State Workshop

On

Water Conservation and Waste Water Recycle / Reuse in Rajasthan- Issues and Challenge

Feb 07 2013

How much energy you need to run water

By

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Center for Science and Environment,
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Department of Urban Development/ RUFIDCO
Government of Rajasthan and HMC RIPA.

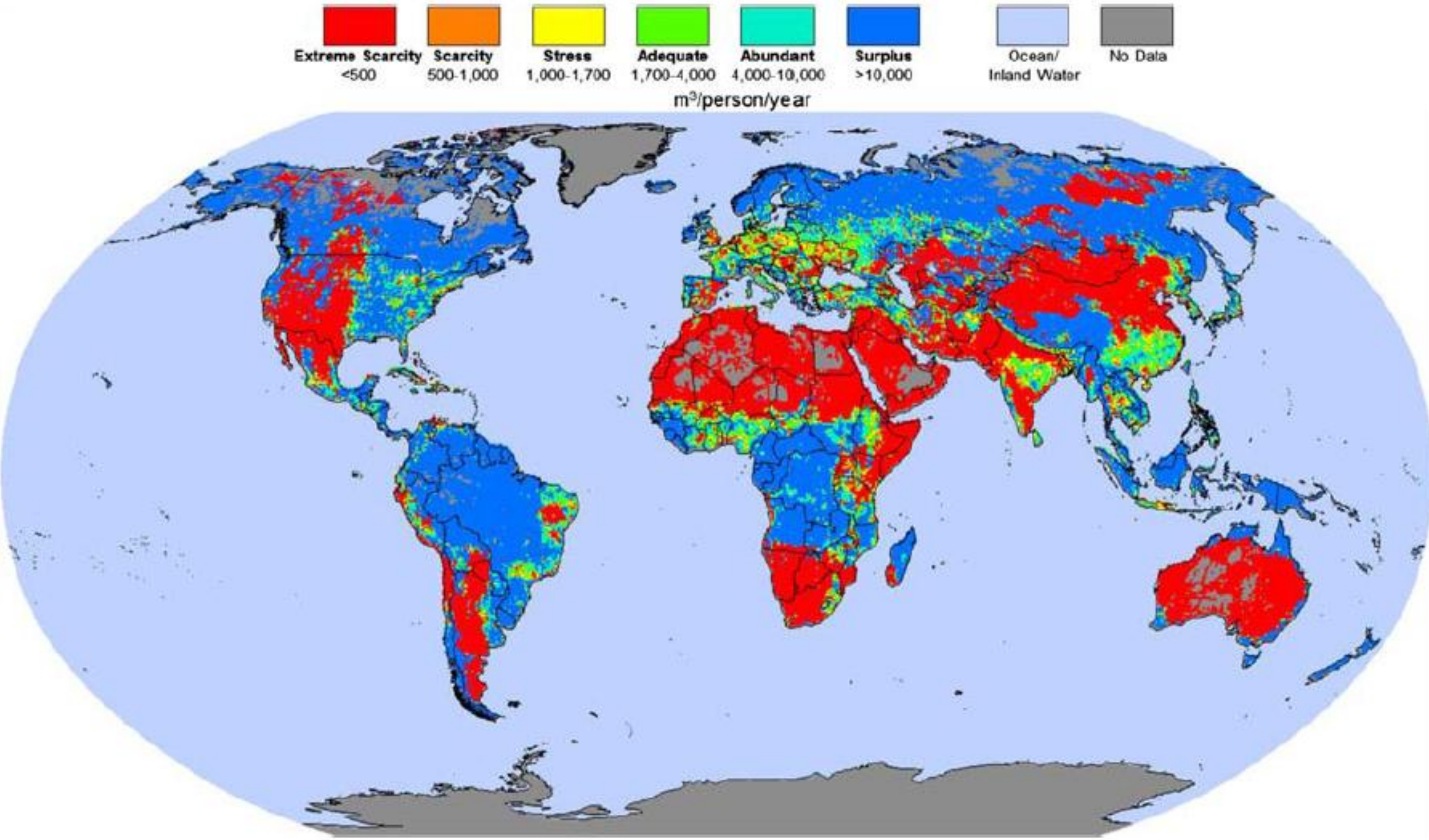
Transport Bottled water: high specific cost

॥ त्वं ज्ञानमयो विज्ञानमयोऽसि ॥

Layout of presentation

1. The problem
2. Rajasthan
3. The Water Life Cycle
4. Elements of Water Life Cycle
    - Supply
    - Treatment
    - Distribution
    - End use
    - Waste Treatment
    - Recycling
    - Reclamation and Reuse
5. Agriculture and Water in India
6. Treating Water in Petroleum Industry
7. Report on India and Awareness of society towards water.

The Problem



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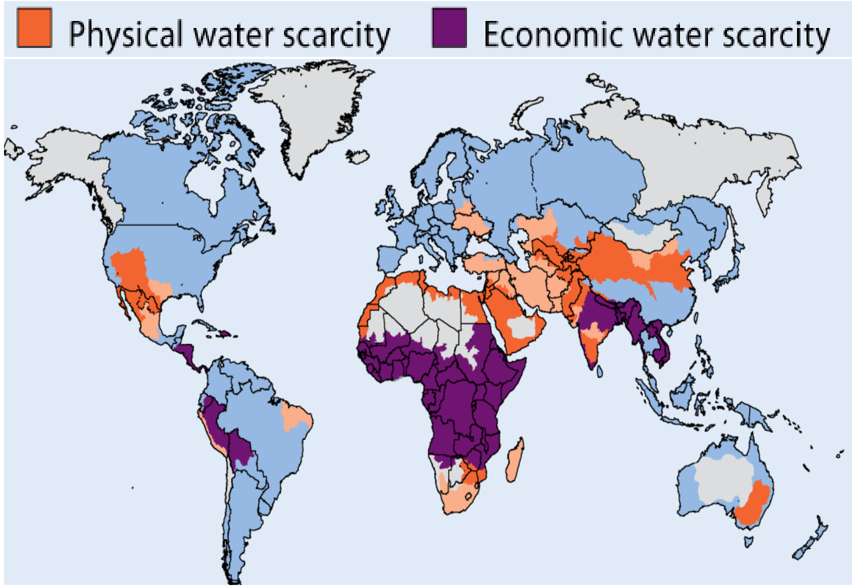
The problem



World water scarcity map
Source: UNEP

Source: Prakash et al 2012, IDA

Cost	Dharavi	Warden Road	Poverty premium
Credit (annual interest)	600 percent-1,000 percent	12 percent-18 percent	53X
municipal-grade water (per cubic meter)	$1.12	$0.03	>37X
phone call (per minute)	$0.04-$0.05	$0.025	1.8X

Ref: CK Prahlad & Al Hammond, HBR

- “Global” water scarcity – most of it in low-income countries;
- Contaminated water: # 1 cause of disease worldwide; 780,000 water-born deaths in 2008 in India alone;
- The poor currently pay a very blotted price for safe water;

Environmental Statistics of Rajasthan / India

Source: Sunday times of India, Feb 03 2013

Industry

Number 1 to issuing mining licenses.

