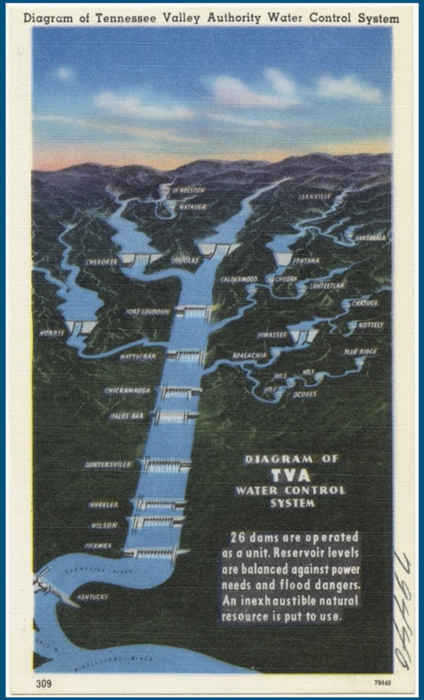
Cascaded Hydropower

A Beckman presentation

Hydropower in the U.S.

History

- Started early 1880’s to provide lighting
- First AC power plant 1893 in California
- 1920s Army Corps core of engineers starts building plants
- 1933 Tennessee Valley Authority (TVA) established
  - Great Depression
  - Government infrastructure economic stimulus
- 1936 Hoover dam project



Today

- TVA operates 29 dams on one river system
- In total US gets 6.3% of electricity from hydropower
- 2021 net summer capacity about 80 GW
- Many dams in the US are for purposes other than electricity (flood control)

Major and notable Rivers

Colorado River: Hoover dam (2GW) , Glen canyons dam, etc

Columbia River: Grand Coulee dam (6.8GW)and Chief Joseph dam (2.6GW)

Tennessee River: Kentucky dam 223 MW

Hydropower in New Zealand

History

- First industrial plant built 1885 for a mine
- First hydro power station (Okere Falls) built near Rotorua 1901
- Hydro schemes built as early as 1903 (Waipori) and 1914 (Coleridge station)
- Waikato River Cascade built between 1953 and 1970 (7 stations)

Today

- Hydro supplies 62% of nations energy needs
- Long distance DC cables connect the islands
- Capacity of over 5GW
- Many retrofits of existing plants

Arapuni Dam

Major Notable Rivers and Schemes

- Waikato river: Cascade setup
- Tongariro power scheme: Water collected from tributaries and mountains feeds three stations
- Lakes Pukaki and Tekapo: System of dams and power plants

The Science:
(Why can't we build infinite dams?)

Topography

- Elevation change
- Narrowing
- Favorable materials (type of soil,rock,etc)
- Open flood plains wouldn’t work

Energy

- Finite amount of energy in the river
- Blocked river flow
- Infinite number of dams is impossible
- Some river have more usable energy than others

Kinetic & Potential Energy

$$KE = \frac{1}{2} m V^2 \qquad PE = mgh$$

Credit:https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DDyaVgHGssos&psig=AOvVaw37ePq-w0AqYencIdYPe2FF&ust=1681493479731000&source=images&cd=vfe&ved=0CBIQjhxqFwoTCJDcqL6xp_4CFQAAAAAdAAAAABAE

Turbine Size

New Zealand:

- Limited space on rivers (width)
- Construction limitations
- Road infrastructure for machinery
- Smaller plants

US:

- More space
- Larger plants = less needed

Environmental

Flooding

US:

-wetlands

-towns (voluntarily)

-more development along rivers

New Zealand:

-planned dams will raise lakes

-protested

-more of an effect on natural lands

Fish

- Dams can destroy habitat
- Cause stagnation and harm oxygenation
- Cause algal blooms (from excess nitrogen and phosphorus)
- Limit migration

US:

