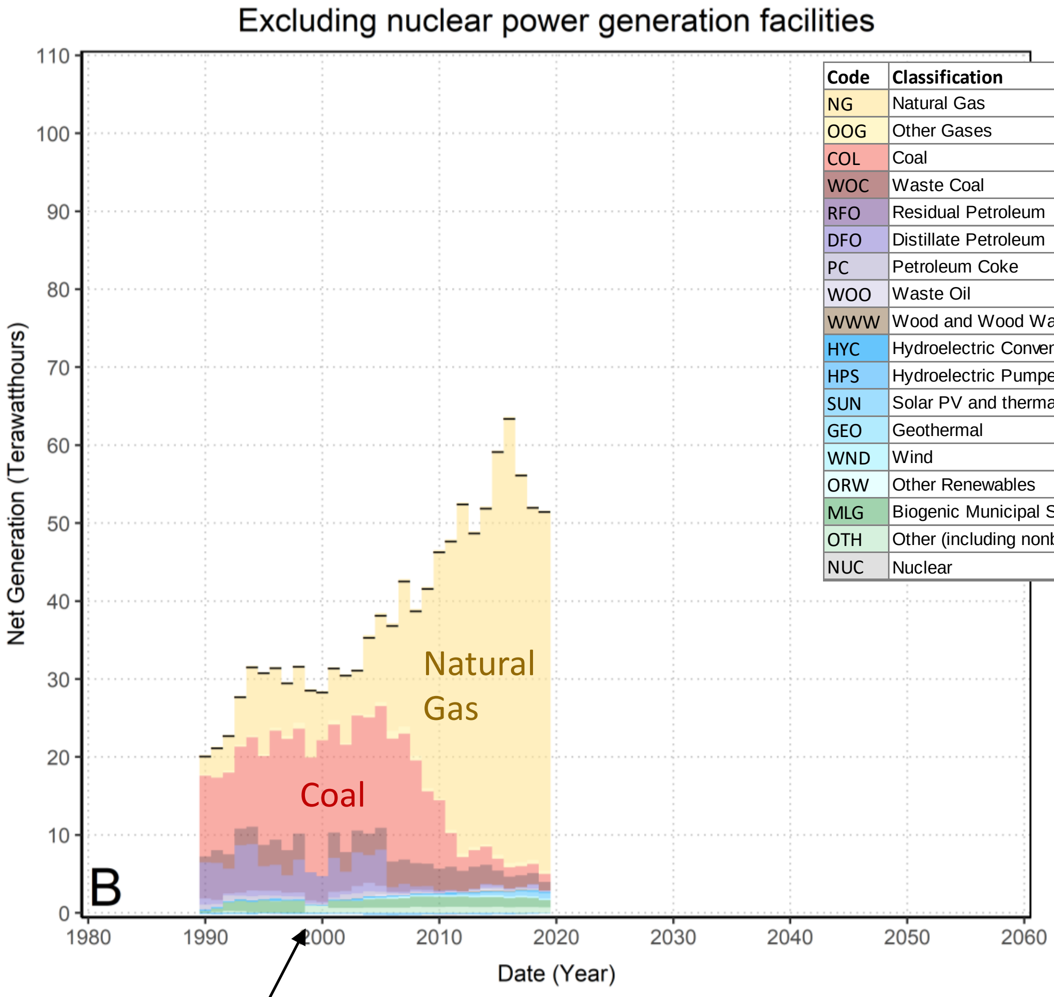
1. Form EIA-759 (1990-2000, utilities) and Form EIA-906 (1999-2000, non-utilities), reported fuel type codes were manually categorized into an AER fuel type codes.
2. Form EIA-906 (1999-2000, non-utilities) primary mover codes were re-classified into current terminology.
3. Primary mover type codes were not available from Form EIA-906 (1990-1998, non-utilities) and Form EIA-906 (2001-2002, utilities and non-utilities).

Energy Information Administration Survey Forms & Data:
https://www.eia.gov/survey/

Peg image obtained from:
https://medium.com/careerschooled/square-peg-round-hole-5e8bcaf14be3

2. Historic power data: DRB-facilities net gen. (AER fuel type)





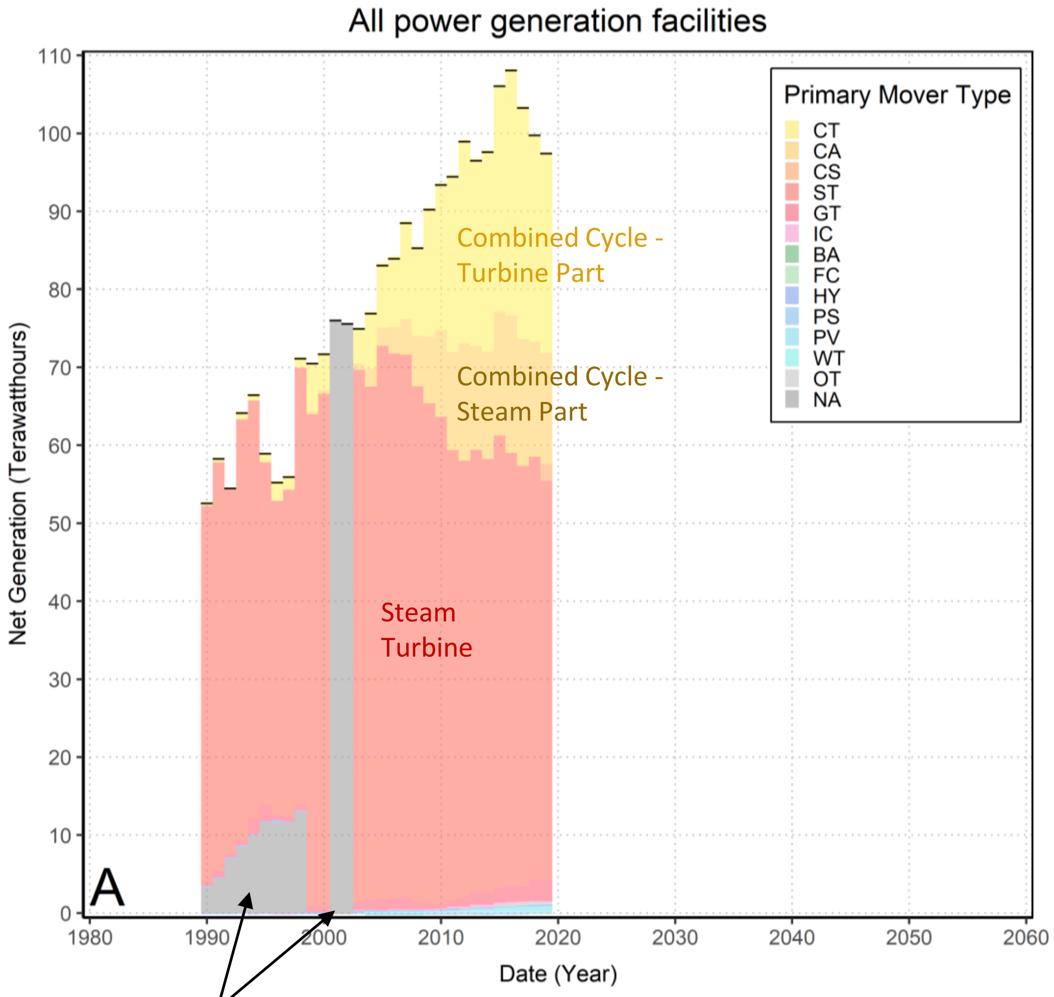
Code	Classification
NG	Natural Gas
OOG	Other Gases
COL	Coal
WOC	Waste Coal
RFO	Residual Petroleum
DFO	Distillate Petroleum
PC	Petroleum Coke
WOO	Waste Oil
WWW	Wood and Wood Waste
HYC	Hydroelectric Conventional
HPS	Hydroelectric Pumped Storage
SUN	Solar PV and thermal
GEO	Geothermal
WND	Wind
ORW	Other Renewables
MLG	Biogenic Municipal Solid Waste and Landfill Gas
OTH	Other (including nonbiogenic MSW)
NUC	Nuclear

Proportions of each facility's net generation to each fuel type are from annual reports.

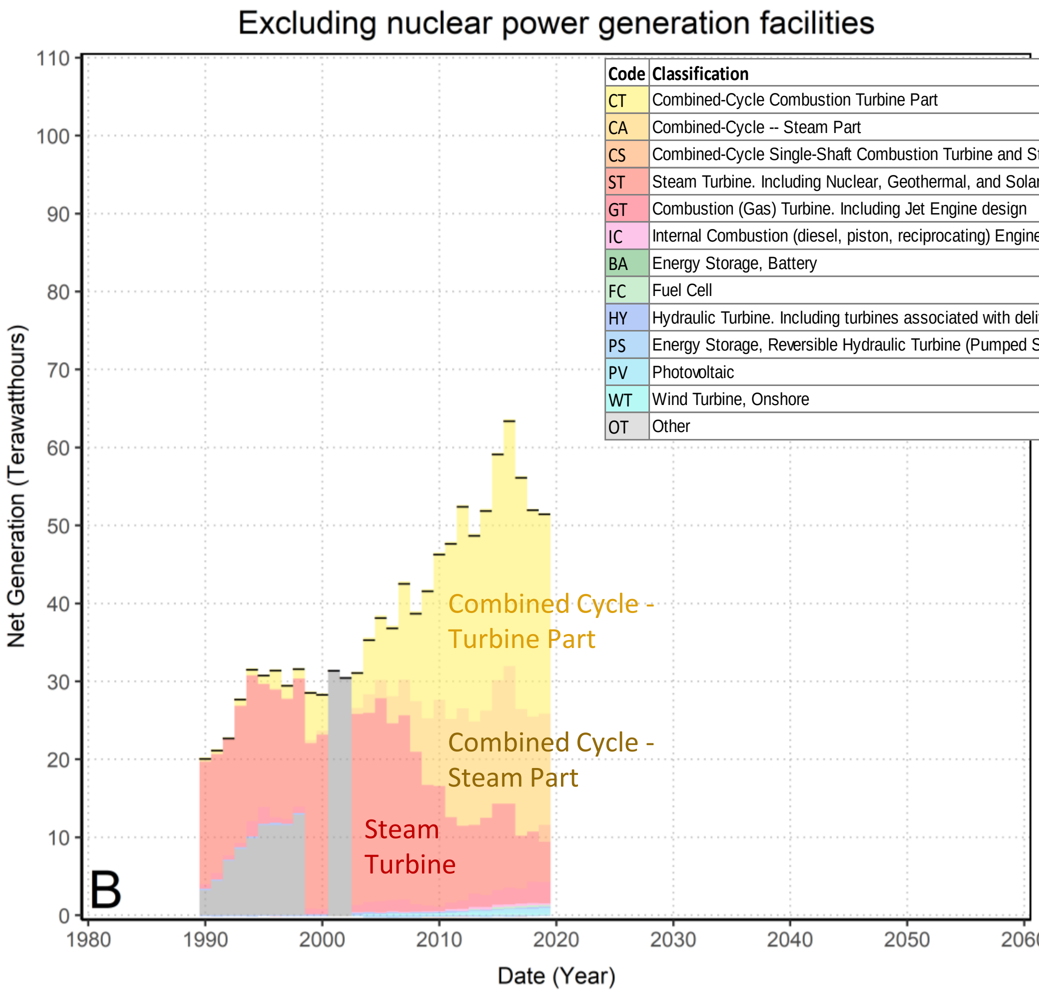
Salem Generating Station temporarily shut down around 1996 (including part of 1995 & 1997)

e.g., no data for “WOC” (1999-2000) due to manual classification of AER fuel types, given the best available data resolution. Likely captured as “COL”

2. Historic power data: DRB-facilities net gen. (primary mover)



Data gaps due to unavailable information reported to EIA forms



Code	Classification
CT	Combined-Cycle Combustion Turbine Part
CA	Combined-Cycle -- Steam Part
CS	Combined-Cycle Single-Shaft Combustion Turbine and Steam Turbine share of single generator
ST	Steam Turbine. Including Nuclear, Geothermal, and Solar Steam (does not include Combined Cycle).
GT	Combustion (Gas) Turbine. Including Jet Engine design
IC	Internal Combustion (diesel, piston, reciprocating) Engine
BA	Energy Storage, Battery
FC	Fuel Cell
HY	Hydraulic Turbine. Including turbines associated with delivery of water by pipeline.
PS	Energy Storage, Reversible Hydraulic Turbine (Pumped Storage)
PV	Photovoltaic
WT	Wind Turbine, Onshore
OT	Other

Proportions of each facility's net generation to each primary mover type are from annual reports.