Year	No. of Mining leases	Area (hectares)	% increase
2009	2068		
2011	2696	107000	30%

Agriculture

Financial Year	Pesticide Quantity (metric ton)	% increase
2007-2008	3050	
2008-2009	3575	17.2%

Water Conservation

Withdrawal (bcm/y)	Recharge (bcm/y)	Future availability of Ground water
14.15	11.15	0.75%
6	1	Recharge

Equivalent electrical energy consumed for irrigating wheat in India [197].

Location in India	District	Timeline	Energy for irrigation (kW h/ha)	Productivity (kg/ha)
Rajasthan				
	Bikaner	1999–2001	160.9	1668.9
	Jodhpur	1999–2001	388.7	2118.3
	Pali	1999–2001	550.26	2133.8
Punjab				
	Nawasahr	1998	374.84	1895
	Hosiarpur	1998	152.15	2952
	Jaisinghwala	1998	277.8	3947
	Sangrur	1998	236	4341
	Bhatinda	1998	147.5	3539
Uttar Pradesh				
	Khamaria and Phulsangi (Tarai)	1998	195.5	2919
	Jaipur Padli and Tejpur Negi (Hill)	1998	81.5	2125
Madhya Pradesh				
	Berkari, Jabalpur	1996–1998	224.5	1241.7
	Sihoda, Jabalpur	1996–1999	328.4	3015.6
	Gwalior	1996–2000	475.26	2857

Plappally et al 2012

Matrix for ideal solution

Transport Bottled water: high specific cost

Standalone Reverse Osmosis– resource intensive

Community level water supply (Decentralized)

