Future Transportation Energy Water Use under California's Climate Goals

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Key Conclusions

- Overall water demand for California oil production has increased.
  - Aging California oil fields use more fresh water and generate more produced water that goes into (unlined) evaporation ponds and surface water.

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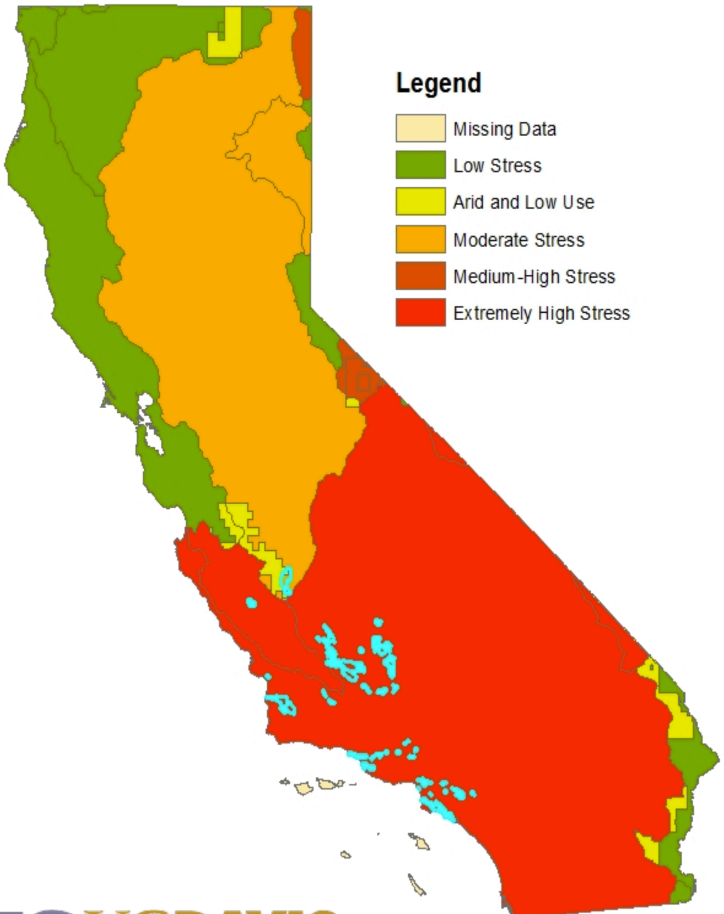
  - Aging California oil field uses more fresh water and generate more produced water that goes into (unlined) evaporation ponds and surface water.
- Total transportation energy use and petroleum consumption decrease under the 2050 climate goals.
- A climate policy that cuts transport emissions will reduce the state's demand for fresh water.
  - Proactive planning will be needed in maximizing the availability of water of appropriate quality for the best use.

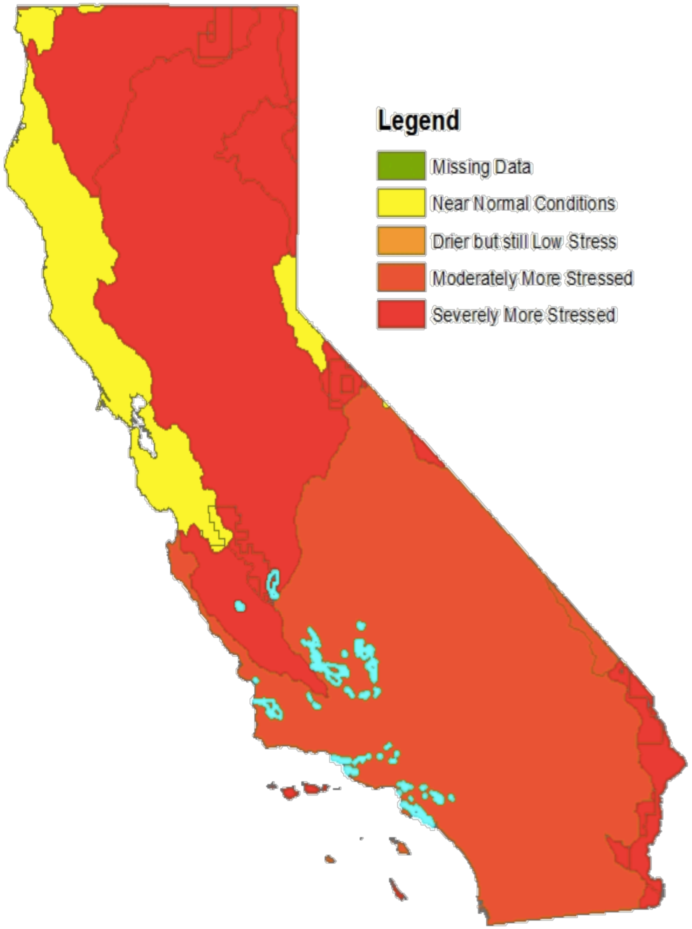
Trends toward greater water demand and supply scarcity

Projected increase in groundwater stress in California due to climate change.

2005 levels

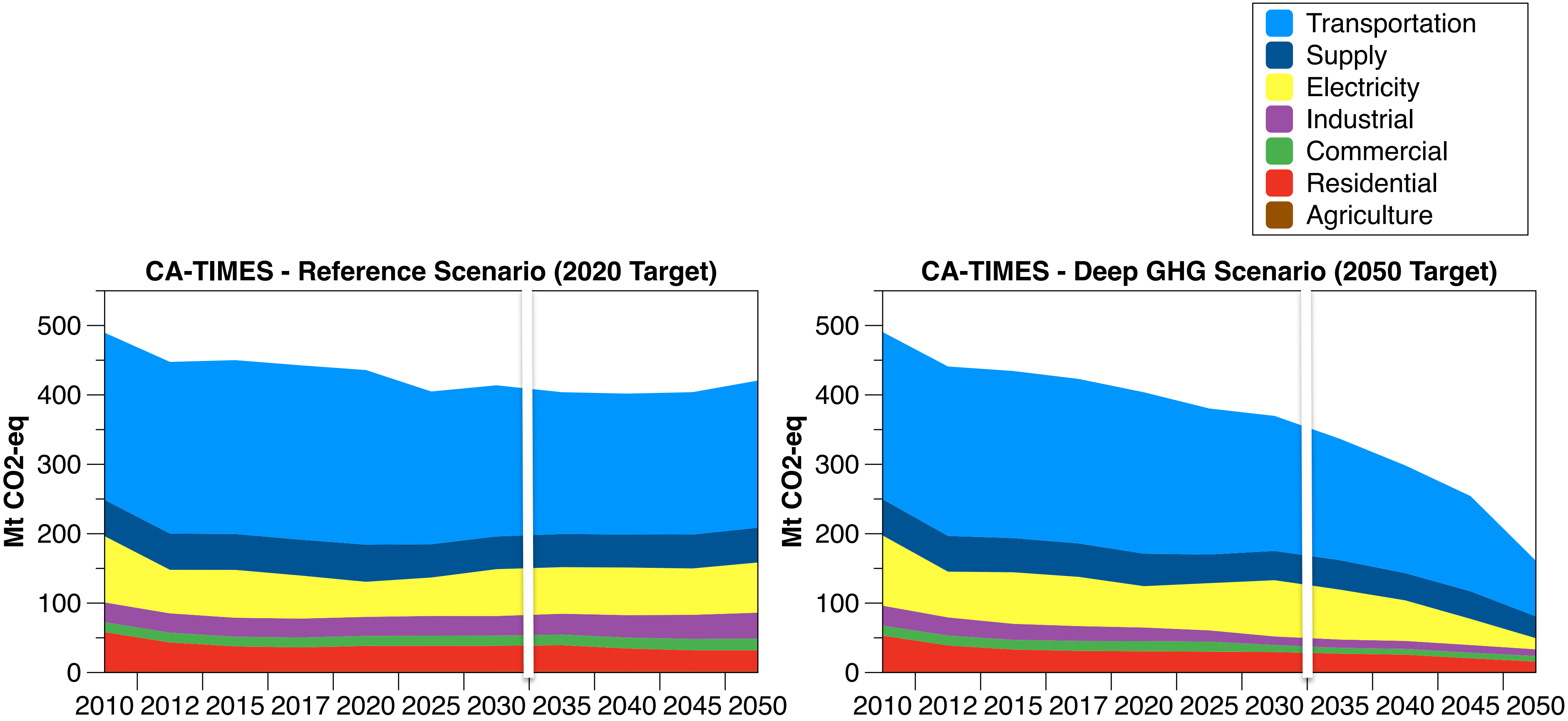


As projected in 2025 under IPCC A1B Scenario



Source: Reig, Shiao et al. (2013)