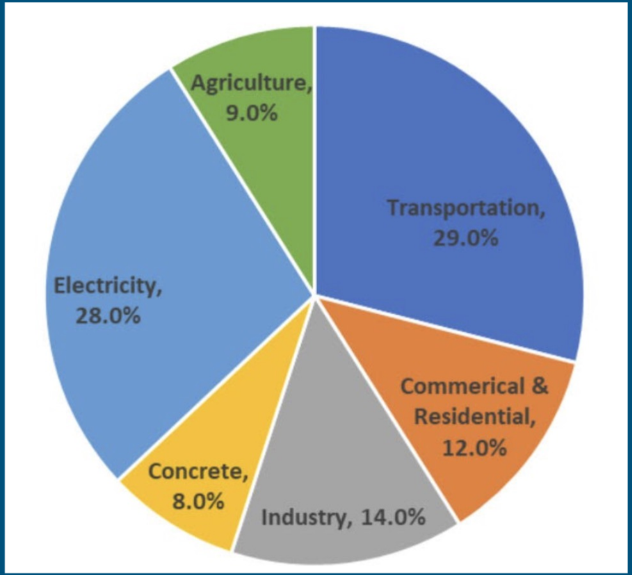
- Salmon migrations
- Less food from natural flooding

New Zealand:

- Less variety of fish after the dam
- Large effect on eels
- Less of a problem for salmon (farmed commercially)

Concrete

- Example: Hoover dam uses 4,360,000 cubic yards of concrete
- 1 cubic yard is 3900 pounds
- 1 cubic yard creates 400 pounds of co2
- New Zealand has access to limestone
- Similar costs

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Economics


DEPTH GAUGE
90 ft
CARL BARKS
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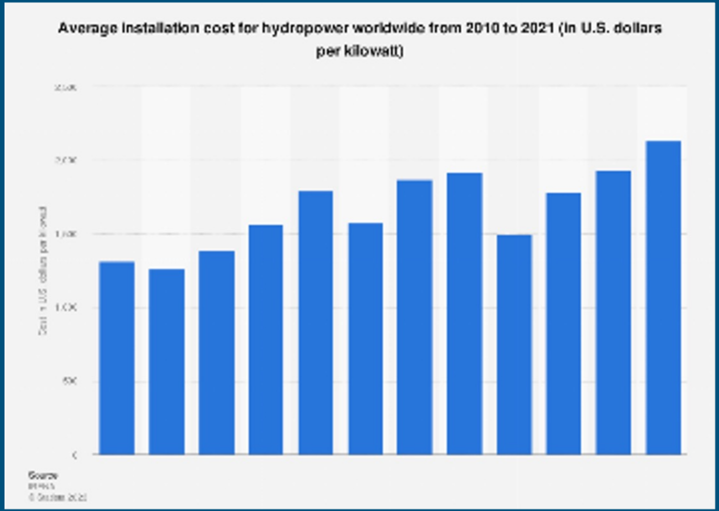
Capital Costs (US)

- A large dam can cost Billions of Dollars today ($1000-$6000 per KW)
- Hoover dam cost was around $750 Million (inflation adjusted)
- Construction time up to a decade



LCOE (US)

Table 4b. Value-cost ratio (unweighted) for new resources entering service in 2027

Plant type	Average unweighted LCOE[a] or LCOS[a] with tax credits (2021 dollars per megawatthour)	Average unweighted LACE[a] (2021 dollars per megawatthour)	Average value-cost ratio[b]	Minimum[c]	Maxi
Dispatchable technologies					
Ultra-supercritical coal	$82.61	$38.69	0.47	0.40	
Combined cycle	$39.94	$39.54	0.99	0.91	
Advanced nuclear	$81.71	$38.42	0.47	0.41	
Geothermal	$37.62	$45.11	1.20	1.08	
Biomass	$90.17	$39.84	0.45	0.28	
Resource-constrained technologies					
Wind, onshore	$40.23	$34.54	0.88	0.60	
Wind, offshore	$105.38	$36.00	0.34	0.27	
Solar, standalone[d]	$33.83	$32.85	0.98	0.72	
Solar, hybrid[d,e]	$49.03	$45.53	0.93	0.64	
Hydroelectric[e]	$64.27	$37.87	0.60	0.45	
Capacity resource technologies					
Combustion turbine	$117.86	$101.74	0.86	0.61	
Battery storage	$128.55	$101.01	0.79	0.52	