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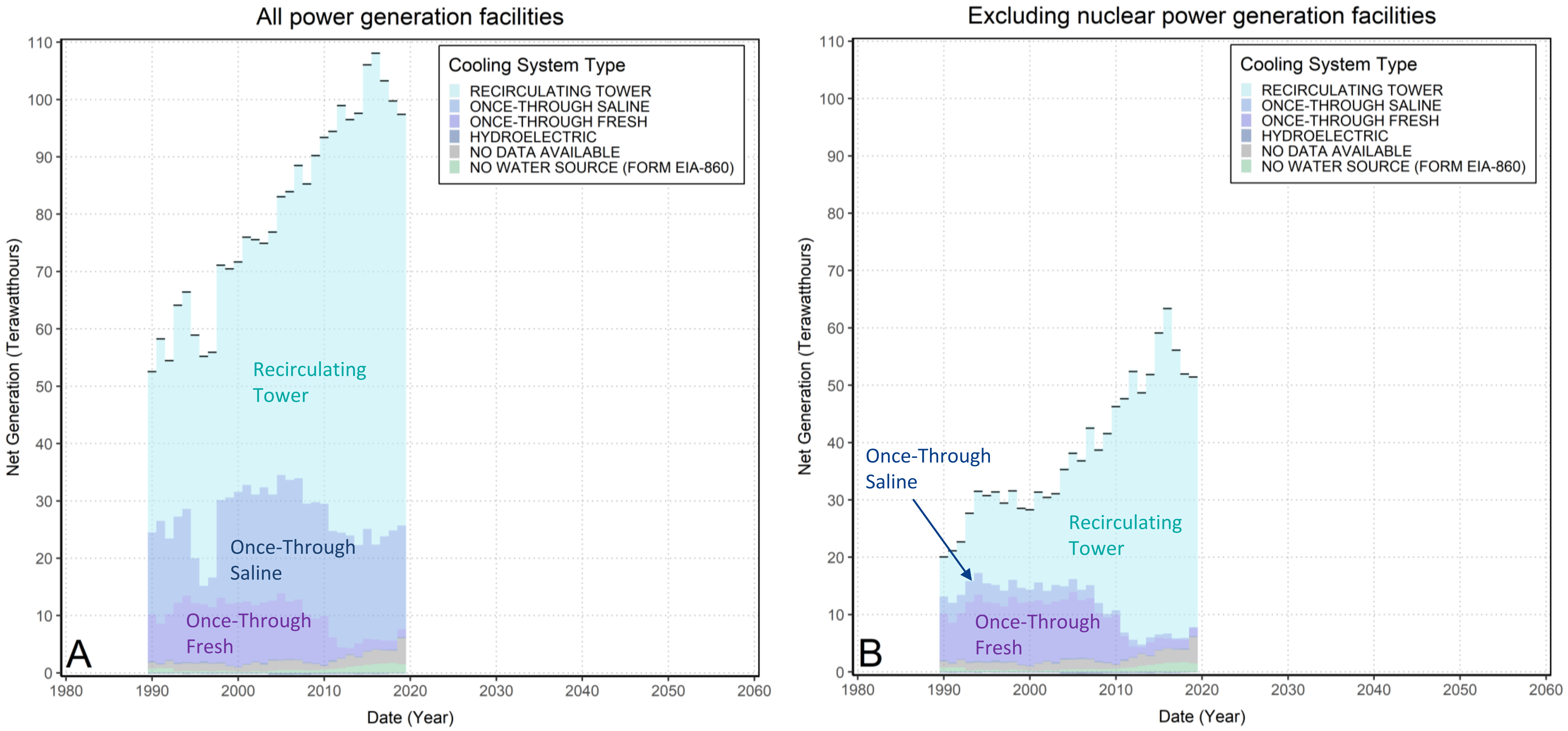
2. Historic power data: DRB-facilities net gen. (cooling system)



A single cooling system classification is assigned to each facility's historic net generation data (i.e., not reported annually).

Cooling system classifications primarily obtained from supplemental data for (Harris & Diehl, 2019). Facilities which were not classified (mainly retired facilities) were classified by DRBC.

Harris, M. A., & Diehl, T. H. (2019). *Withdrawal and Consumption of Water by Thermoelectric Power Plants in the United States, 2015: Scientific Investigations Report 2019–5103*. Reston, Virginia. U.S. Geological Survey. https://doi.org/10.3133/sir20195103

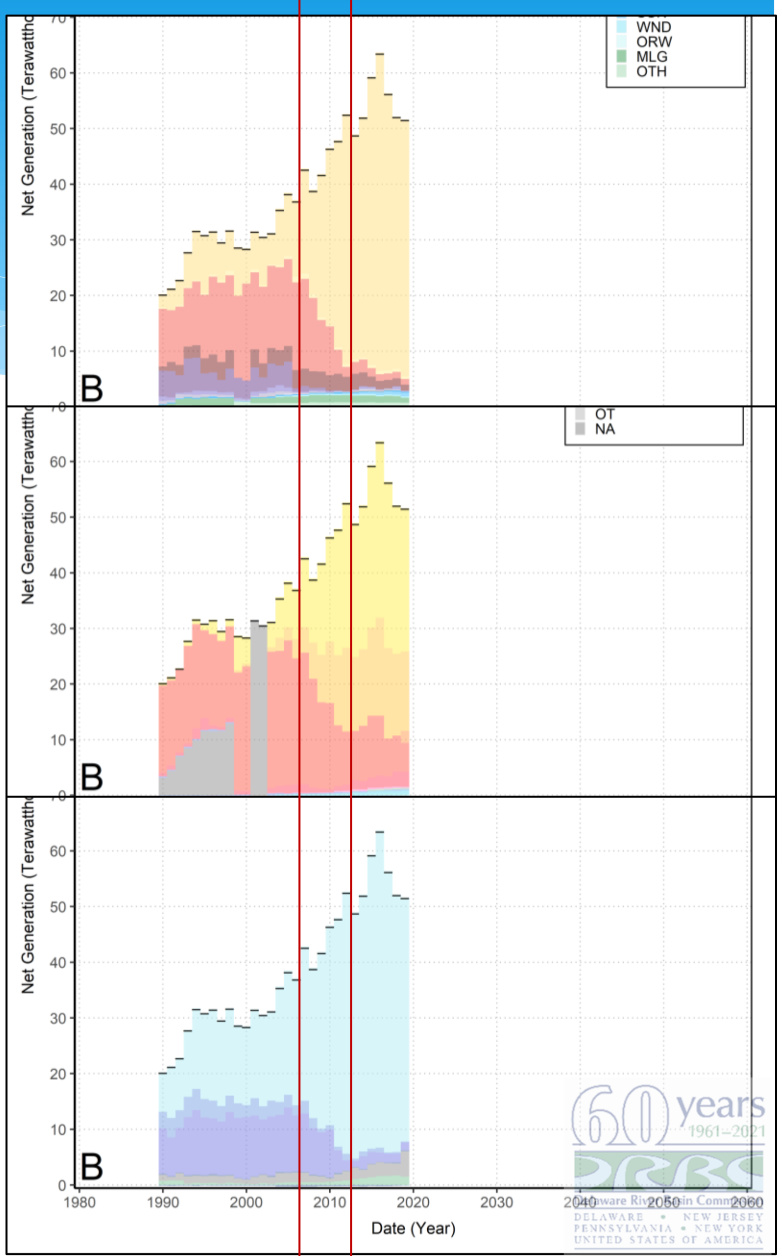
2. Notes on historic DRB net generation

Key notes:

1. In the DRB, total net generation reached a peak of 108.328 Twh in 2016, followed by the largest decrease in recent history (-10.748 Twh), to 97.580 Twh in 2019.
2. As a percent of total **non-nuclear** net generation, DRB decreases in the following categories are observed from 2007-2012:
   - i. AER Fuel Type “COL” (coal) decreased from 38.0% to 3.4%
   - ii. Primary Mover “ST” (steam turbines) decreased from 55.4% to 18.2%
   - iii. Once-through freshwater cooling decreased from 24.6% to 3.5%
   - iv. Counter to findings reported by (Harris & Diehl, 2019) for 2010-2015 where the national net generation decreased ~7%, the DRB increased ~13.6%
3. However, (Harris & Diehl, 2019) also reported:
   - i. For 2008 through 2017, 47% of total retired generation capacity was from coal-fired power plants, and 26% were NG steam turbines (EIA, 2018)
   - ii. More than half the plants which became active were NGCC, all but one with recirculating cooling system

These are notes based on observations of reported data. It is understood that regulations such as Clean Air Act, Clean Water Act and market forces have influenced the observed trends; however, it is not in the scope of this study to determine such cause-and-effect relationships.

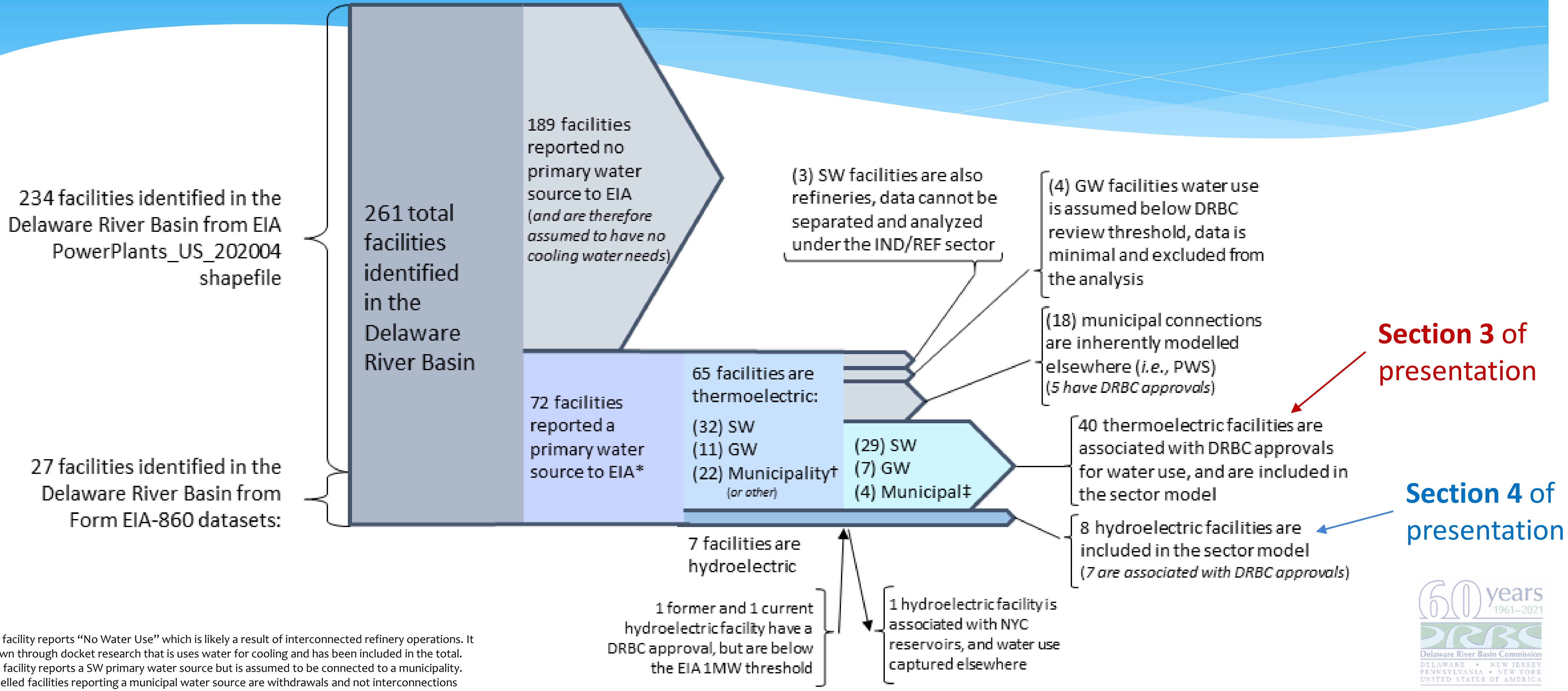
Timeframe between lines: 2007-2012



Non-nuclear facilities

USEIA. (2018). Almost all power plants that retired in the past decade were powered by fossil fuels. U.S. Energy Information Administration. https://www.eia.gov/todayinenergy/detail.php?id=34452