CA-TIMES GHG Emission Trajectories



Data extracted from Yang, Christopher, Sonia Yeh, Kalai Ramea, Saleh Zakerinia, David L. McCollum, David S. Bunch, Joan M. Ogden (2014) Modeling Optimal Transition Pathways to a Low Carbon Economy in California: California TIMES (CA-TIMES) Model. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-14-04

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California Transportation Fuel Use

(PJ)	2012	2030 – ***Reference*** *(2020 Target)*	2030 – ***Deep GHG*** *(2050 Target)*
Total	3,655	3,830	3,420
Petroleum (Billion GGE)	3,480 (25.0)	3,000 (21.5)	2,660 (19.1)
Alt fuel	177	830	760
Electricity - Transportation	3.6	13	21
Electricity (TWh)	316	330	410

Water Source and Disposition by Energy Pathway

Pathway	Source	Disposition
Oil & gas production	• Produced; • Other (ocean, combination, and 'other'); • Fresh (groundwater, domestic); • Waste (domestic waste, industrial waste).	• Evaporation ponds (line sump; percolation); • Injected into subsurface wells; • Sewer; • Surface.
Oil refining	• Degraded; • Fresh; • Potable.	• Other
Electricity	• Freshwater (slightly brackish water); • Degraded (degraded groundwater, degraded surface water); • Recycled; • Ocean.	• Evaporation; • Surface water.
Biofuels	• Irrigation (withdrawal, application losses, conveyance losses); • Rainwater.	• Evaporation; • Transpiration; • Groundwater infiltration; • Runoff.

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Biofuel water use will be covered in an upcoming webinar (date TBD)
- *Focus on impacts of land use (displacement, expansion, intensification) and water management (irrigation, rainfed)*

Data Source and Assumptions – Consumption Based Water Use

Fuel	Projection of fuel use	Projection of fuel source	Projection of water use
Crude-derived fuels	**CA-TIMES** estimates fuel demand given climate/energy policies	*California*: CEC low/high rates of decline in future oil production; *Domestic*: EIA projections of shale oil production. *Imports*: Current proportions of imports.	*California*: oil-water use study Out-of-state: literature review
Electricity	**CA-TIMES** estimates electricity sources broken down by conversion technologies.	In-state vs. out-of state production: assume 20% imports	Scenario-based assumption of shares of cooling technologies and water sources.

- This presentation focuses only on **in-state** water consumption/disposition

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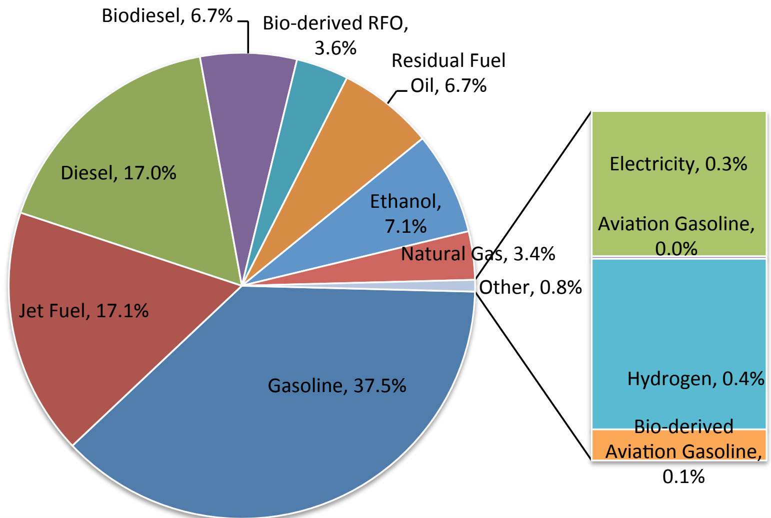
Four 2030 Scenarios by Climate Policy and Water Management

GHG Mitigation Level

Water Use Intensity (WUI) / Water Use Management

Reference Scenario (2020 Target)



Total = 3830 PJ ; petroleum = 78.3% ; non-petroleum = 21.7%

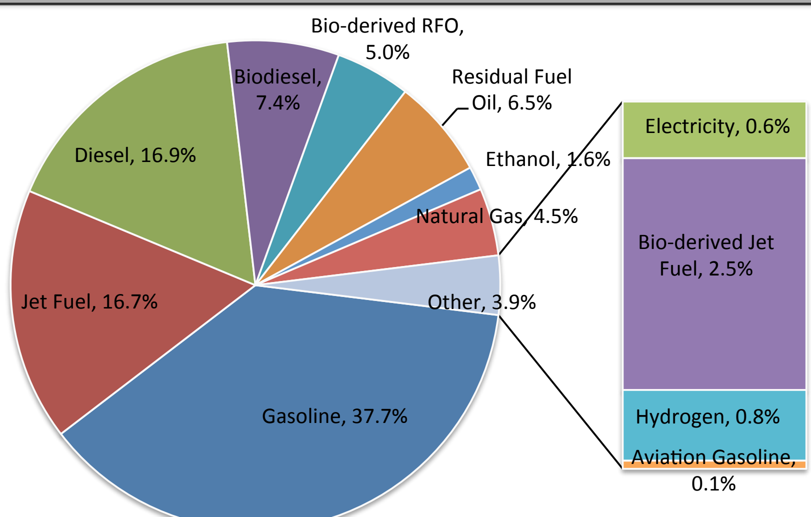
Water 'Smart'

Low WUI

'Baseline'

High WUI

Deep GHG Scenario (2050 Target)



Total = 3420 PJ ; petroleum = 77.8% ; non-petroleum = 22.2%

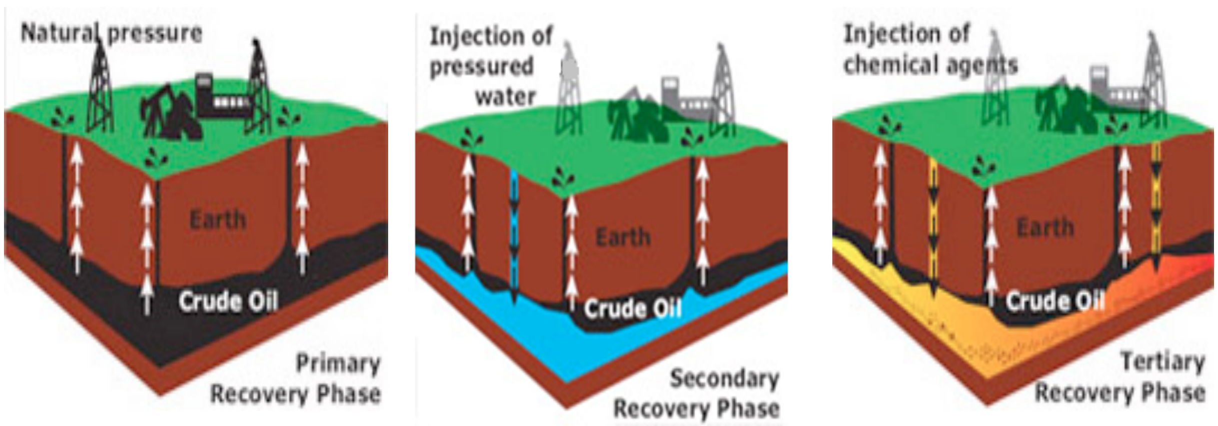
Water 'Smart'

Low WUI

'Baseline'

High WUI

Types of Oil Production



Primary

- Natural Pressure
- Off-shore

Secondary

- Injection of Water
- "Water Flooding"

Tertiary (Enhanced Oil Recovery)

- Injection of Steam and/or chemical agents
- "Steam Flooding"
- "Cyclic Steam"