New Zealand Levelized Costs per MWh

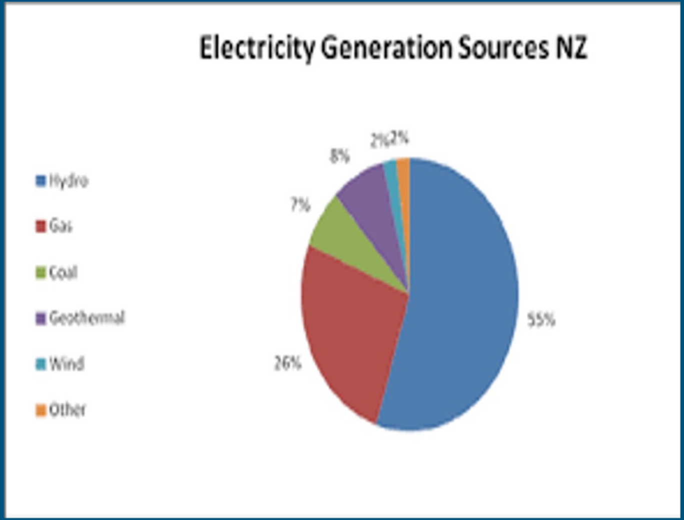
Geothermal: $70 (limited resource/best sites are used first)

Gas:$85 (with carbon costs)

Coal: $110 (with carbon costs)

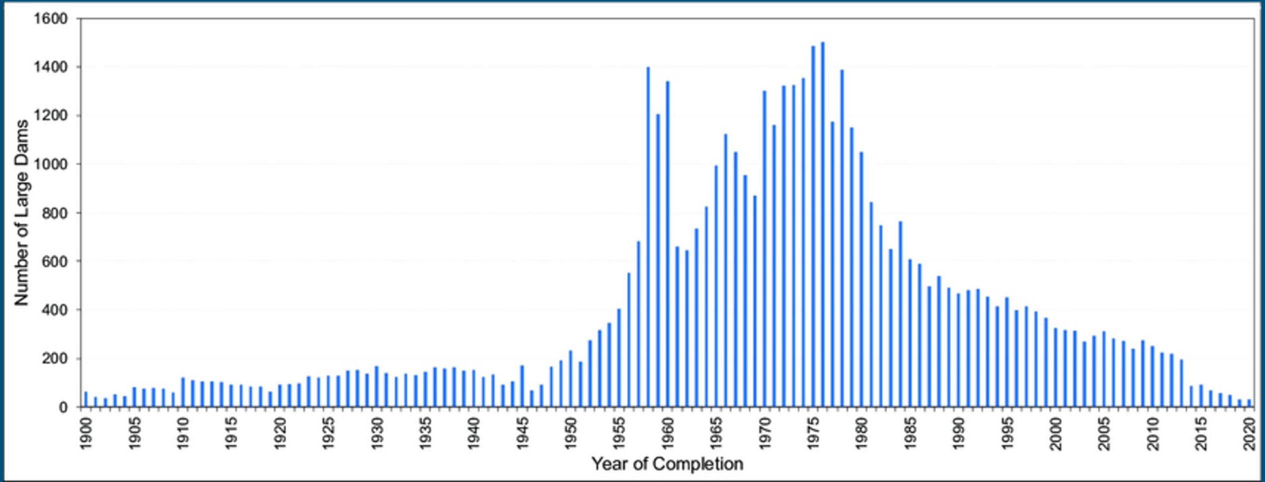
Wind:$80 (limited resource/best sites are used first)

Hydro:$75-$100 (long construction times)



Conclusion

- Hydro power has become expensive
- Can cause flooding and harm fish
- Limited resource potential (location and available energy)
- New Zealand has access to fewer alternatives



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