Water cone –specific cost very high

Lifesaver – only for economic water scarce regions

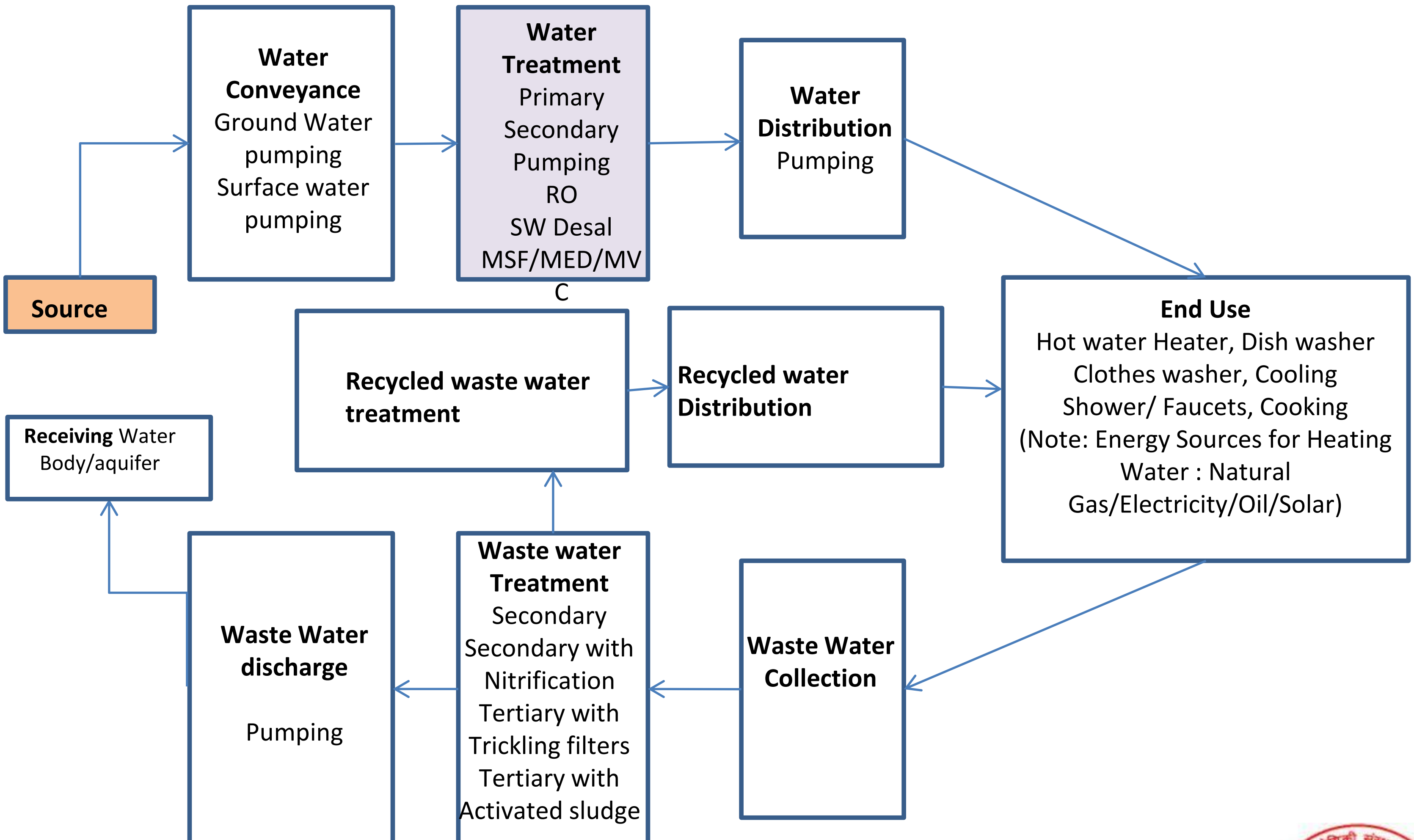
PuR – not scalable

Scalability **(can it be taken to a million people?)**

Implement-ability **(related to cost and resource)**

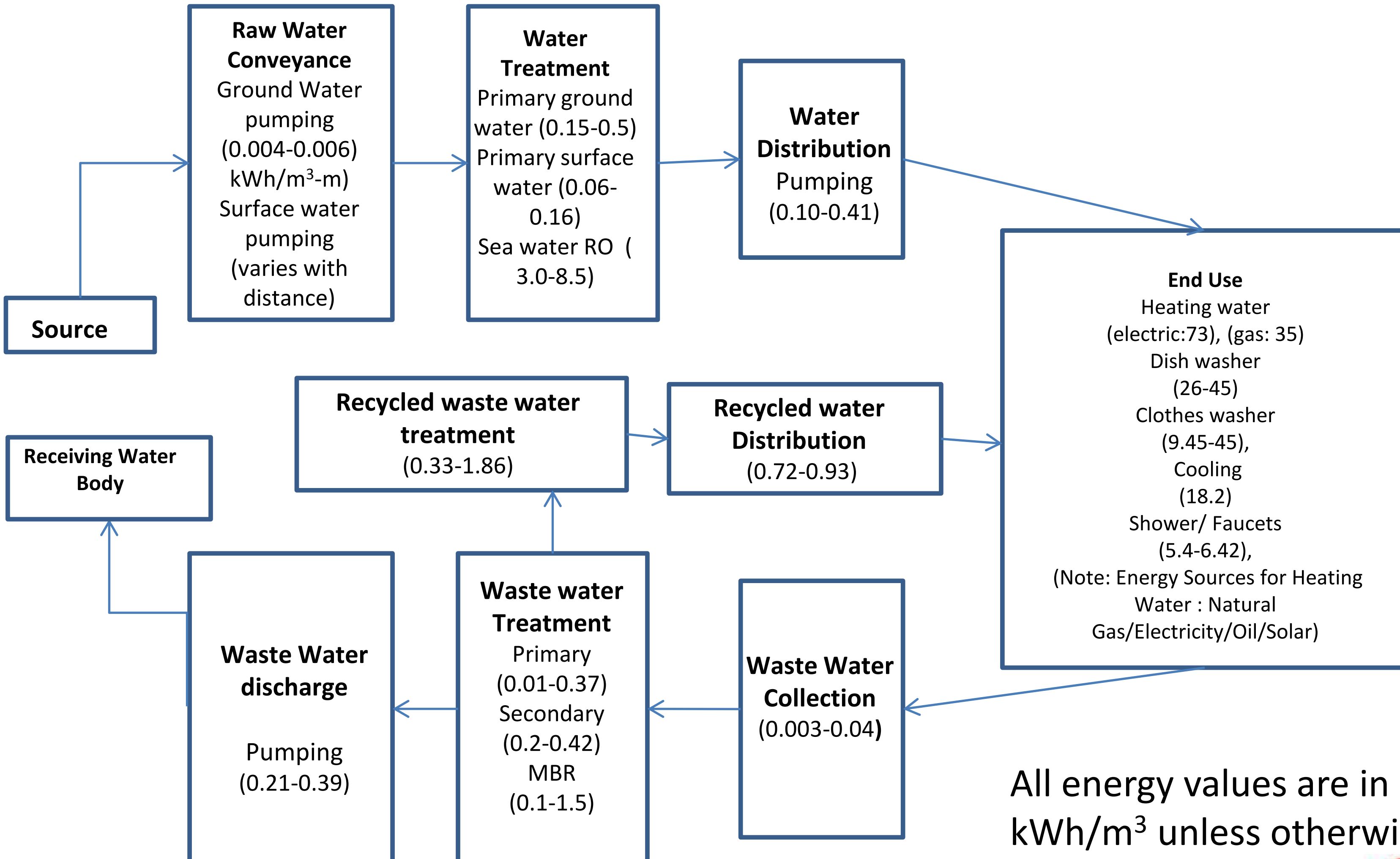
Prakash etal, 2012, IDA

Proposed Water Cycle for Indian Water Management



Source: Plappally and Lienhard 2012, RSER

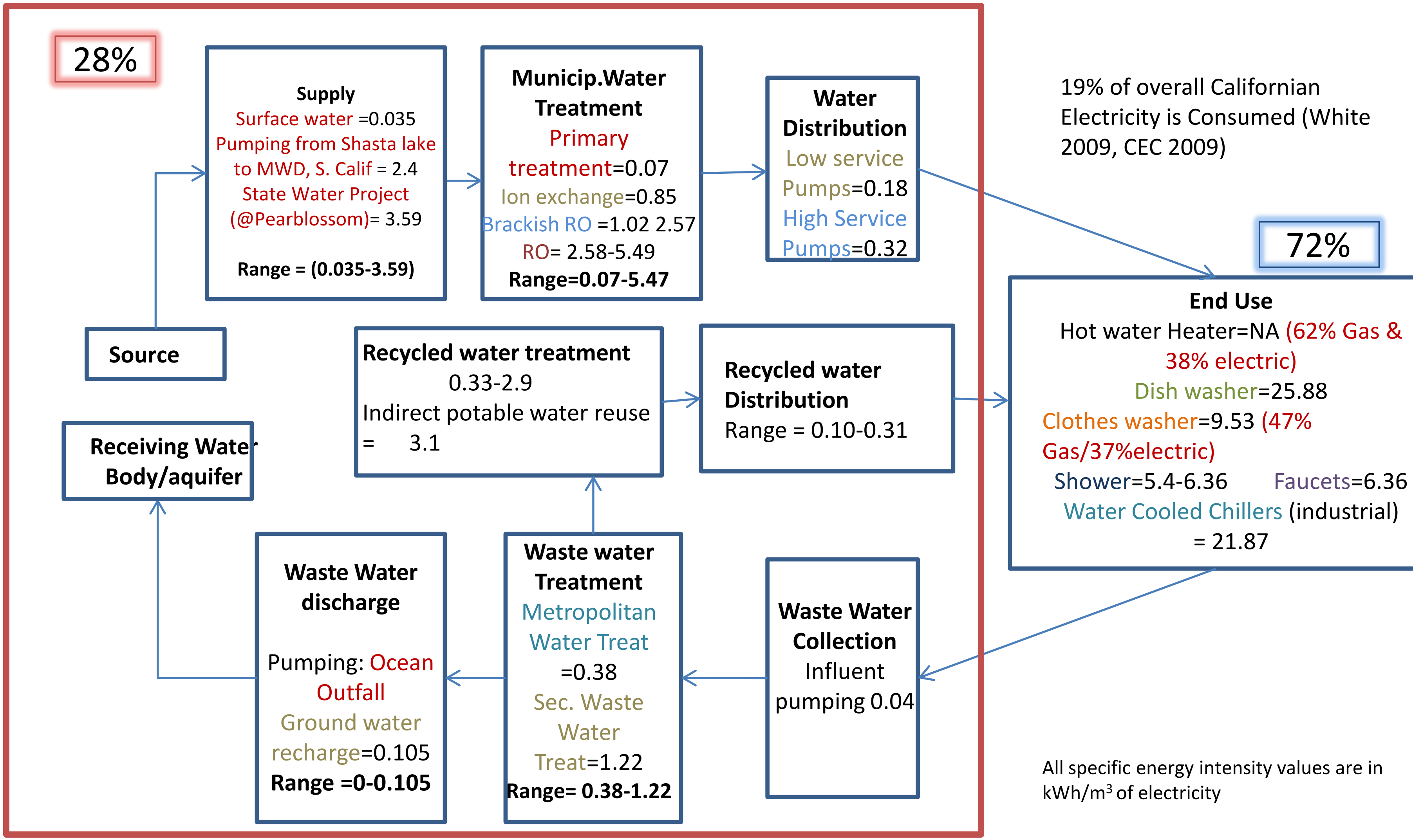
Example: WATER CYCLE FOR THE UNITED STATES