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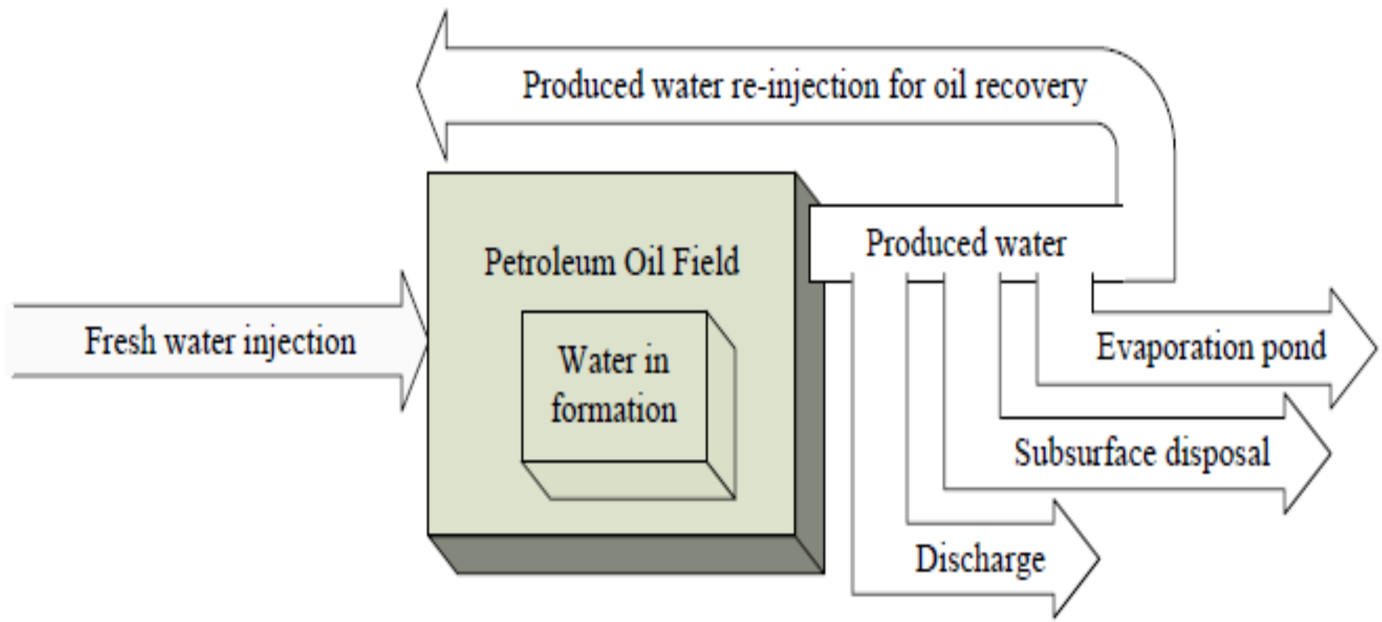
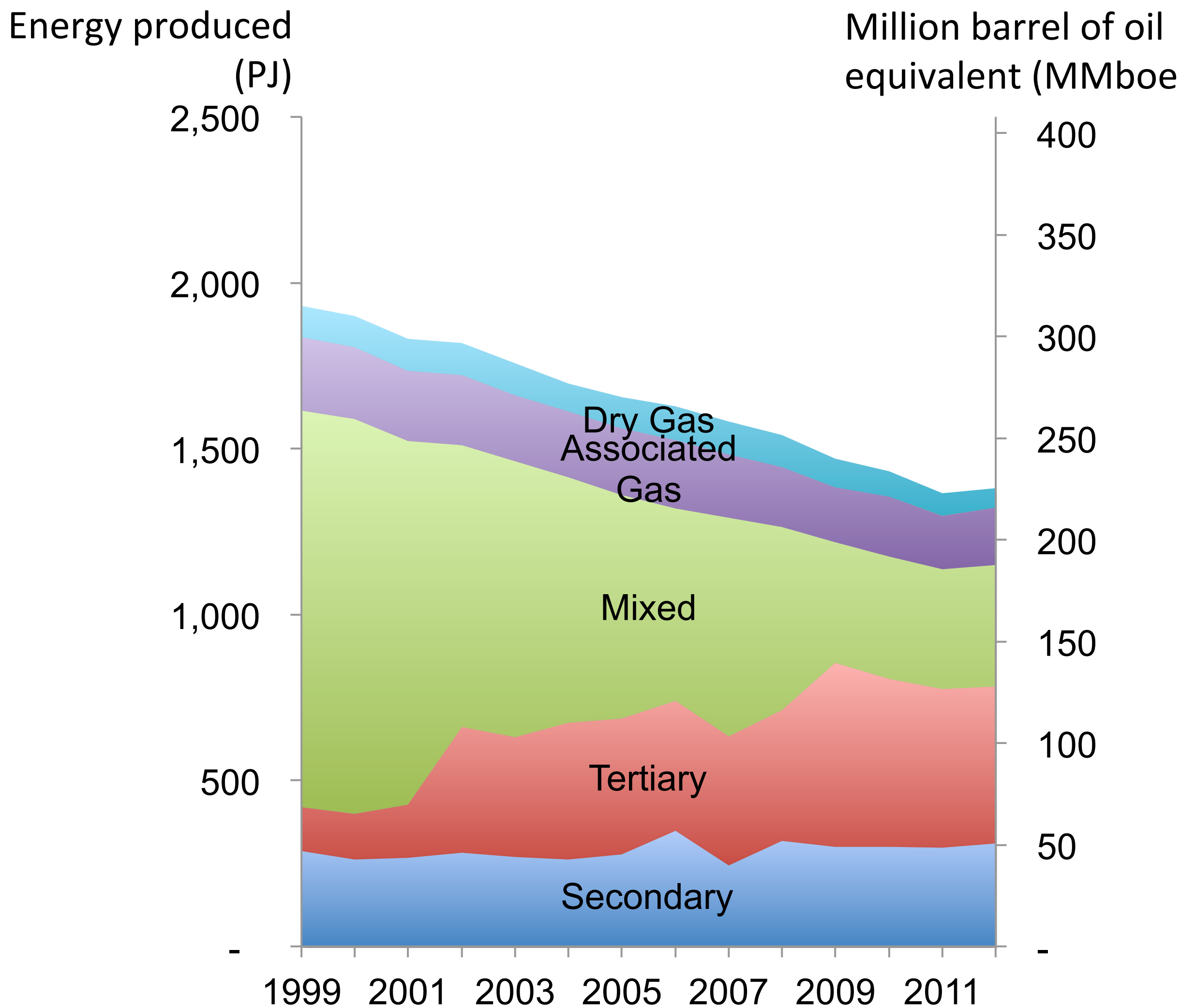
Water Use and Disposition in Petroleum Recovery