2. Linking energy and water withdrawal data (Sankey diagram)

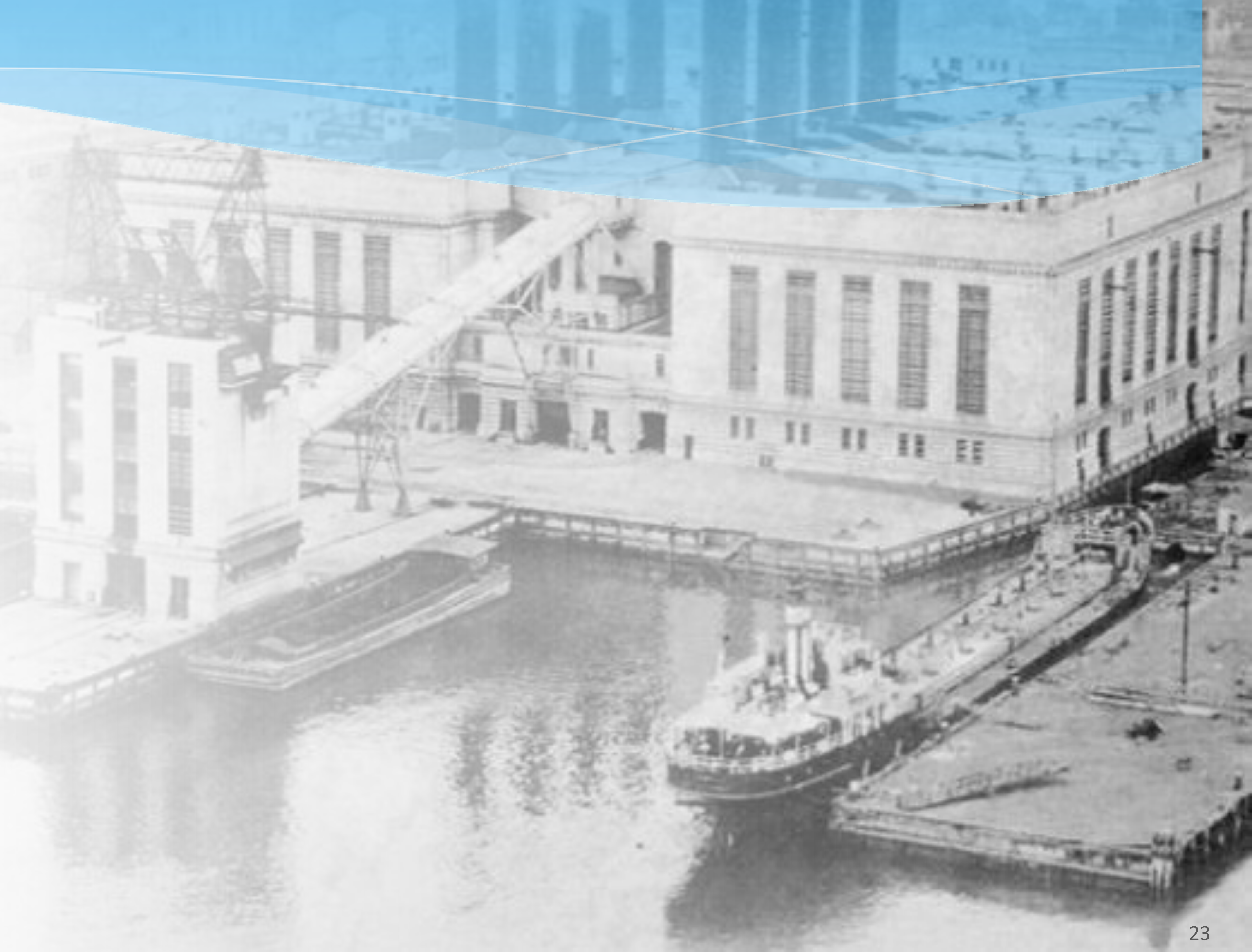


* One facility reports "No Water Use" which is likely a result of interconnected refinery operations. It is known through docket research that is uses water for cooling and has been included in the total.
† One facility reports a SW primary water source but is assumed to be connected to a municipality.
‡ Modelled facilities reporting a municipal water source are withdrawals and not interconnections (e.g., withdrawal of a municipal effluent stream).

3. Thermoelectric water withdrawals & projection

"Today's 50-year projections are not the ones which will be used 10 to 40 years hence. The planning process is continuously building on the best information obtainable."

- DRBC Comprehensive Plan, 1973



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Photograph of PECO Delaware Generating Station, obtained from https://www.phillyvoice.com/fishtowns-peco-delaware-station-nominated-historic-register/

3. Thermoelectric: characterizing water withdrawals

Initial notes:

1. From the energy analysis with EIA data, it is fairly well established that only a few facilities withdrawing water are unassociated with DRBC approvals, and below the review threshold.
2. The 40 facilities being modeled here have the average characteristics provided in the table (1990-2017) under "Associated"
3. More than 99% of water withdrawn for thermoelectric purposes in the DRB are surface water, and regulated
4. Unassociated data (assumed below the review threshold) is not considered in this analysis

ALL DATA PRESENTED IS CONSIDERED PRELIMINARY AND SUBJECT TO CHANGE PRIOR TO FINAL PUBLICATION

Data Category	System level identifier* (OAID)	Water Type	Source level identifier (WSIDs)	Avg. WD (MGD)	Percent Total WD
Associated	47	SW	46	4,021.785	99.96%
		GW	41	1.708	0.04%
Unassocaited	7	SW	0	0.000	0.00%
		GW	13	0.063	0.00%
Totals:	54	--	100	4,023.556	100%

Notes:
GW : groundwater
SW : surface water
WD : withdrawal
MGD : million gallons per day

*It is important to note that the number of system level identifiers (OAIDs) will likely not match the number of facilities, as when a facility changes name or ownership, one facility may have multiple sources of data affiliated with it.

Three analyses presented here:

1. All facilities
2. Non-nuclear facilities
3. State-wide aggregations

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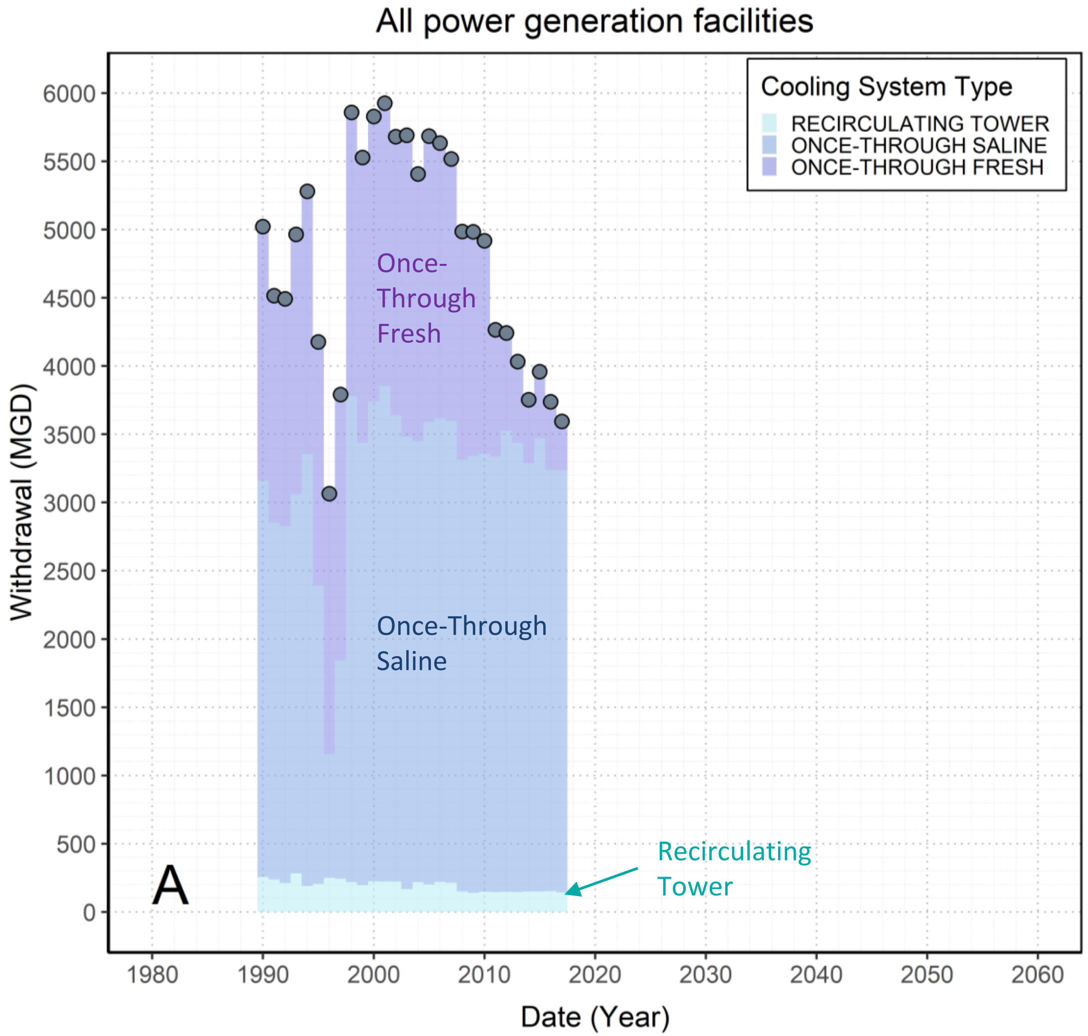
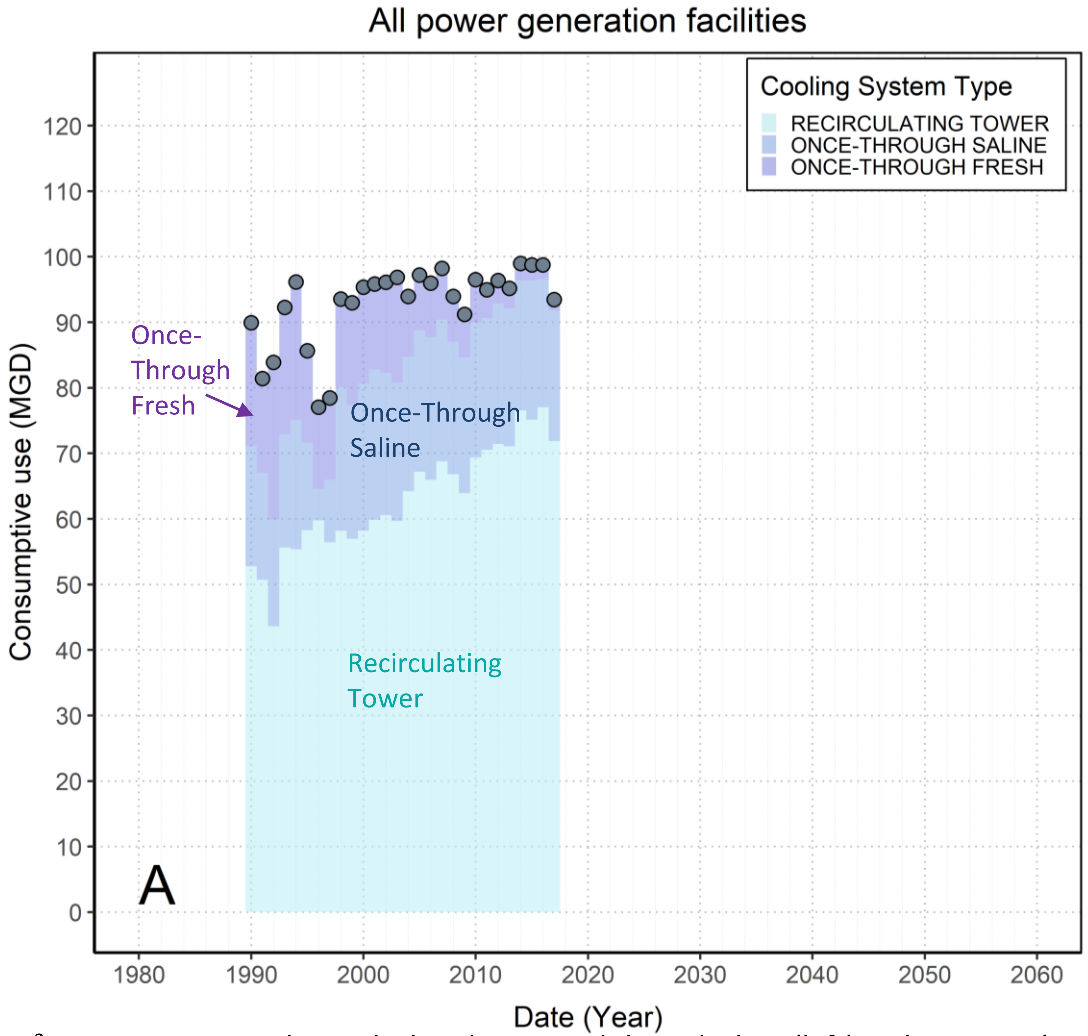
3. Thermoelectric: all facilities