All energy values are in kWh/m^3 unless otherwise stated

Reference: Plappally A K and Lienhard V, J H Energy Requirements for Water Production, Treatment, End Use, Reclamation, and Discharge, Renew. Sustain. Energy Reviews, Vol 16, 2012.

Example: Energy Consumption in California Water Supply



19% of overall Californian Electricity is Consumed (White 2009, CEC 2009)

All specific energy intensity values are in kWh/m³ of electricity

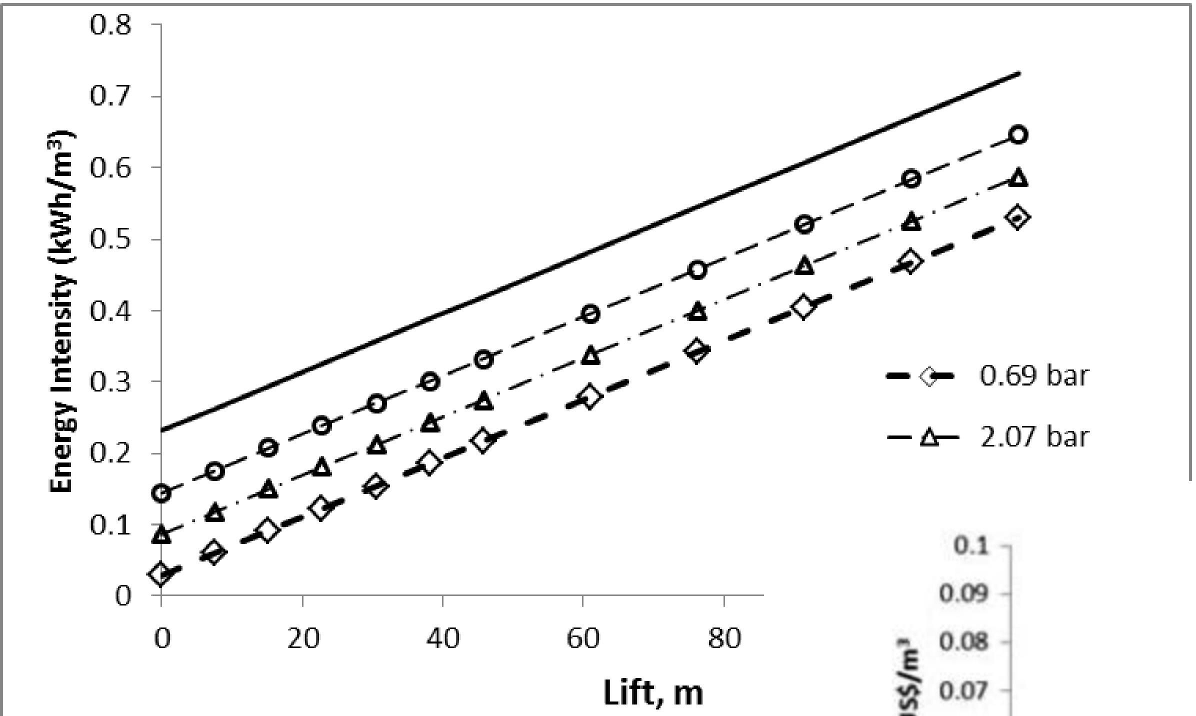
Reference:

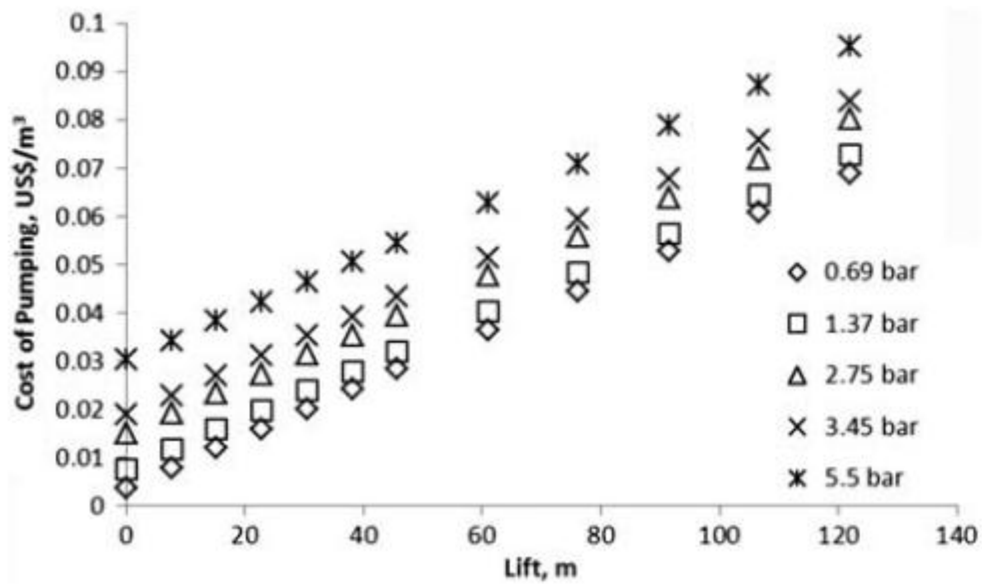
Plappally and Lienhard 2012 , Renew. Susts. Eenergy. Reviews, Vol 16