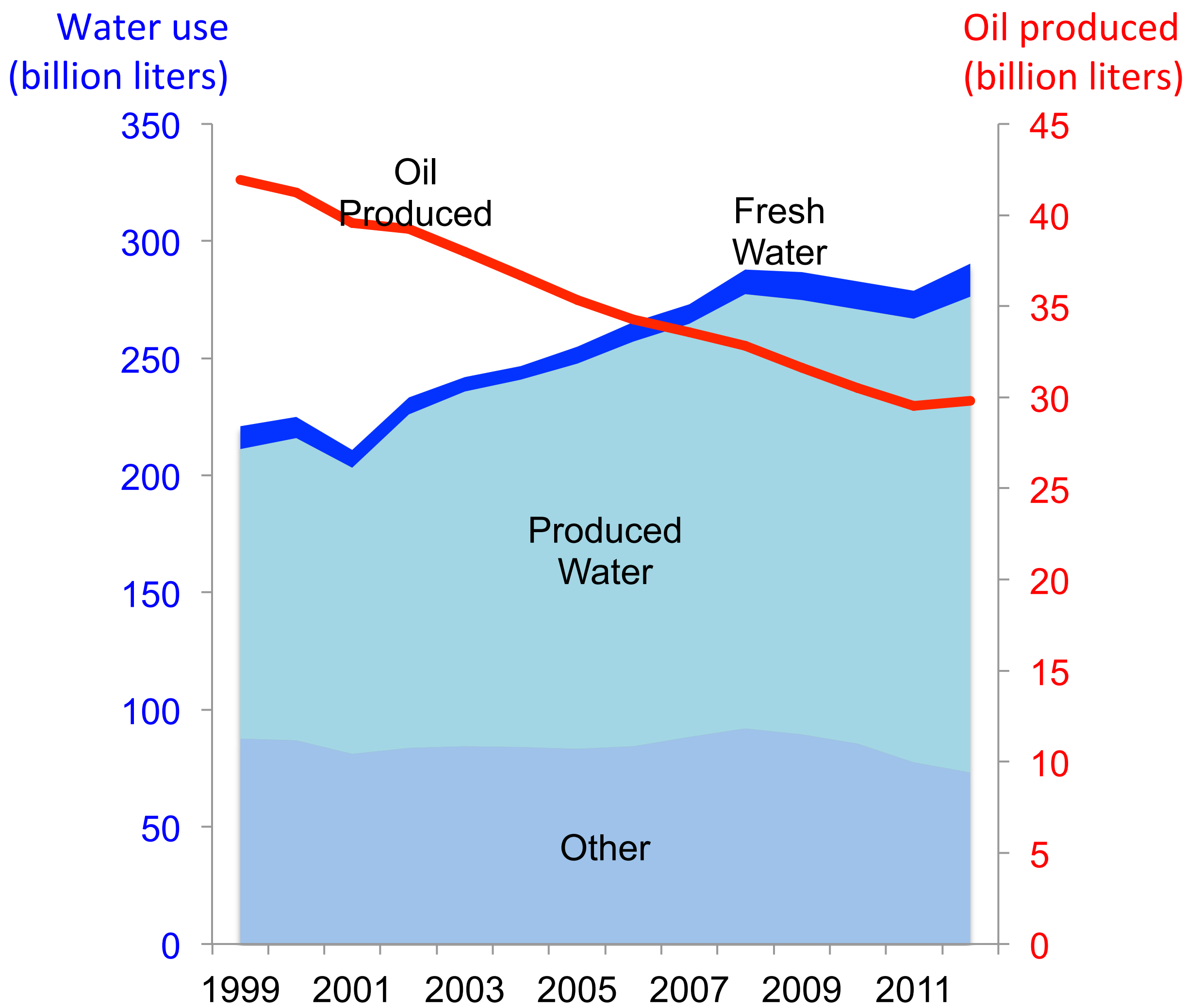
Source: Wu, Mintz et al. 2009

California Oil Production History by Type of Extraction Method



Source: California Department of Oil, Gas, and Geothermal Resources (2013)

California Oil Production has Decreased While Total Water Use has Increased

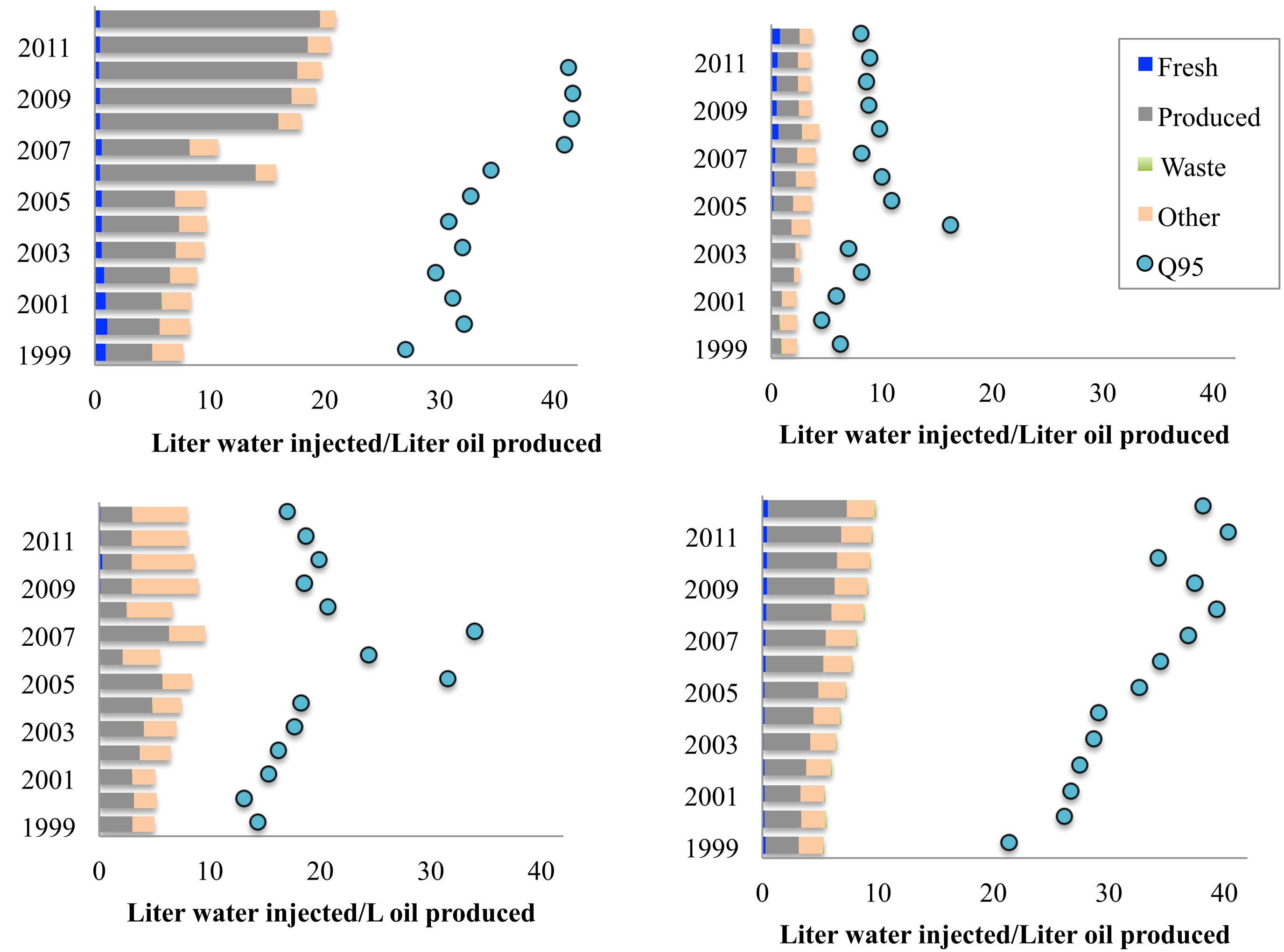


Data: California Department of Oil, Gas, and Geothermal Resources (2013)

Total Water Intensity 1999-2012

Secondary

Tertiary



Mixed

Total

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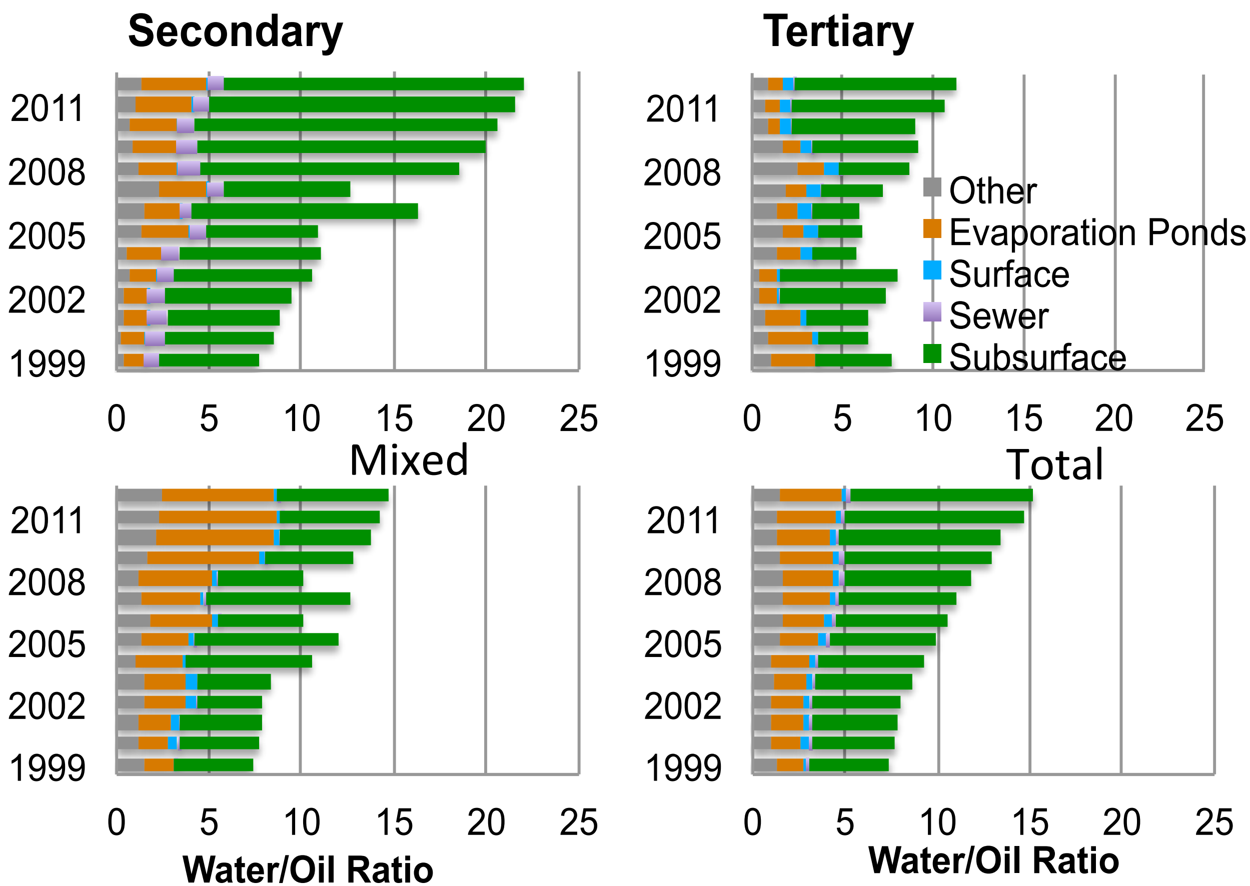
Produced Water Intensity 1999-2012