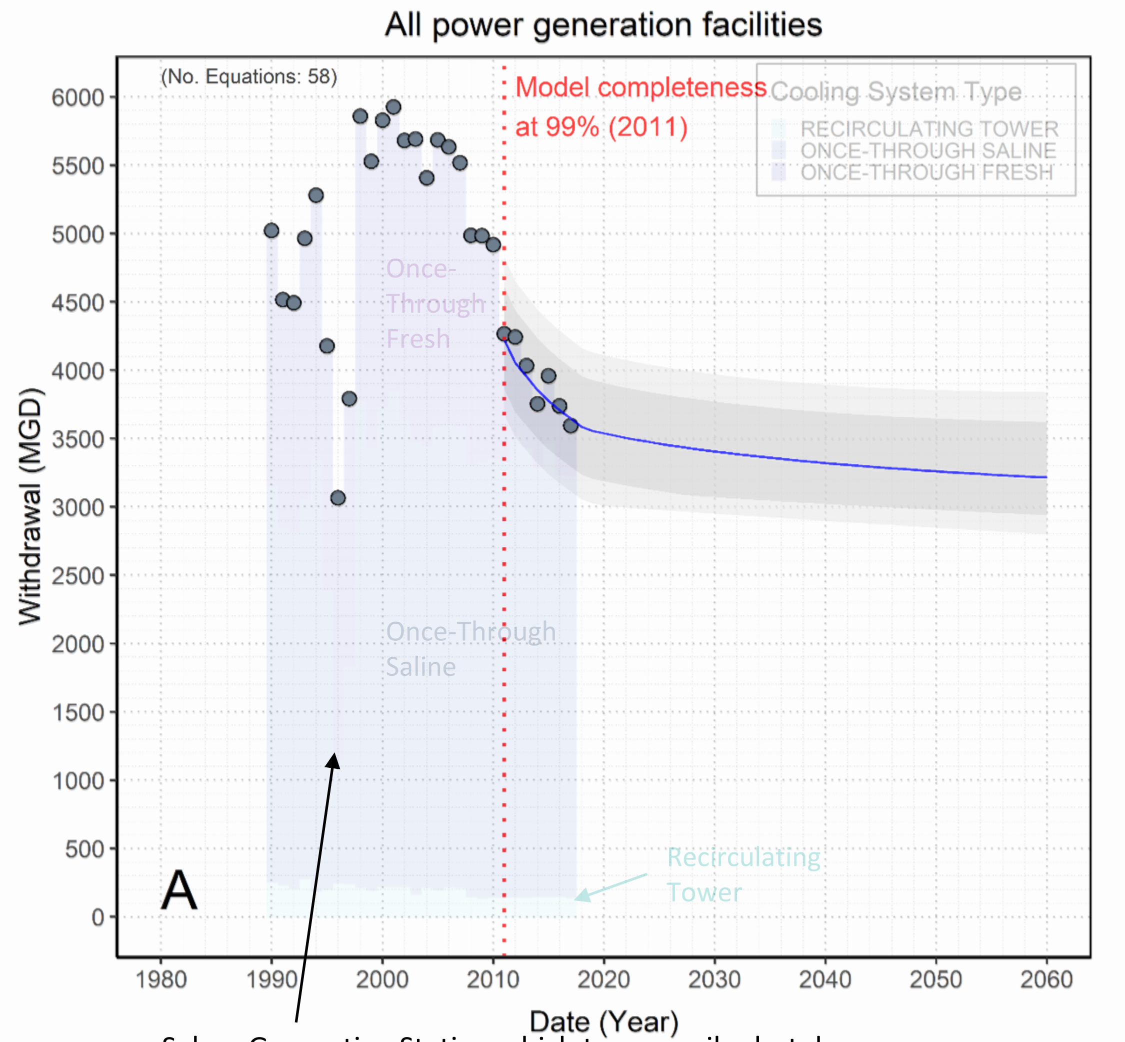




[1] *A single cooling system classification was assigned per facility and applied to historic data sets, under the assumption that cooling systems are not regularly changed.*

[2] *Consumptive use data calculated using withdrawals data (left) and a system (or source) level consumptive use ratio. All surface water withdrawals (aside from 3) had consumptive use ratios calculated based on reported data.*

3. Thermoelectric: all facilities (water withdrawals)



Salem Generating Station which temporarily shut down around 1996, uses once-through saline water cooling (including part of 1995 & 1997)

Regarding withdrawal data:

1. Overall, water withdrawals by thermoelectric facilities appears to have peaked around the year 2000 with a reported annual average of about 5,927 MGD (*in 2001*).
2. The decrease in total withdrawal from 2007-2017: 1,923 MGD (~34.8%)
3. Most decreases associated with facilities using once-through freshwater cooling systems.
4. Findings are generally consistent with those estimated nationally by the model presented in in Harris & Diehl, 2019.

Regarding projections:

1. Projected continued decrease 2017-2060 (430 MGD, 11.7%) with dramatic plateau (non-nuclear facilities)
2. Uneven predictive intervals, skewed higher
(when a predictive interval for an individual facility is calculated to be negative, it is instead taken as zero)

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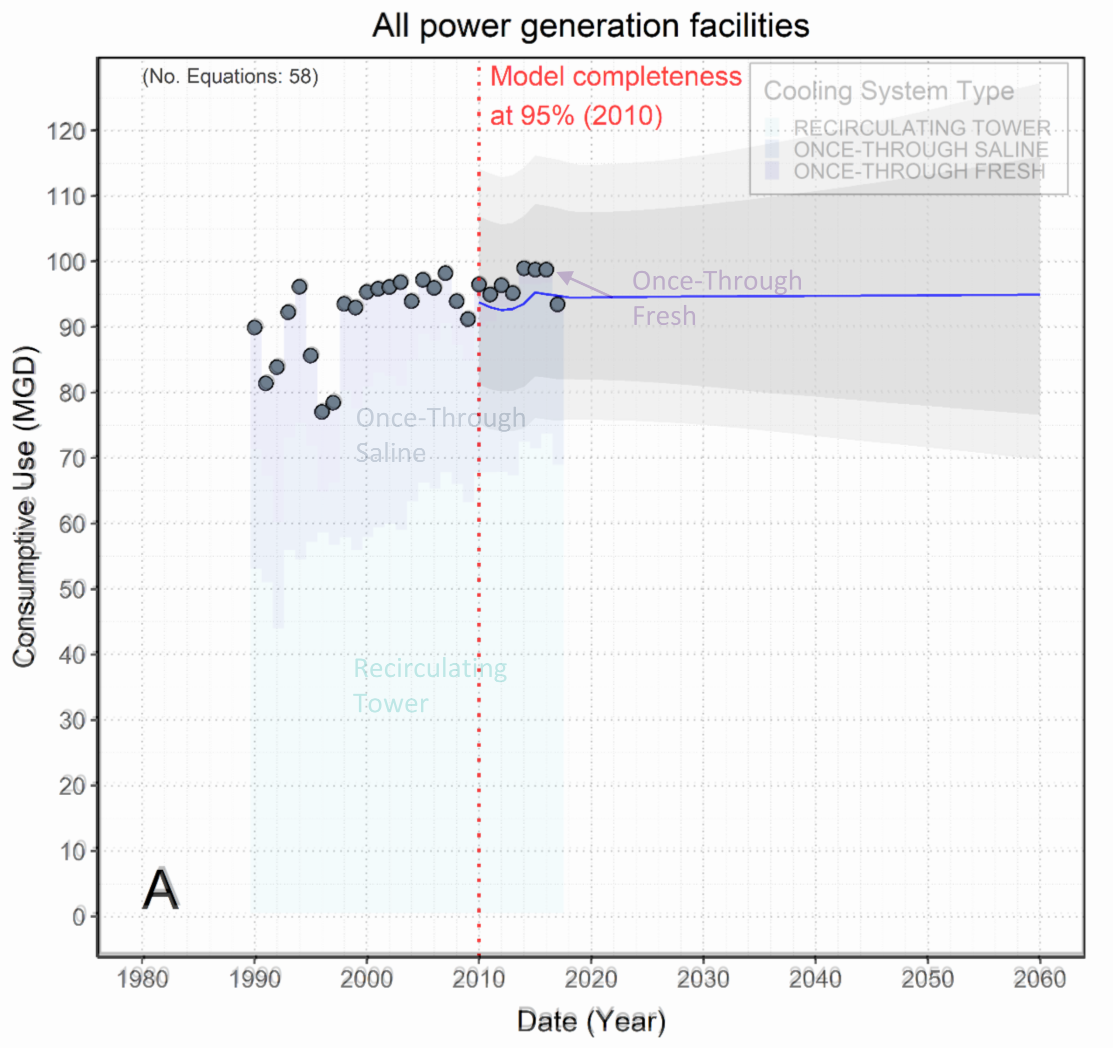
3. Thermoelectric: all facilities (consumptive use)



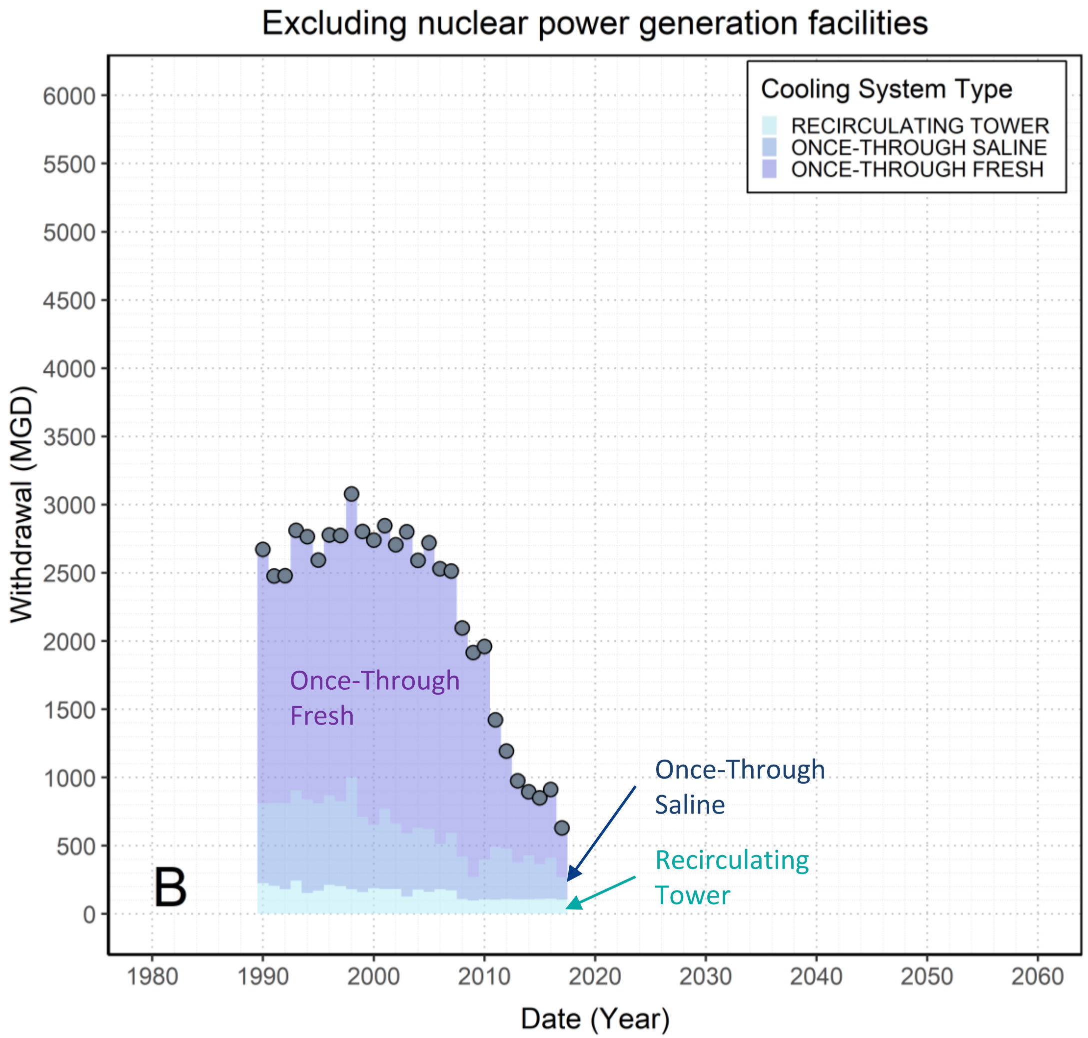
Regarding consumptive use data:

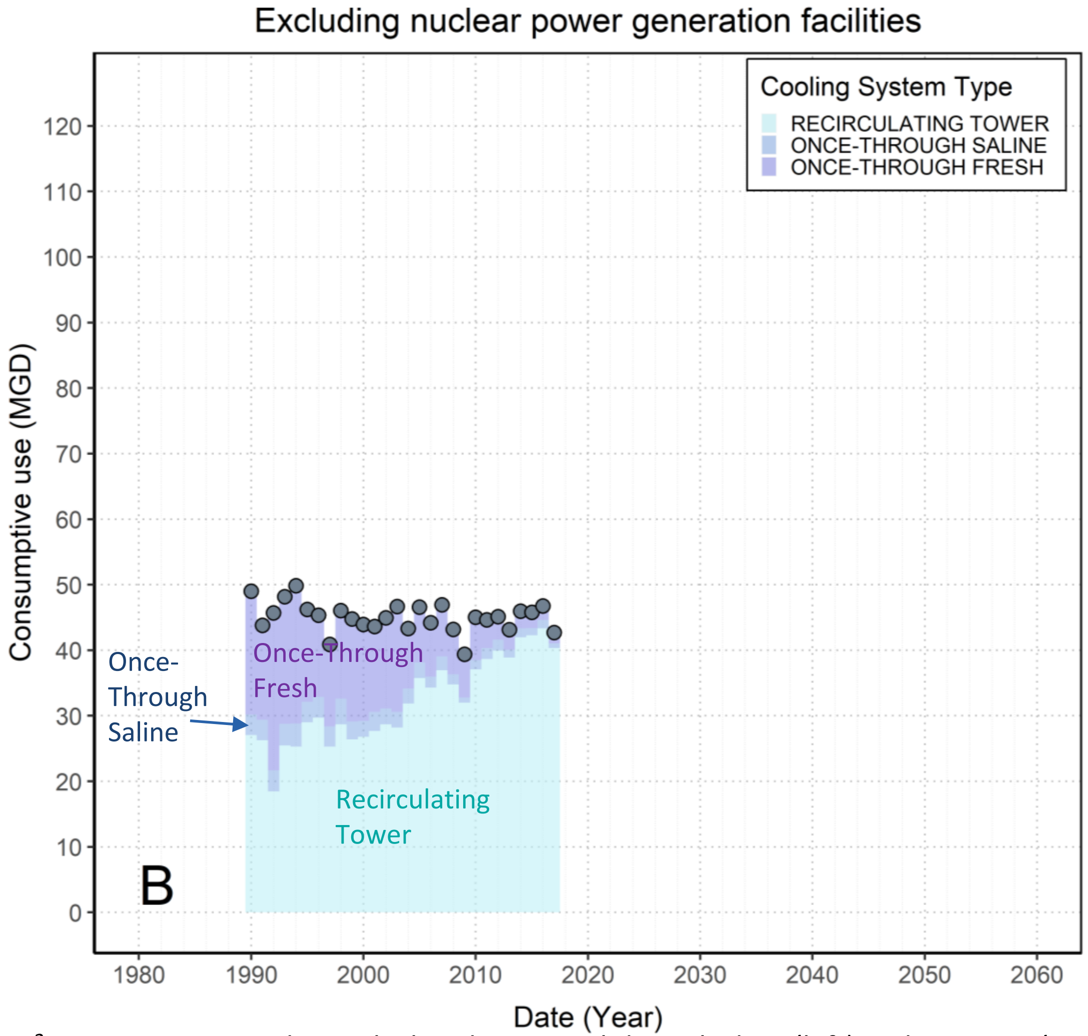
1. Relatively stable over the last 20 years: Average annual value of 95.7 MGD (1998-2017).
2. Consumptive increasingly attributed to facilities using recirculating cooling.
3. Nationally, the model in Harris & Diehl, 2019 estimated that thermoelectric water consumption decreased about 21% between 2010 and 2015. The DRB appears to be counter to the national trend
(*note*: a national trend is likely inherently comprised of many varying sub-trends).

Regarding projections:

1. The same projection equations as total water withdrawal… each projection equation had a CUR applied to it. (The same as calculating the consumptive use data).
2. Aggregated projections create an “average model” of about 93 MGD, predictive intervals relatively symmetric.

3. Thermoelectric: non-nuclear facilities

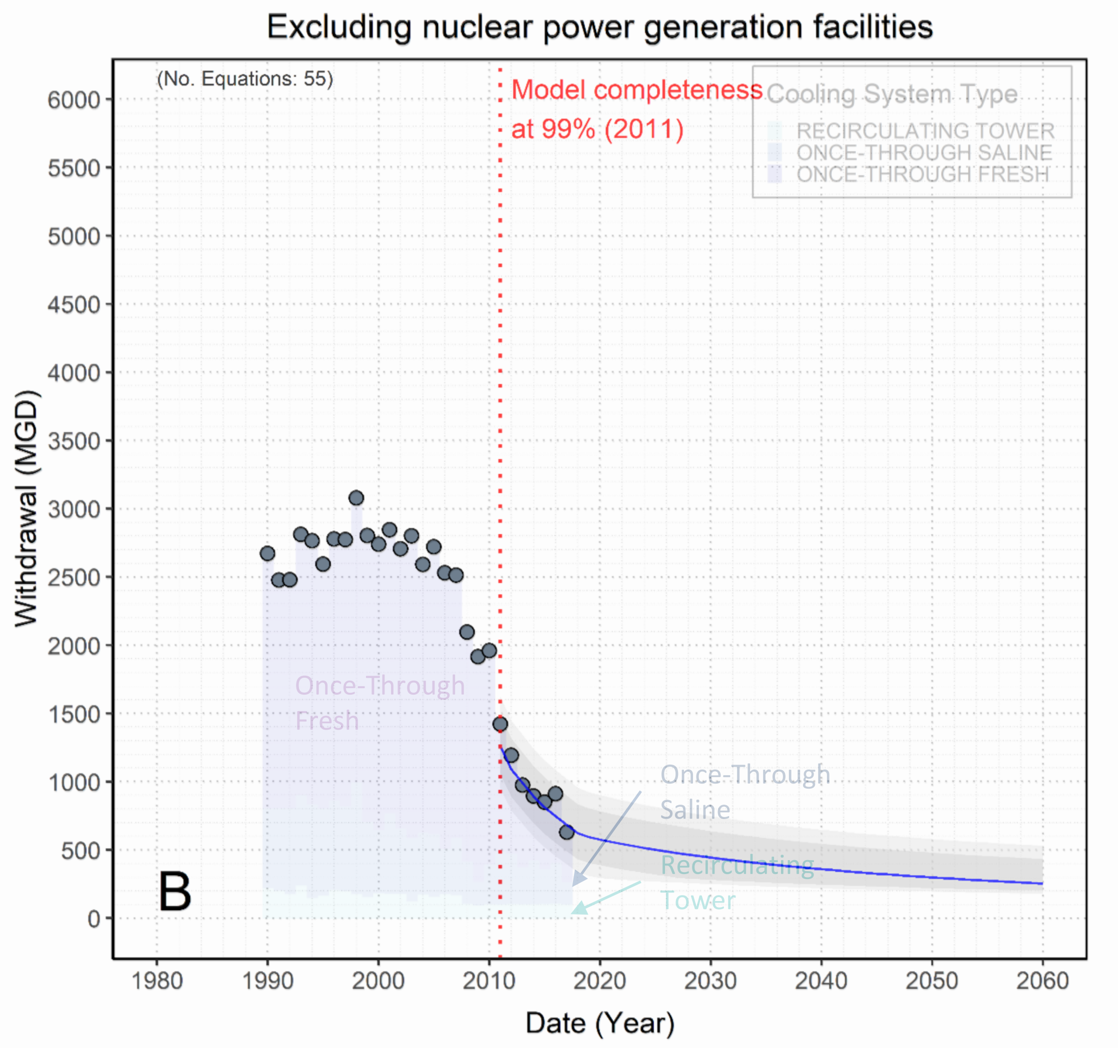




[1] *A single cooling system classification was assigned per facility and applied to historic data sets, under the assumption that cooling systems are not regularly changed.*

[2] *Consumptive use data calculated using withdrawals data (left) and a system (or source) level consumptive use ratio. All surface water withdrawals (aside from 3) had consumptive use ratios calculated based on reported data.*

3. Thermoelectric: non-nuclear facilities (water withdrawals)



Regarding withdrawal data:

1. Water withdrawals by thermoelectric facilities appears to have peaked around the year 2000 with a reported annual average of about 3,078 MGD (*in 1998*).
2. Summary for average data (1990-2007): 2,704 MGD
   i. Recirculating tower: 184 MGD (7%)
   ii. Once-through saline: 563 MGD (21%)
   iii. Once-through fresh: 1,957 MGD (72%)
3. Summary for average data (2013-2017): 852 MGD
   i. Recirculating tower: 107 MGD (13%)
   ii. Once-through saline: 263 MGD (31%)
   iii. Once-through fresh: 481 MGD (56%)
4. Decrease between two periods (items 3 &4): 1,852 MGD (~68.5%)

Regarding projections:

1. Projected continued decrease from 2020 to 2060 by about 56% (-322 MGD), with skewed predictive interval.

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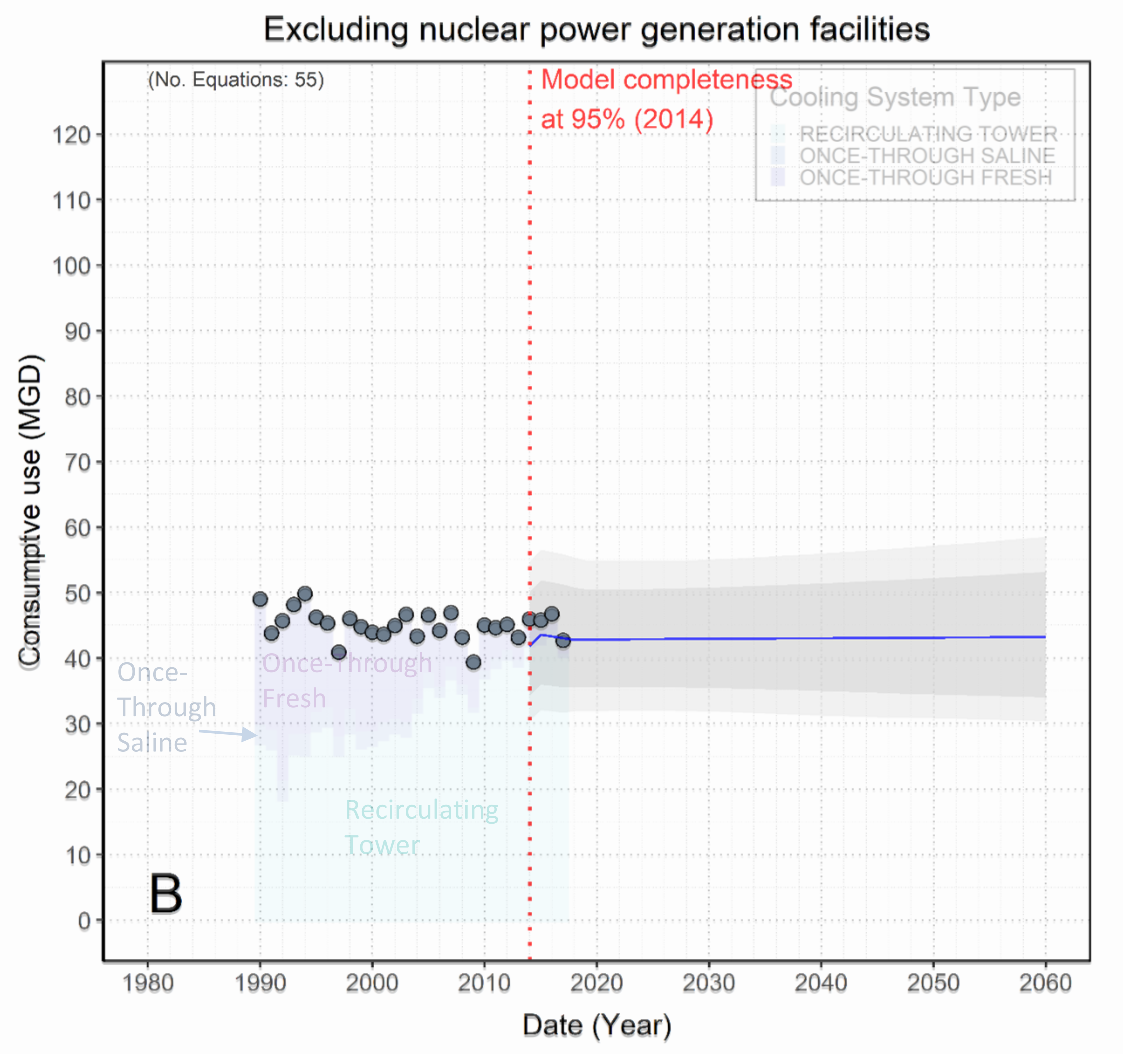
3. Thermoelectric: non-nuclear facilities (consumptive use)



Regarding consumptive use data:

1. Relatively stable over the last 30 years:
   Average annual value of 44.6 MGD (1990-2017).
2. The observed change over time is that consumptive use historically reported by once-through fresh systems is replaced largely by recirculating tower systems.
3. Summary for average data (1990-2007): 45.5 MGD
   i. Recirculating tower: 28.4 MGD (63%)
   ii. Once-through saline: 2.8 MGD (6%)
   iii. Once-through fresh: 14.3 MGD (31%)
4. Summary for average data (2013-2017): 44.9 MGD
   i. Recirculating tower: 44.8 MGD (92%)
   ii. Once-through saline: 1.1 MGD (3%)
   iii. Once-through fresh: 2.4 MGD (5%)

Regarding projections:

1. The same equations as previous slide…
   each projection equation had a CUR applied to it.
2. Creates and "average model" (~43 MGD).