REALIZE THAT MAXIMUM ENERGY EXPENDED ON WATER IS AT HOME or ENDUSE

$$WHP = \frac{Q \times H}{3960}$$

Extracting Gound Water: Its Expensive

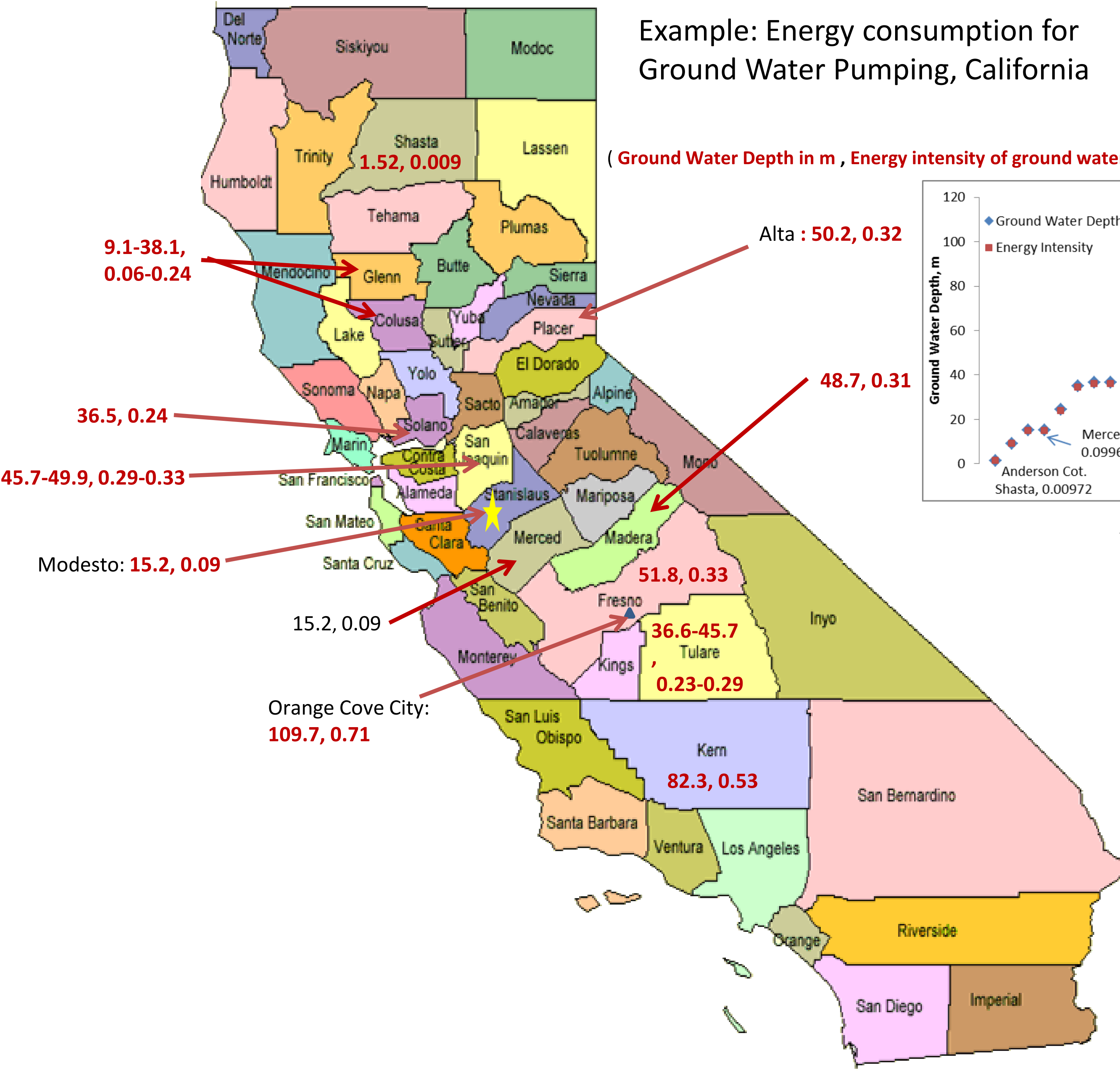




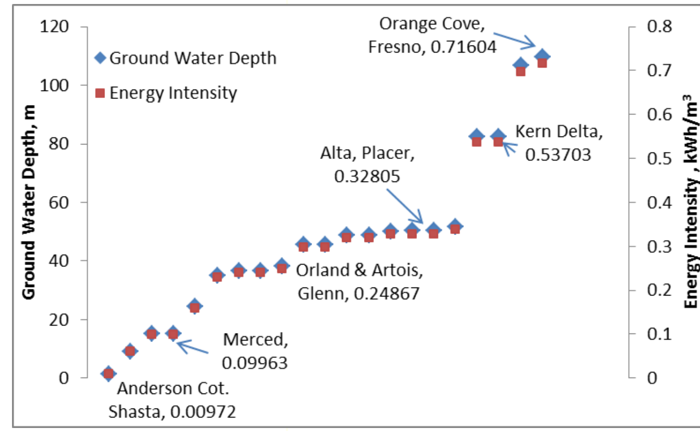
All reported energy consumptions per unit distance approximates to 0.002-0.006kWh/m^3-m

Plappally and Lienhard 2012, RSER, Plappally and Lienhard 2012 Desal and Water Treatment

Example: Energy consumption for Ground Water Pumping, California



(**Ground Water Depth in m** , **Energy intensity of ground water pumping in kWh/m³**)



All reported energy consumptions per unit distance approximates to 0.006kWh/m³-m

North of California is fertile than to arid South: Condition similar to Rajasthan