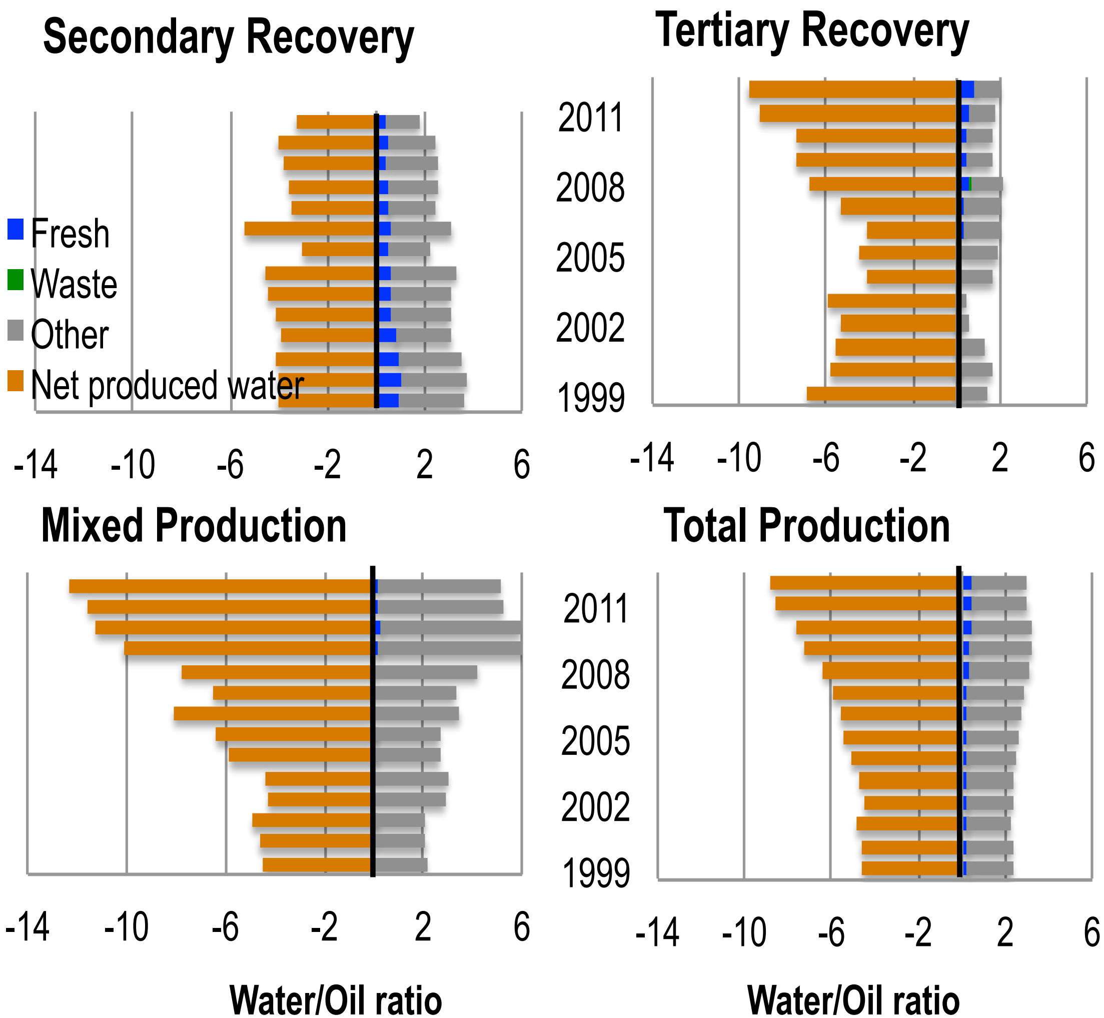
- Unlined percolation ponds:
  - **97** billion liters in 2012,
  - **63** billion liters in 1999
- Water disposal to surface water
  - **8.9** billion liters in 2012
  - **4.6** billion liters in 1999

Evaporation Ponds


Evaporation ponds next to a typical fracking operation. (Source: Ted Wood/Corbis)

- Ninety -seven billion liters were sent to unlined percolation ponds in 2012
- Evaporation ponds pose environmental problems:
  - Off-gassing volatile organic compounds
  - Leakage
  - Wildlife mortality

Net water use intensity of Oil Production in CA (1999-2012)



- Fresh water use intensity doubled, from 0.2 gal fresh water/gal oil to 0.5 gal/gal.
- Total fresh water use 3.8 billion gallons in 2012.
- Total produced water use 54 billion gallons in 2012.