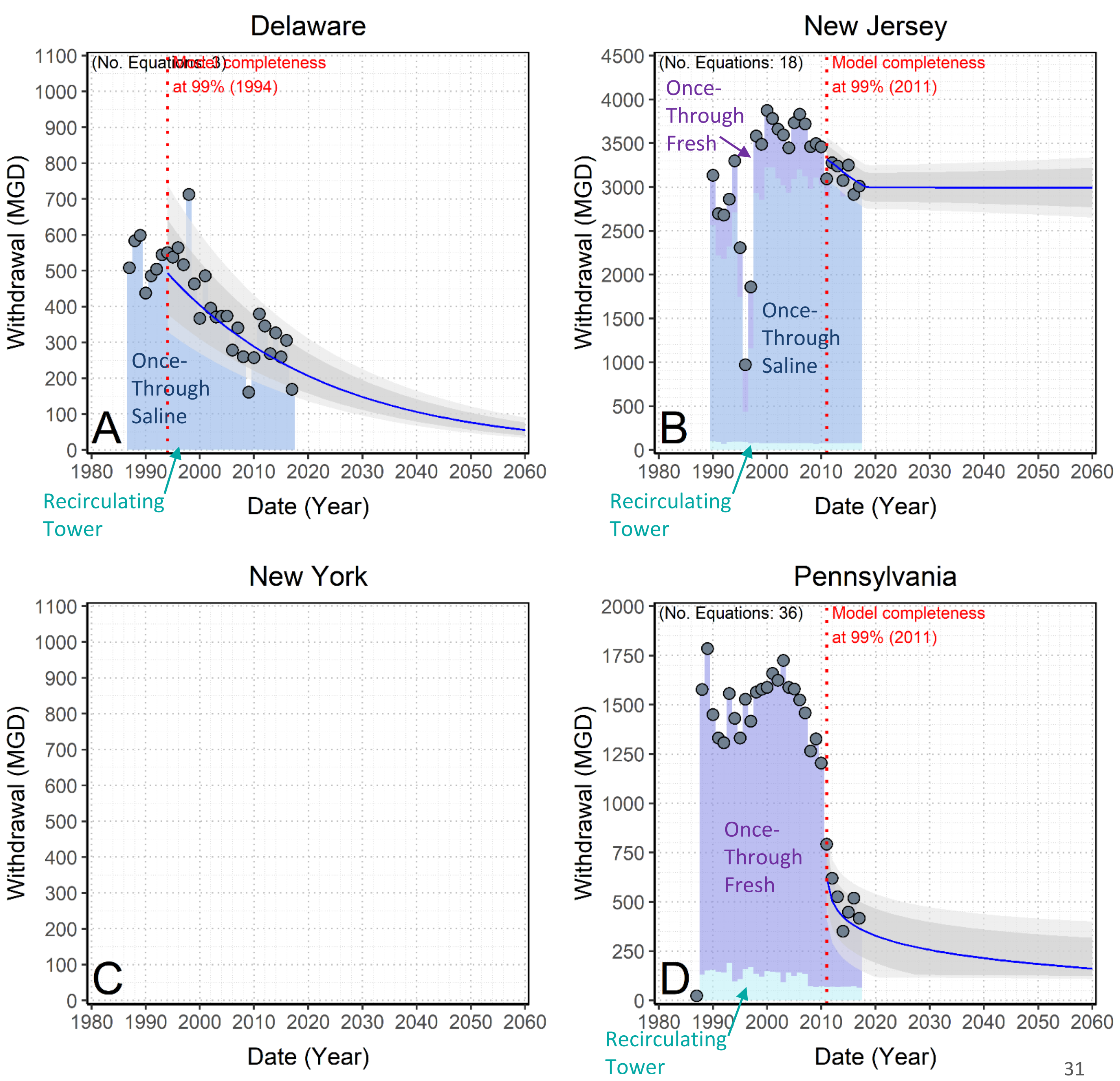
3. Thermoelectric: States

All facilities (withdrawals)

Regarding all power facilities:

1. Assessment can be broken down by state (*shown here as proof of concept*)
2. This form of analysis can also be done excluding nuclear powered facilities (*not shown in this presentation*)
3. There are withdrawals for Recirculating Tower in DE, they are so small they can't be seen
4. **DE & PA**: Continued decline
5. **NJ**: Plateaued decline

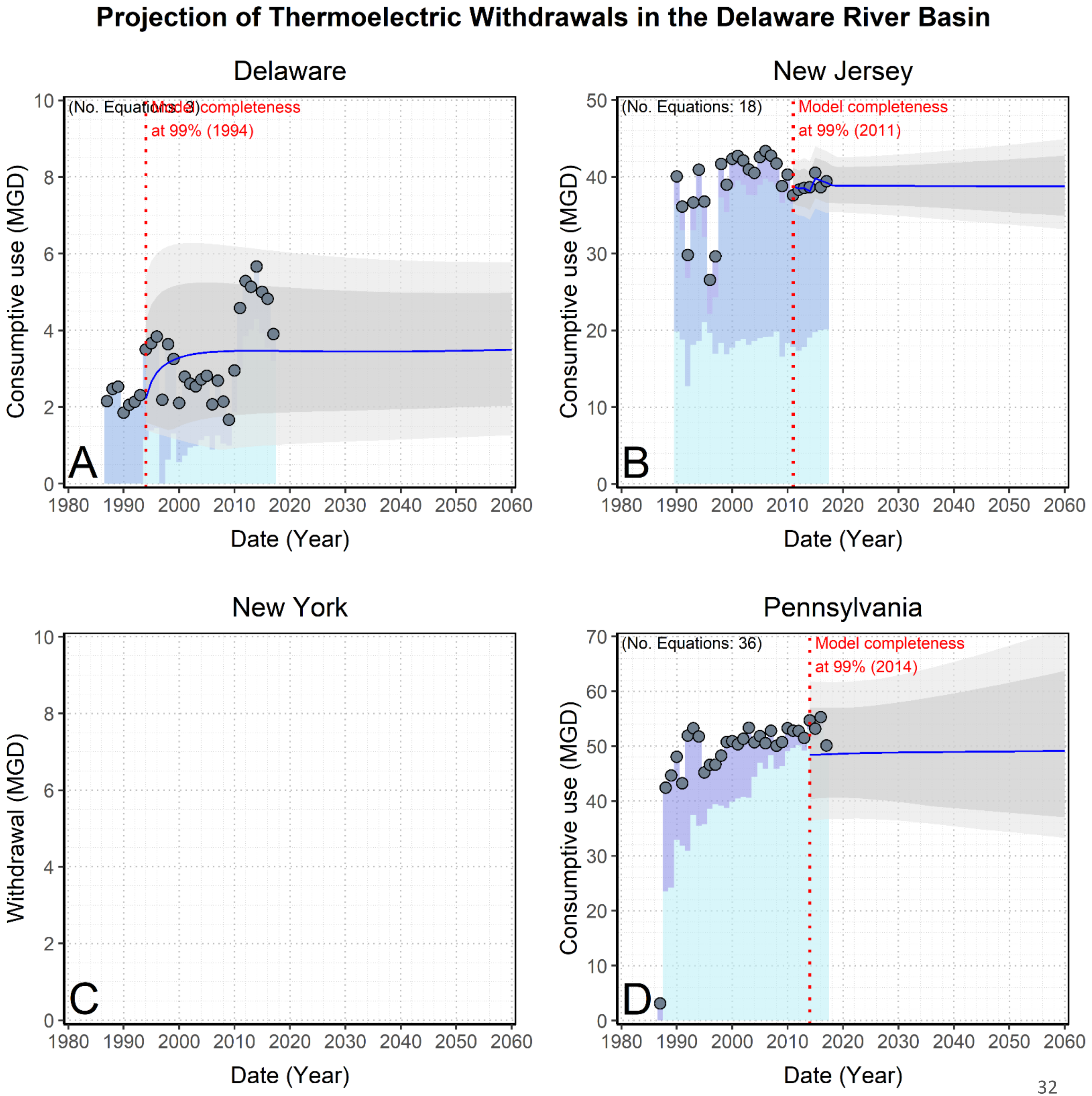
Projection of Thermoelectric Withdrawals in the Delaware River Basin



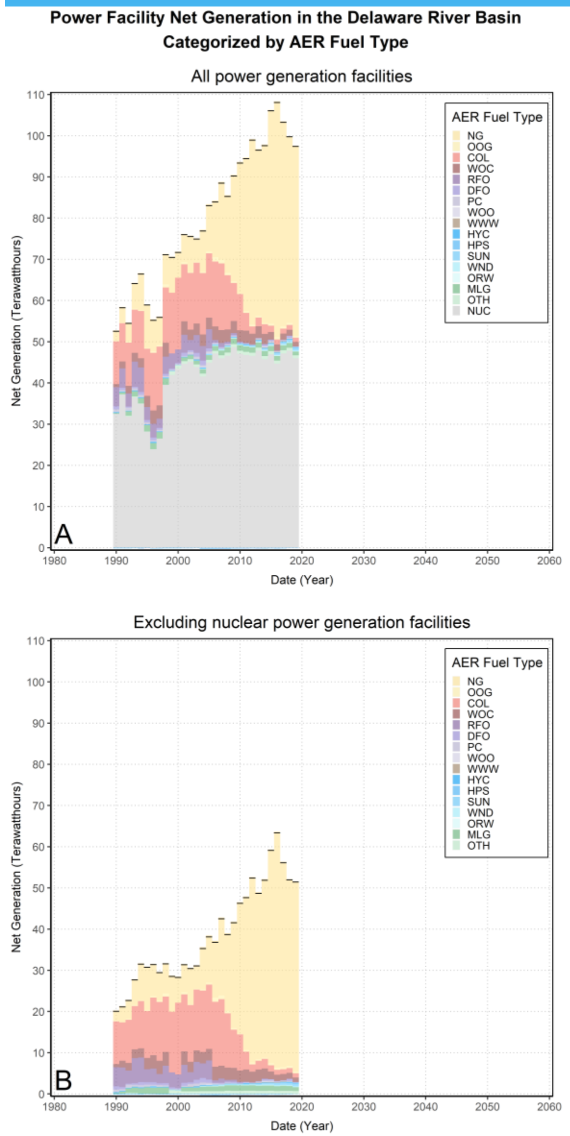
3. Thermoelectric: States
All facilities (consumptive use)

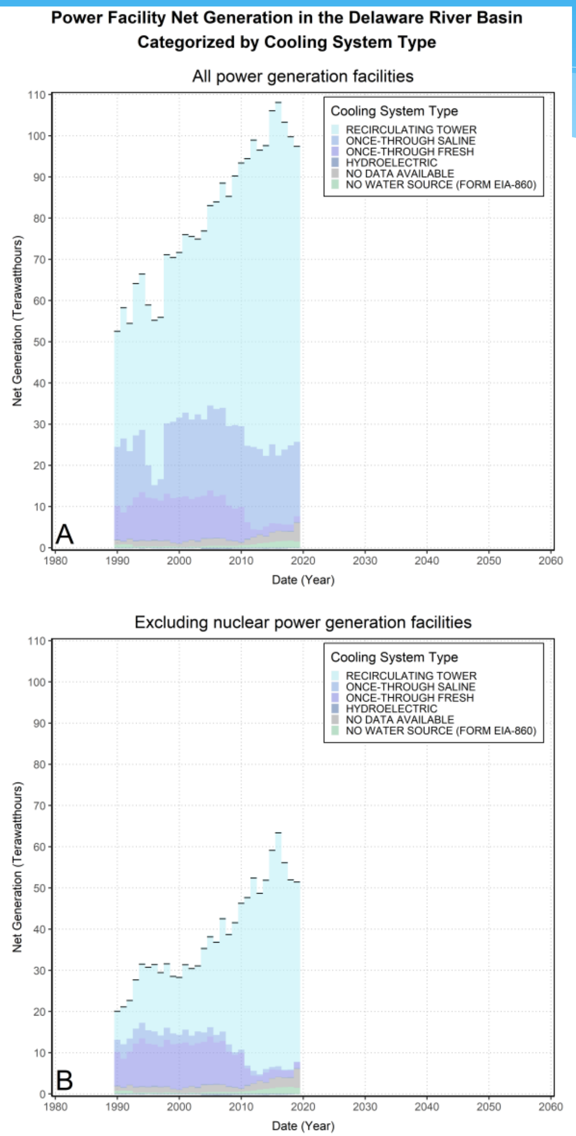
Regarding all power facilities:

1. Same equations shown on previous slide – however, have been multiplied by respective CURs
2. **PA** –Slight underestimate is more pronounced than the withdrawal data. Largest increase in recirculating tower
3. **DE** – Driven by three equations
4. **NJ** – Plateau