Surface Water Pumping

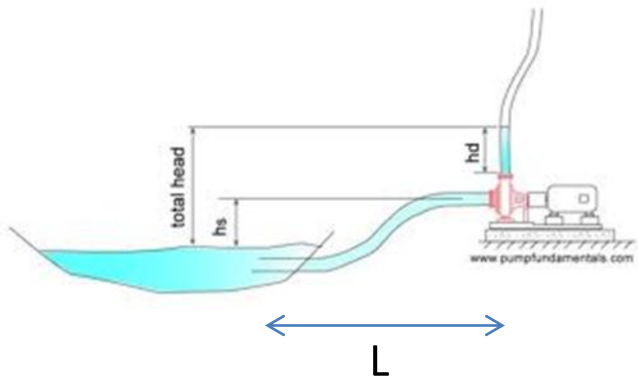
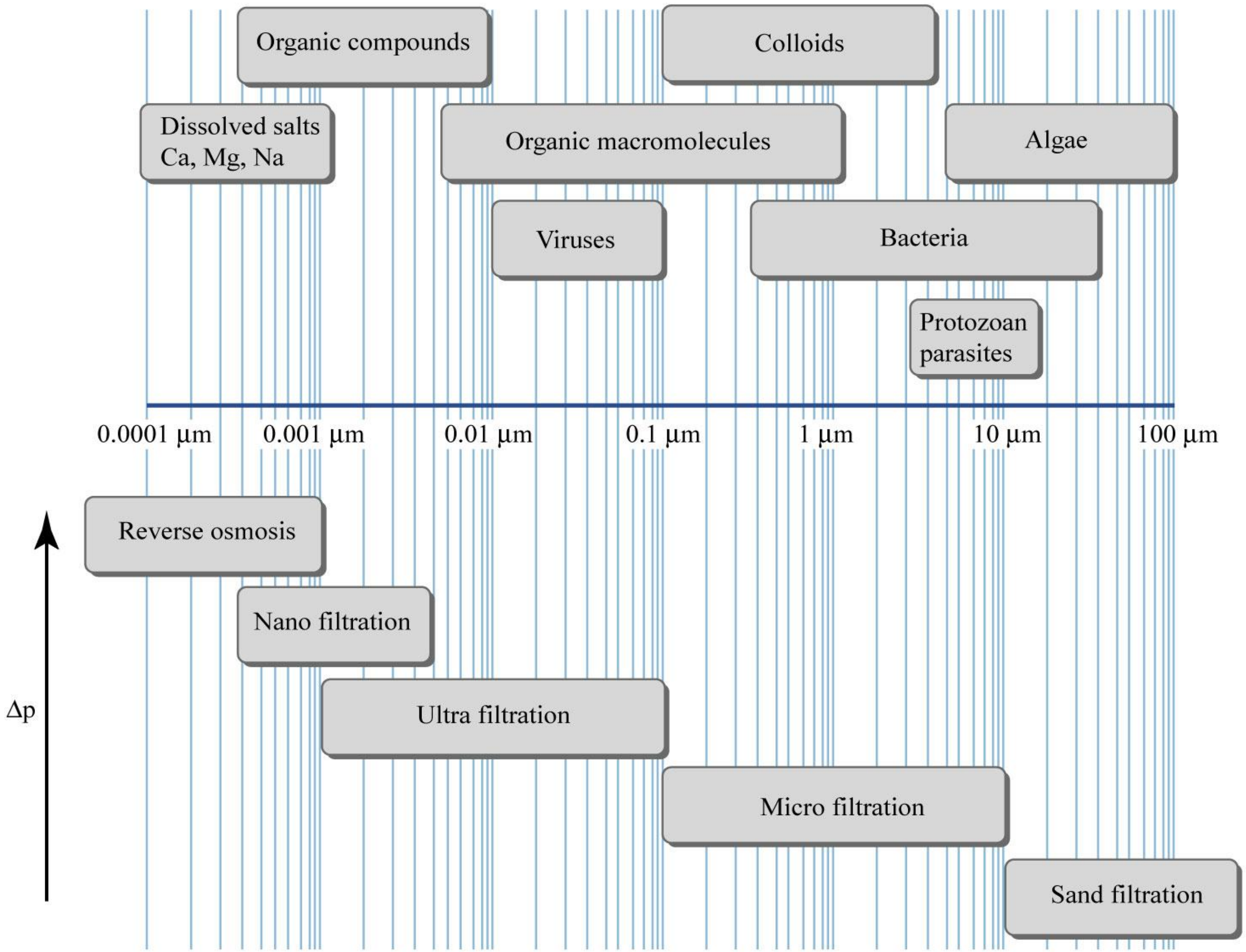


Figure Source: http://www.pumpfundamentals.com/what%20is%20head.htm

Name of the surface water supply	Length 'L' (km)	Energy Consumed (kWh/m³)	Energy Use per unit distance (kWh/m³-km)	Reference
California, USA				
West Branch Aqueduct, CA	51.5	2.07	0.04	Munoz et al. 2010[38]
Coastal Branch Aqueduct, CA	186	2.31	0.012	Munoz et al. 2010[38]
Transfer From Colorado River to Los Angeles, CA	389	1.6	0.004	Wilkinson 2000[8]
Australia				
Water Pipe, Australia	450	3.3	0.007	Anderson 2006 [39]
*SSDP to **PIWSS	116	0.21	0.002	Anderson 2006 [39]
***PSDP to PIWSS	11.2	0.055	0.005	Anderson 2006 [39]
Spain				
Tortosa to Abora	171.4	1.79	0.01	Raluy et al. 2005[37]

*Southern Seawater Desalination Plant, Perth; ** Perth Integrated water supply system; ***Perth Sea Water Desalination Plant

Reference: Plappally A K and Lienhard V, J H Energy Requirements for Water Production, Treatment, End Use, Reclamation, and Discharge, Renew. Sustain Energy Reviews, Vol 16 ,2012



Comparison of treatment methods with particle size.

Ref: Twort et al., Lienhard 2012

WATER TREATMENT

Energy consumption of unit processes in conventional surface water treatment

Surface Water Treatment Process/Device	Energy Range (kWh/m3)
Raw Water Pumping	0.02-0.05
Coagulant Feeding	0.001-0.002
Rapid Mixing	0.008-0.02
Flocculation	0.002-0.006
Sedimentation	0.0005-0.014
Gravity Filtration	0.005-0.014
Hydralic Surface Washing	0.0005-0.001
Back Wash Pumping	0.0009-0.002
In-plant Pumping	0.015-0.04
Chlorine Feeding	0.0007-0.001
Lab and Maintanenence	0.003-0.009
Total	**0.06-0.16**

Reference : WEF 2010, Plappally and Lienhard 2012, BP ESC Report

Conventional raw water treatment energy consumption ranges in some countries.