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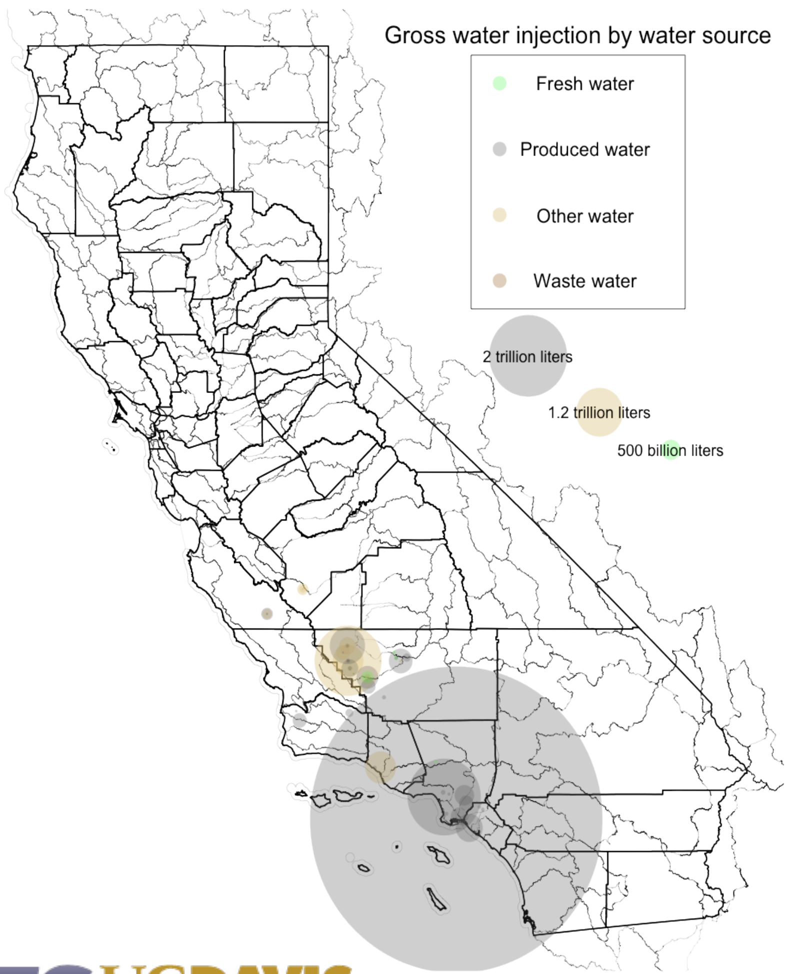
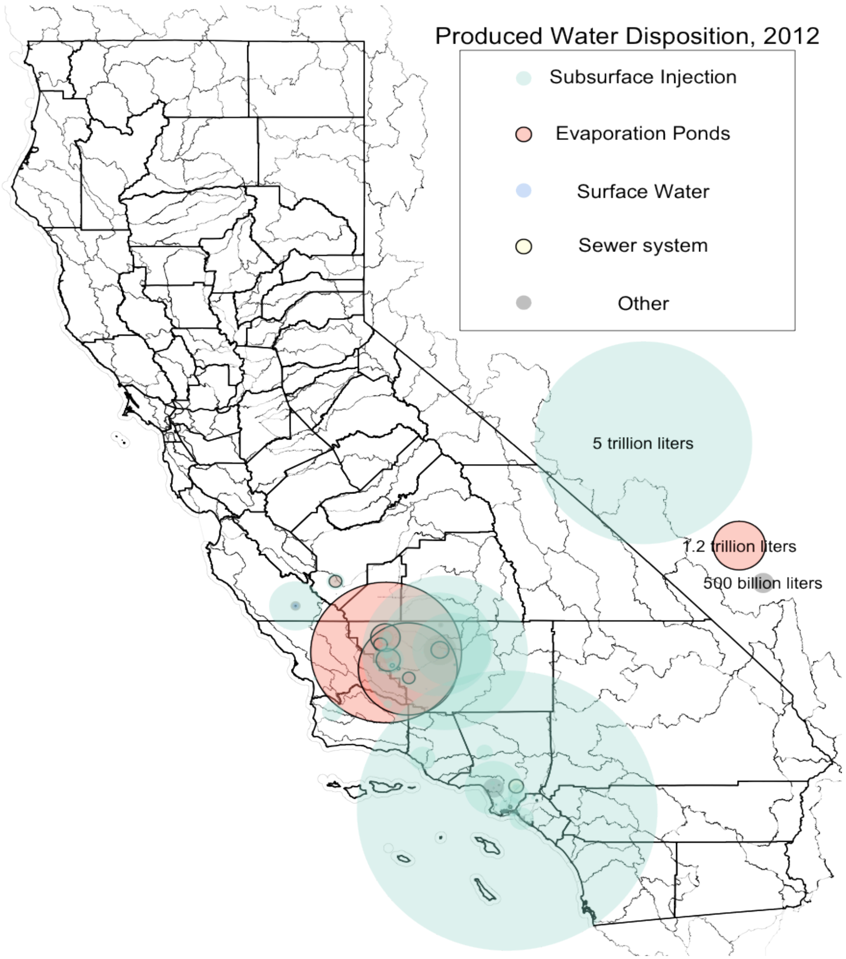
Spatial Distribution of Water Injected and Produced 2012





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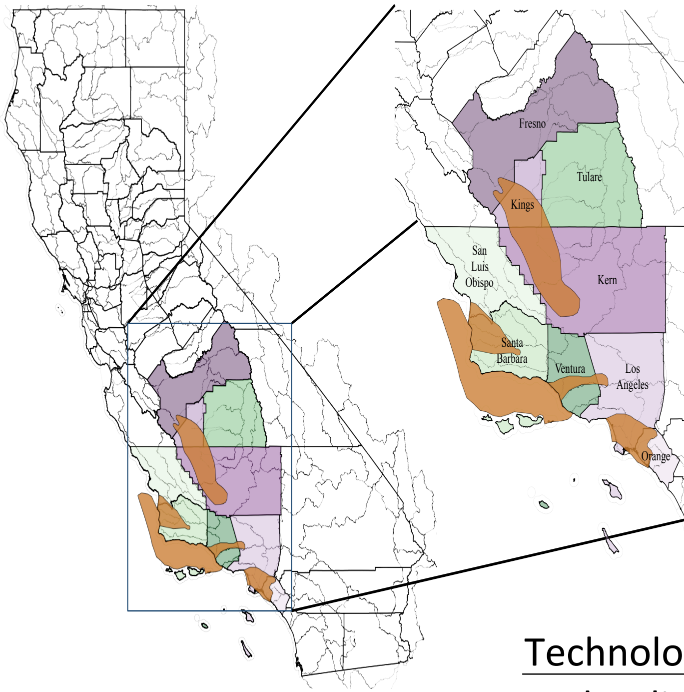
Hydraulic Fracturing in California



- In California, hydraulic fracturing is principally used to ensure that previously conventional wells attain maximum production.
- Generally vertical wells. Well age ranges 1-54 years.
- Hydraulic fracturing produced 1% of oil in 2012.

Technology	Median (gal/gal)	Mean (gal/gal)	Net (2012)
Hydraulic Fracturing	1.0	3.5	
Total Conventional	5.0	10.5	**3.0**
Secondary	7.2	13.7	**1.8**
Tertiary	3.6	3.4	**2.0**
Mixed	6.5	7.6	**5.1**

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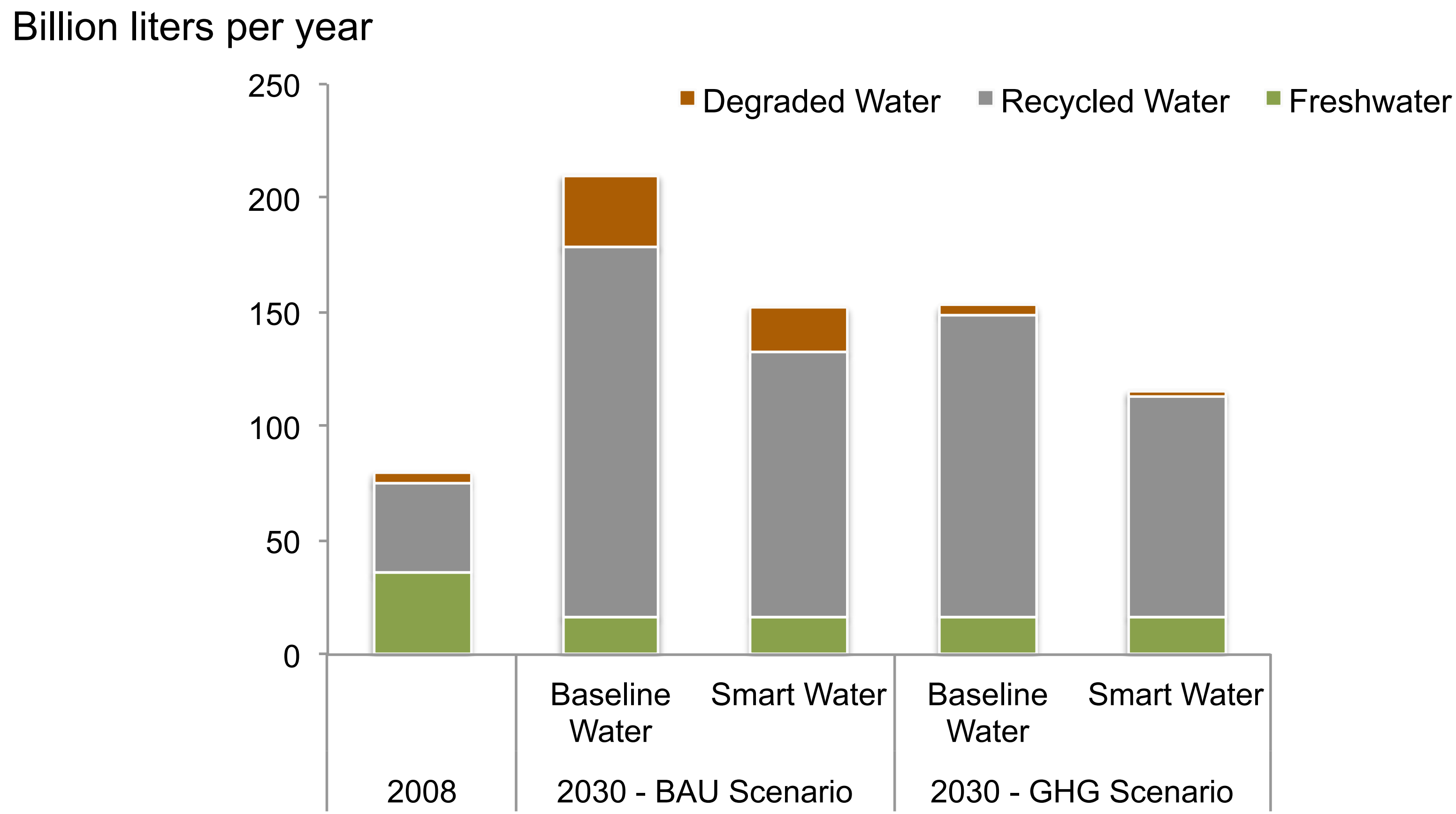
Projected Electricity Generation in California