3. Thermoelectric: summary and notes (energy generation)





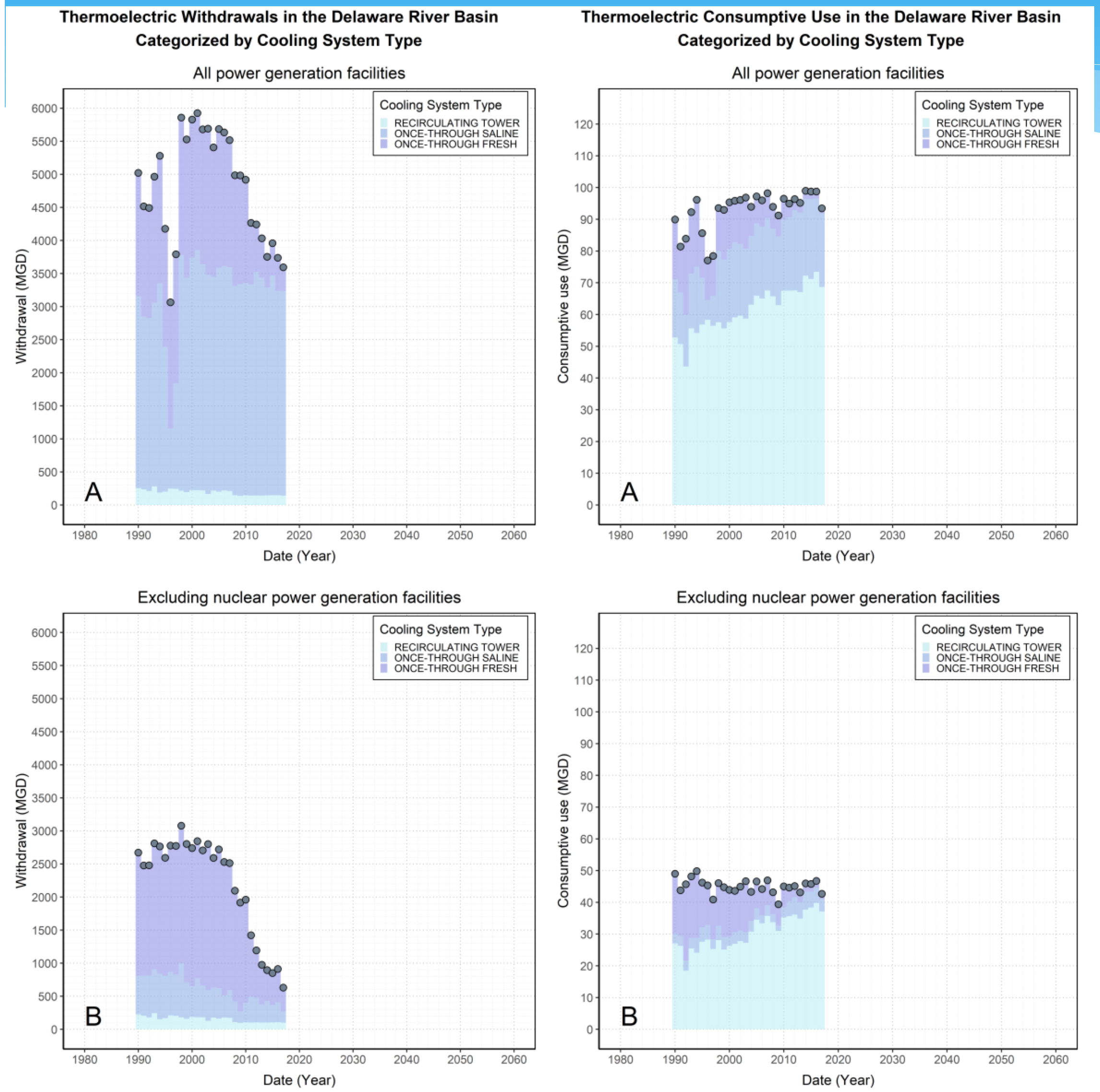
Summary notes on energy generation:

1. The Lower Delaware River Basin is one of the highest installed capacity HUC-6 basins in the country, and is adjacent to the highest (Lower Hudson)
2. Net electricity generation in the basin appears to have "a peak" around 108.328 Twh in 2016. The time-frame 2016-2019 is the largest decline in 20 years.
3. There have been dramatic shifts between 2007-2012 in terms of energy generation technology (shifts from coal-fired steam boiler units using once-through cooling).
4. Future trends may be impacted by state initiatives
   - NJ Offshore Wind Strategic Plan; 7,500 MW by 2035
   - NJ Renewable Portfolio Stds; 50% by 2035
   - DE Renewable Energy Portfolio Stds; 25% by 2025

Relevant links:

https://www.nj.gov/bpu/pdf/Final_NJ_OWSP_9-9-20.pdf
https://nj.gov/dep/aqes/opea-clean-energy.html
https://dnrec.alpha.delaware.gov/climate-coastal-energy/renewable/portfolio-standards/

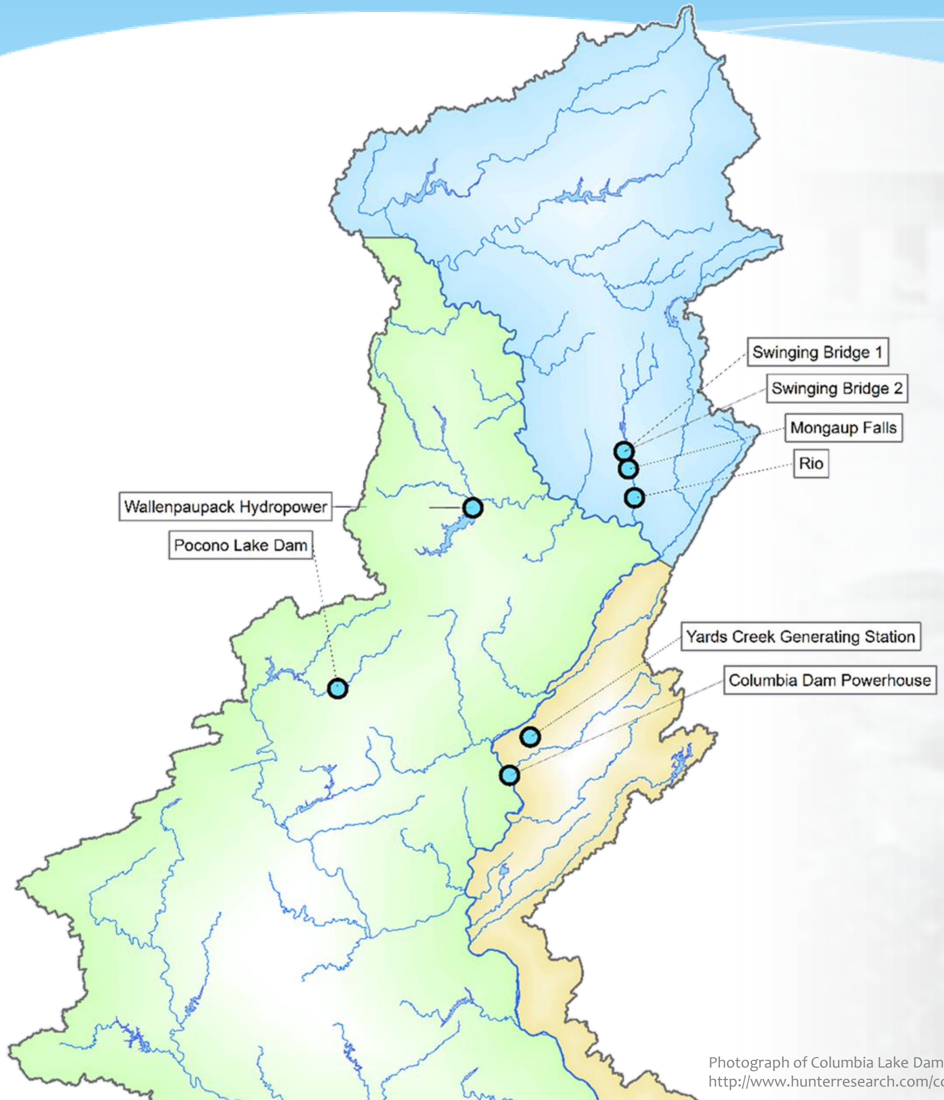
3. Thermoelectric: summary and notes (water withdrawals)



Summary notes on water withdrawals:

1. Water withdrawals by thermoelectric facilities appear to have peaked around the year 2000:
    1. 5,927 MGD in 2001 (all facilities)
    2. 3,081 MGD in 1998 (non-nuclear facilities)
2. Total water withdrawals showed decrease corresponding to net generation, namely from non-nuclear facilities which used once-through freshwater cooling.
    i. Projections of total withdrawal indicate continued slight decreases, attributed to non-nuclear generation facilities. Predictive intervals are skewed, having a wider upper predictive range.
3. Consumptive use remains relatively constant, with an increasing proportion attributed to higher-consumptive facilities using recirculating cooling towers.
    i. Projections of consumptive use remain constant and have symmetric predictive intervals.

4. Hydroelectric water withdrawals & projection



Photograph of Columbia Lake Dam and Powerhouse, obtained from http://www.hunterresearch.com/columbia-lake-dam

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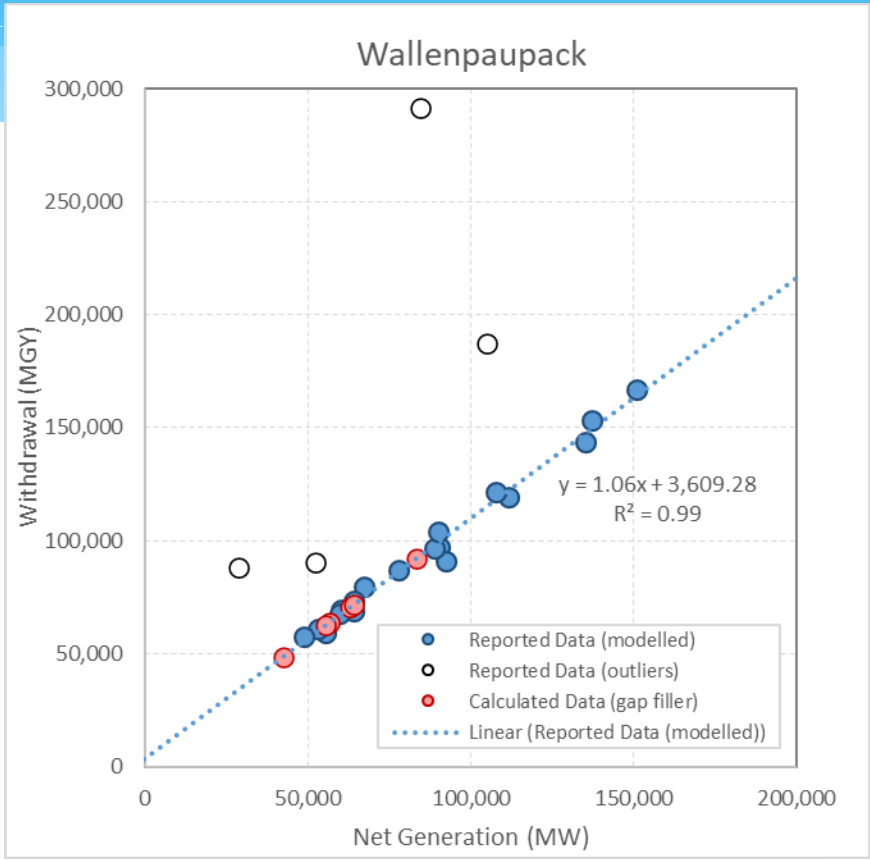
4. Hydroelectric: characterizing water withdrawals

Initial notes:

1. From Sankey Diagram – considering 8 facilities
2. All surface water, and "instream"
3. Some data needs to be estimated based on net generation. This involves either estimating water withdrawals based on:
   i. A relationship between net generation data and available historic water withdrawal data.
   ii. Net generation data and generating unit specifications (e.g., performance curves).
4. Back on Slide 18, net generation for the Basin in 2016:
   i. All fuel types: 108.328 Twh
   ii. Thermoelectric: 106.791 Twh (98.58 %)
   iii. Hydroelectric: 0.078 Twh (0.07 %)