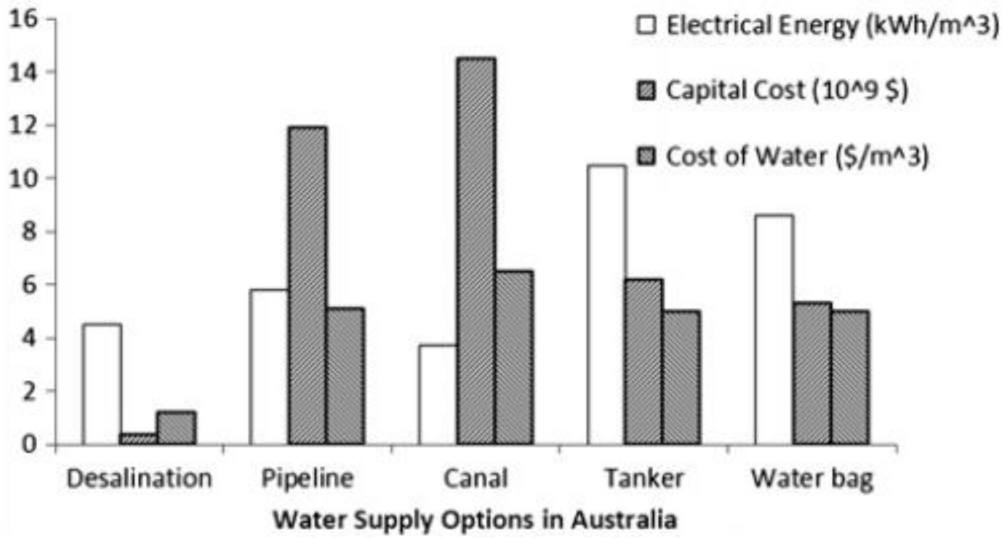
Country	**Energy Consumption Ranges (kWh/m^3)**	Comments
Australia	0.01-0.2	Good ground water quality and high temperature climate
Taiwan	0.16-0.25	
USA	0.184-0.47	
Canada	0.38-1.44	Cold climates
Spain	0.11-1.5	Requires desalting
New Zealand	0.15-0.44	

Reference: Plappally and Lienhard, 2012, Cost of water supply, treatment, end-use and reclamation, Desalination and Water Treatment, DOI:10.1080/19443994.2012.708996

Comparison Between Water supply and Treatment options

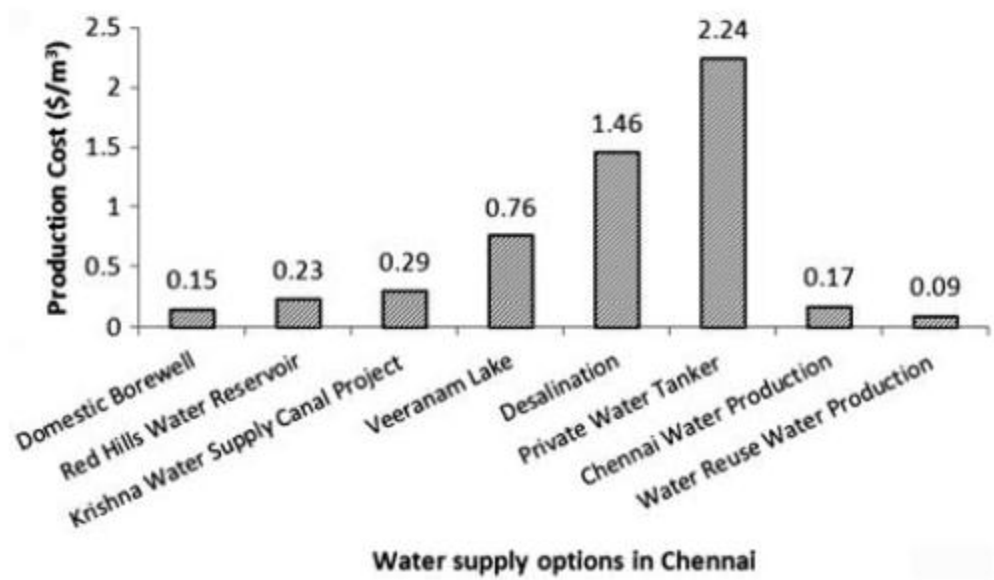
	Equivalent electrical energy required (kWh/m³)
MSF coproduction	11-13
MED-TVC coproduction	9-14
Seawater reverse osmosis	3 to 5+
Ideal reversible seawater desalination	0.7 to 2
Wastewater recycling – MBR*	0.5 to 1.5
Brackish water reverse osmosis	0.4-1.0+
Ground water pumping (50 m lift)	0.25
Distributing water (150 km, no grade)	0.6
Conventional water treatment	0.2 to 1.0
Domestic water heating (electric)	73
Conventional waste water treatment	0.15 to 0.45

Reference: J. H Lienhard V, 2012, Europe, Plappally and Lienhard 2012 Renew. Sust. Energ. Review

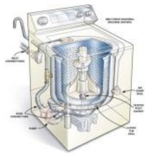
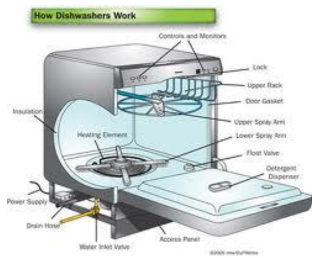


Distribution Costs in India and Australia a companison, : Indian Government should understand to manage to manage energy