(GWh)	2012	2030 *Reference*	2030 *Deep GHG*
Nuclear LWR	30,800	-	-
Coal	700	-	-
Coal Steam	30,500	-	-
Bio CT	300	300	-
Bio Steam	1,000	600	600
Tidal	-	-	6,400
Geo	10,400	28,200	14,500
Hydro	41,600	31,300	31,200
Renewable	200	-	-
Solar PV	-	-	59,400
Solar Therma	500	500	500
Wind	4,900	58,300	42,000
NG	19,500	-	-
NGCC	108,700	137,800	169,900
NGCT	-	2,000	-
Oil Steam	3,500	-	-
Other	-	1,900	4,700
Total	*252,600*	*260,900*	*329,200*

Consumptive Water Use for Electricity Generation in CA

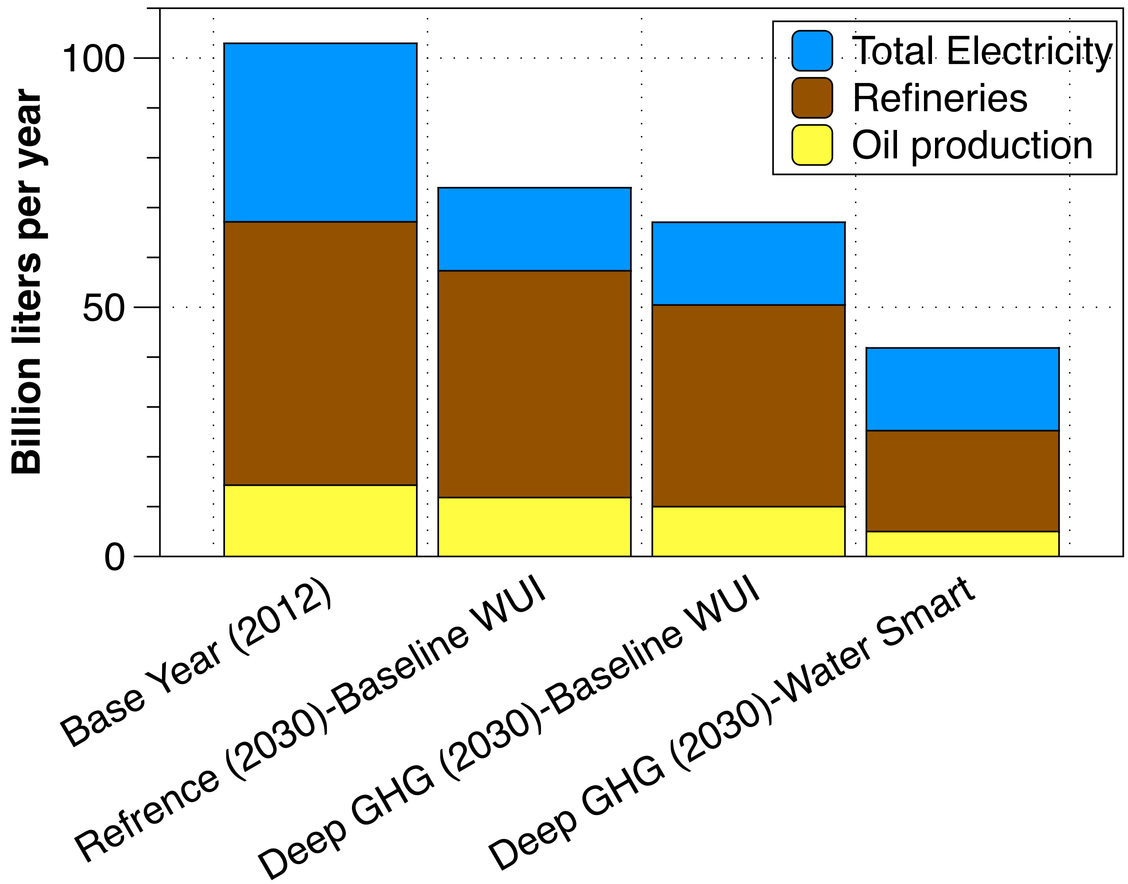


Withdrawal ≈ consumptive water use in future scenarios

The Deep GHG scenario requires the same amount of fresh water, but less degraded and recycled water as a result of less geothermal generation (more solar PV and NGCC).

Ocean water use for once-through cooling (OTC) plants, and water demand by co-generation plants are not included.

Projected Fresh Water Consumption
(In State)



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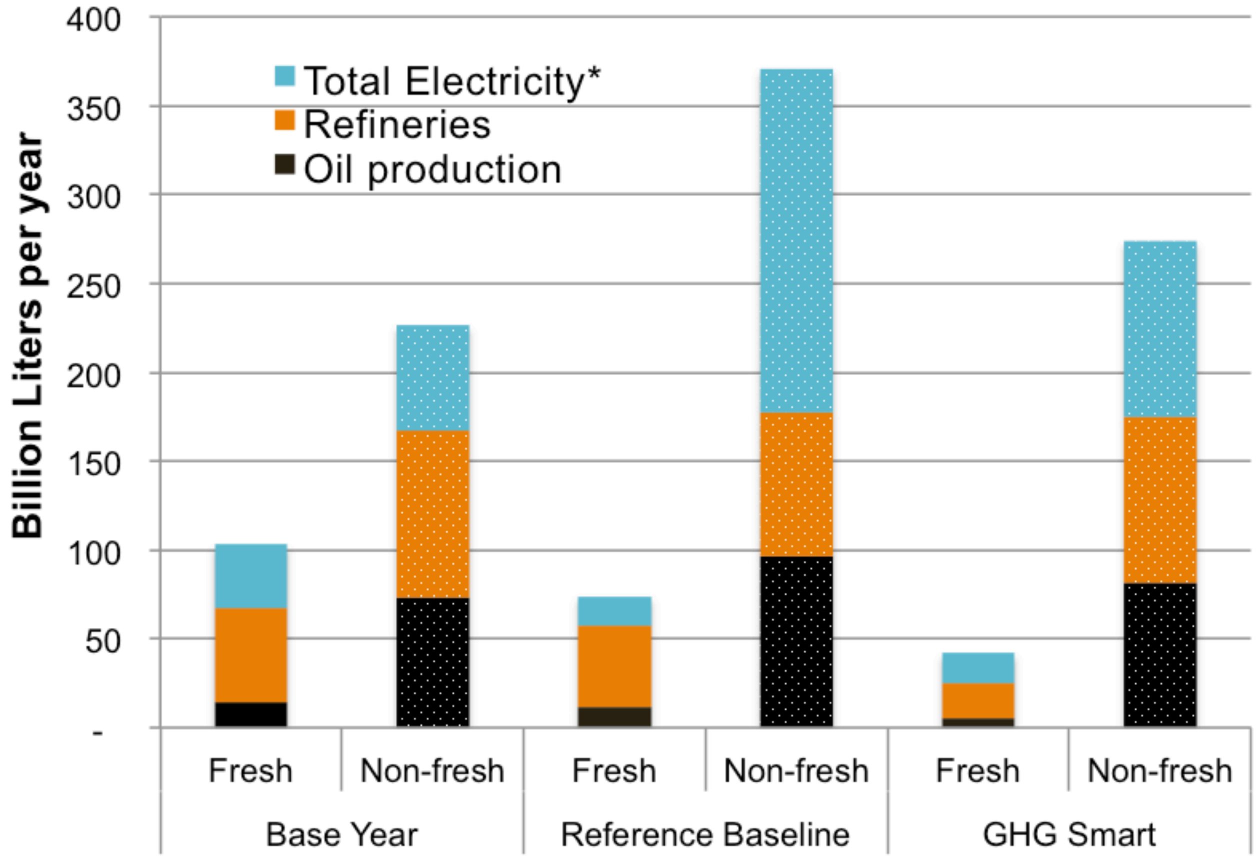
Water Use Across Energy Supply Pathways