ALL DATA PRESENTED IS CONSIDERED PRELIMINARY
AND SUBJECT TO CHANGE PRIOR TO FINAL PUBLICATION

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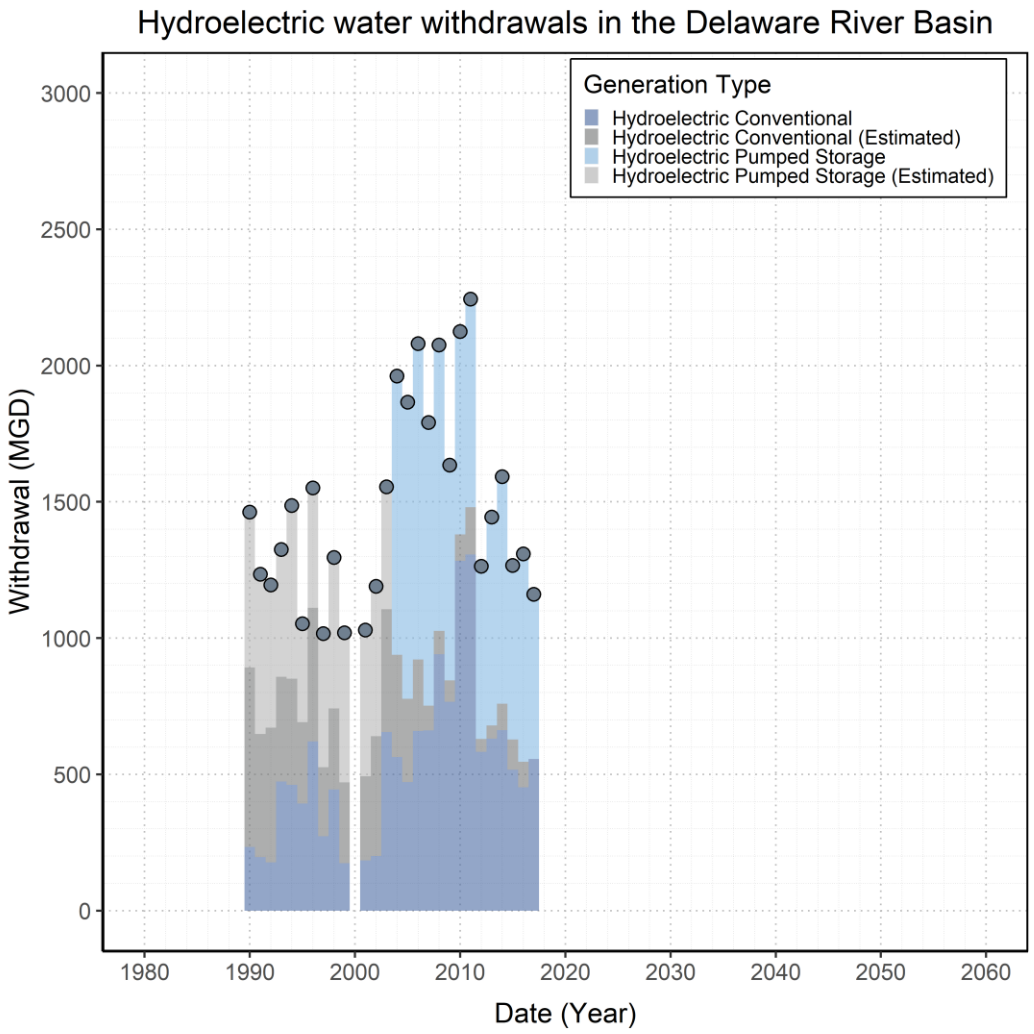
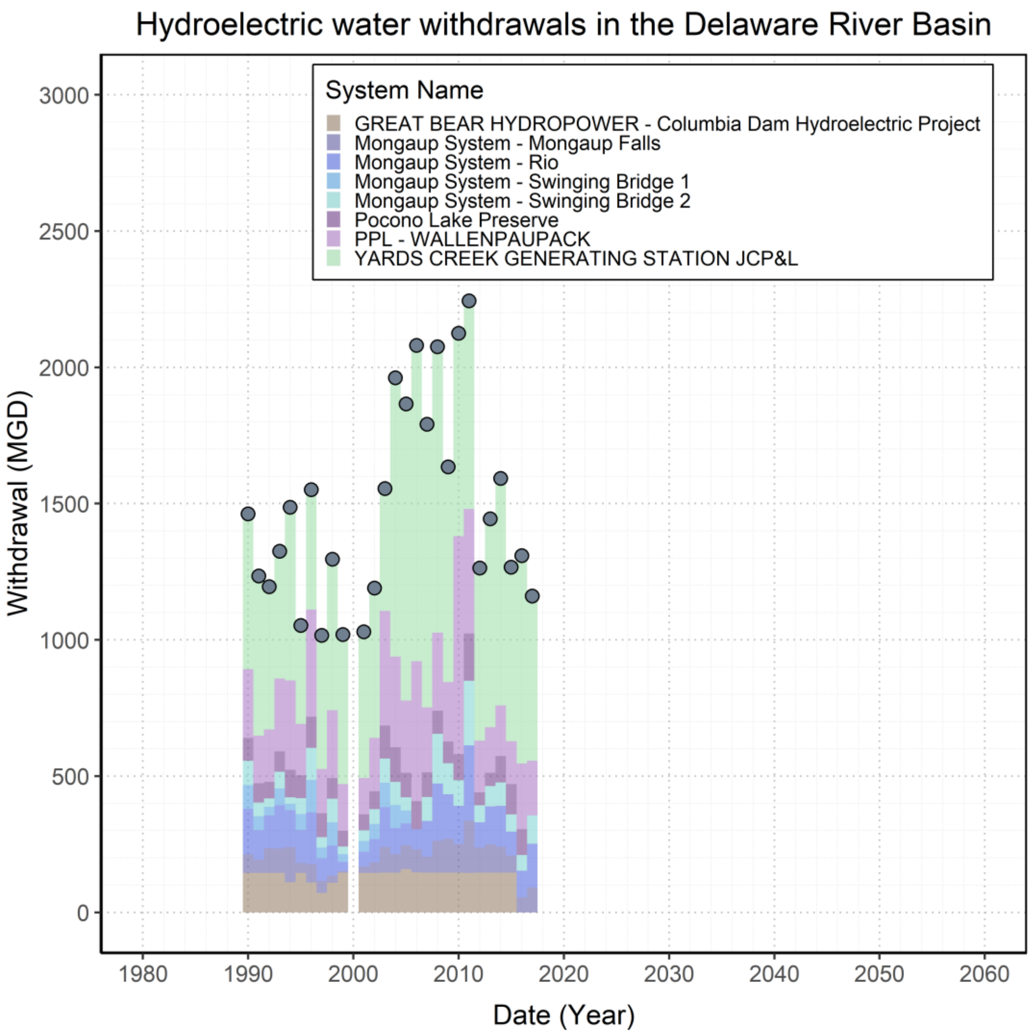
4. Hydroelectric: water withdrawals

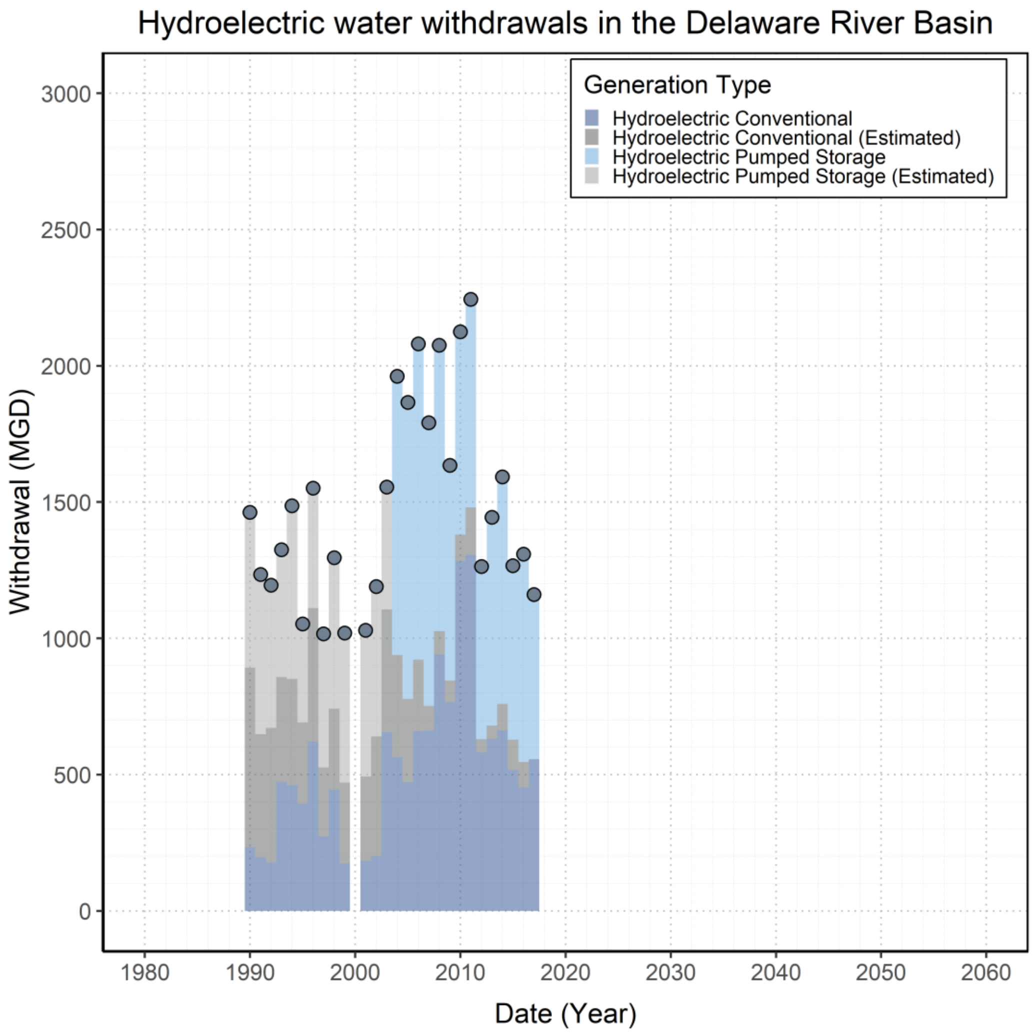




[1] *Without estimating historic water use by hydroelectric facilities, a complete time series would be largely incomplete and not representative. The year 2000 is omitted because net generation data for the Mongaup system was not available.*

[2] *Color coding does not necessarily correlate. Data is aggregated in two separate instances; the results are plotted as stacked values.*

4. Hydroelectric: total water withdrawals (annual)



Regarding all facilities:

1. Historic data is highly variable
2. Oftentimes, conventional power generation is related to available supply of water.
3. Pumped storage hydropower may be more related to demands of the energy sector.
4. Overall trend for hydropower not readily apparent.

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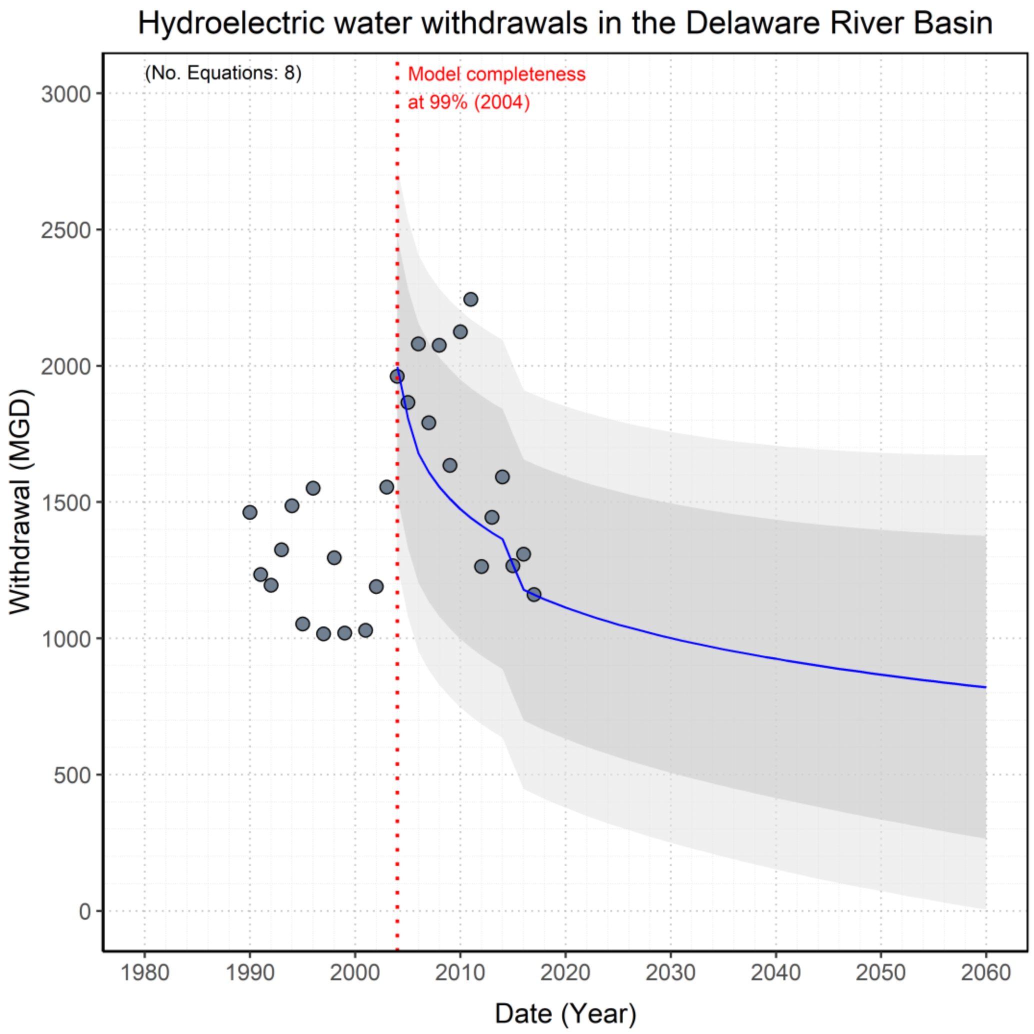
4. Hydroelectric: total water withdrawals (annual)



Summary notes:

1. Most facilities were modelled as average values, based on the historic scatter of data; directly reflected in the magnitude of a calculated predictive interval.
2. Decreases largely due to modelled recent trends in pumped storage hydroelectric generation, and retirement of one small facility.
3. Peak reported use in 2011
4. Smaller effect than thermoelectric on water availability;
5. Mongaup and Wallenpaupack releases require coordination with the office of the Delaware Rivermaster and Montague, NJ flow target
6. Assumed no consumptive use (CUR=0%, not inclusive of potential losses from impoundment evaporation)

5. Next steps in withdrawal projections

TASK	STATUS	Presented at:
• Public water supply	Substantially complete	Oct 2020
• Power generation sector analysis	Substantially complete	Feb 2021
• Industrial & Refinery sector analysis	Substantially complete	June 2021
• Discussions with docket holders	In progress	
• Irrigation sector	In progress	
• Other sectors analysis	In progress	
• Unassociated data projections	In progress	
• Final report	In progress	

Sketch of Pearl Street Station (1882-1890; the first commercial power plant in the US), obtained from https://en.wikipedia.org/wiki/Pearl_Street_Station

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