Projected Water Consumptive Use for Selected Energy Pathways in 2030



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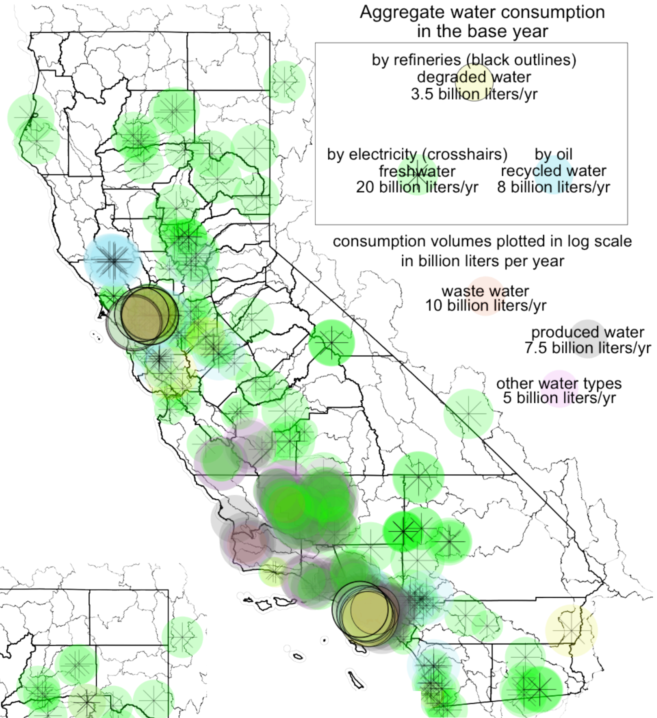
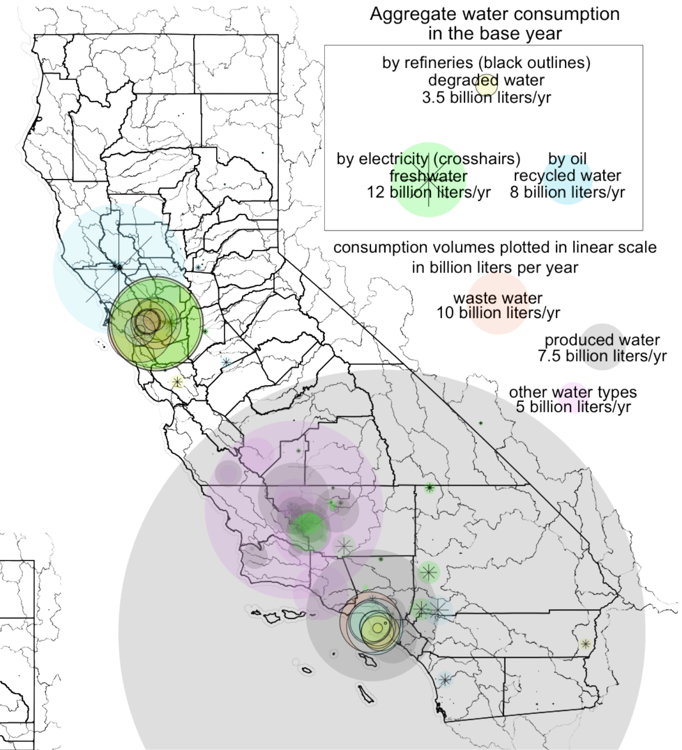
Changes in water use across transport energy supply pathways

Base Year

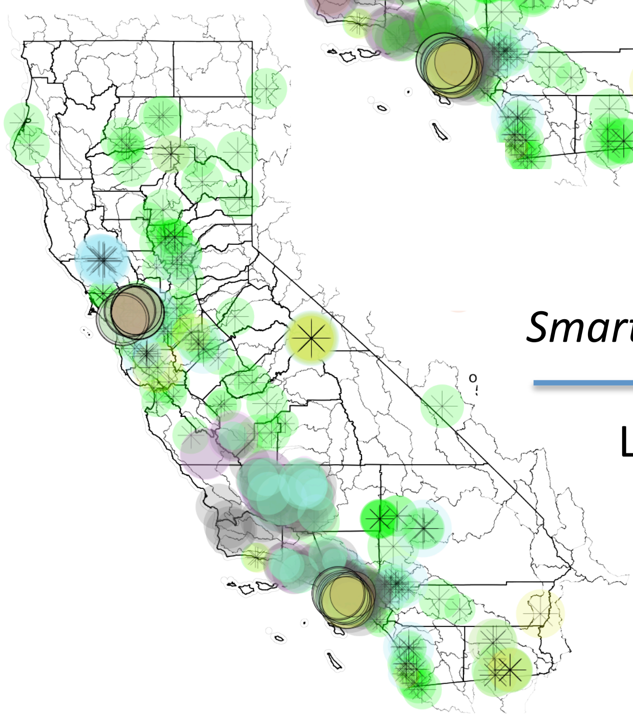
Log Linear

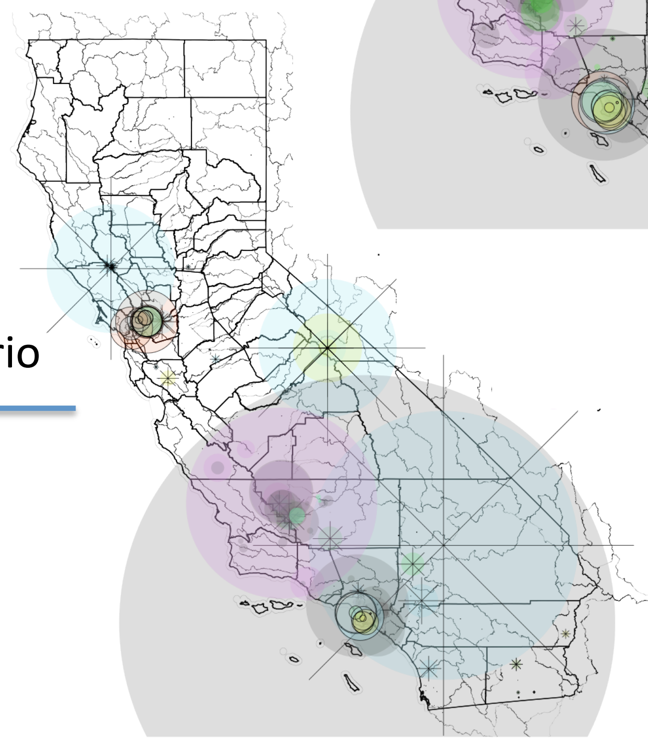




Deep GHG,
Smart water use scenario

Log Linear





Policy Implications

- Three key take home messages
- Further research:
  - Conduct more detail, county- / basin-level research, on regions identified as 'hot-spots'
  - Estimate the cost & efficiency implications of alternative water sourcing in oil and electricity generation
  - Incorporate costs/savings (economic and energetic) of water treatment / cooling systems in energy-economic modeling

Acknowledgements

Many thanks to:

Joe O'Hagan and the California Energy Commission's ***Public Interest Energy Research*** (PIER) research program, for commissioning this research.

BACKUP SLIDES

Water Withdrawal and Consumption Intensities (Liters/MWh)

Fuel	Technology	Cooling System	Withdrawal	Consumption
Natural Gas	Combined Cycle	Tower	806	806
		Dry	38	38
		Hybrid	79	79
	Combined Cycle & CCS	Tower	1,544	1,544
	Combustion Turbine	NA	284	227
Solar	Parabolic Trough	Tower	2,775	2,775
		Dry	382	382
	Power Tower	Dry	167	167
	Photovoltaic	NA	4	4
Geothermal	Hydrothermal (150 ^{0}C, Binary)	Tower	9,993	9,842
		Dry	4	4
		Hybrid	1,401	1,363
	Hydrothermal (200 ^{0}C, Flash)	Tower	0	0
	Hydrothermal (Dry Steam)	NA	2,006	2,006
	EGS (150 ^{0}C, Binary)	Tower	12,075	11,924
		Dry	2,355	2,355
		Hybrid	3,596	3,596
	EGS (200 ^{0}C, Flash)	Tower	0	0
Biomass	Combustion Turbine	NA	8	8
	Steam Turbine	Tower	2,627	2,101
		Dry	8	8
	Combined Cycle	Tower	874	700
		Dry	4	4
		Hybrid	235	235
Wind	NA	NA	0	0