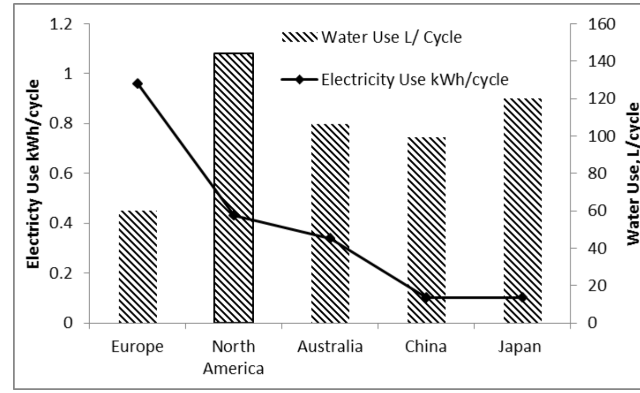
Plappally et al, 2012, DWT



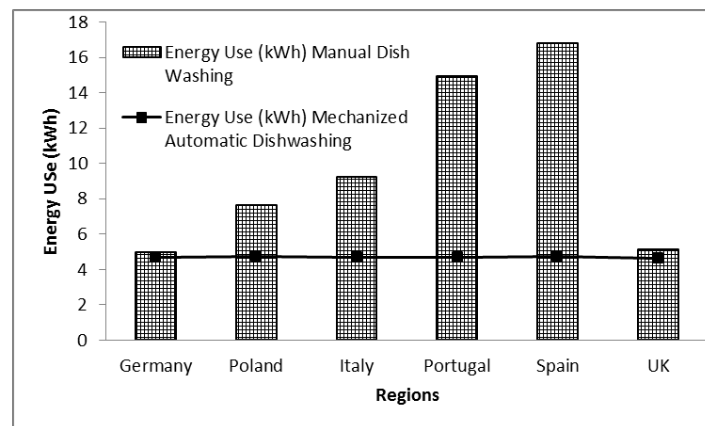
RESIDENTIAL END USE

Appliances	Energy Intensity (kWh/m^3)
Cloth washer (vertical/ drum/ Horizontal)  	9.45-45
Dish washer 	26-45
Faucet 	5.4- 6.42
Shower 	6.42
Heating water (using electric heater)	73
Heating water (using natural gas heater)	35
Heating water (using LPG)	35
Heating water (using Oil)	39
Refrigeration	18.2

Variation of electricity and water consumption in washing (mechanized) clothes



Energy used per single dish wash or cycle

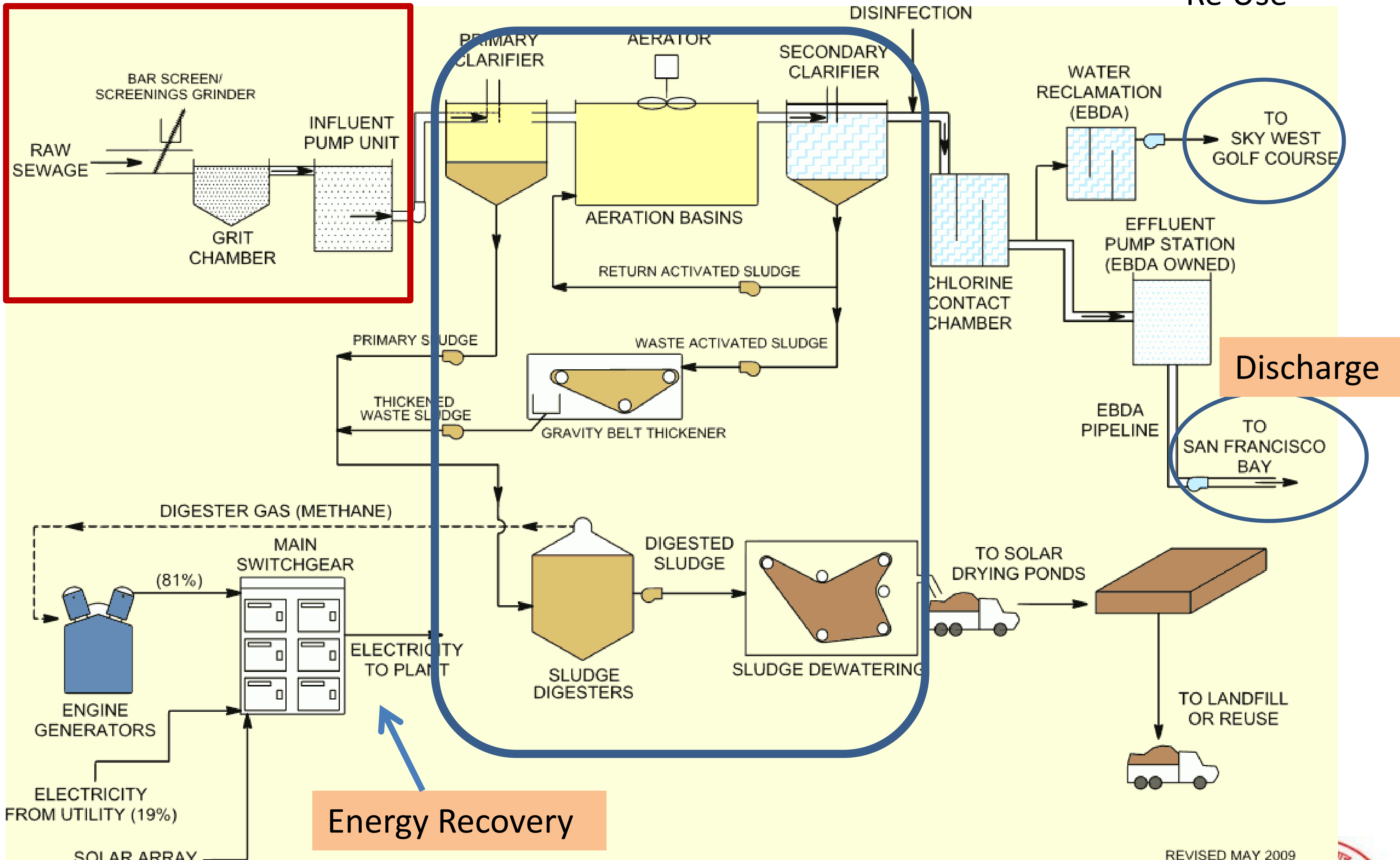


Reference: Plappally A K and Lienhard V, J H Energy Requirements for Water Production, Treatment, End Use, Reclamation, and Discharge, Renew. & Sustain. Energy Review, Vol 16. 2012

Primary

Secondary

Re Use



Source: www.oroloma.org/sewer/treatment

Mean Energy Consumption for Municipal Waste Water Treatment in various countries

Countries	Energy Consumption (kWh/m^3)	References
New South Wales, Australia	0.418	Radcliffe 2004
Ontario, Canada	0.46	Maas 2009
Taiwan	0.41	Cheng 2002
New Zealand	0.49	Kneppers 2009
USA	0.43	Crawford 2007

Energy for wastewater treatment		Energy Intensity (kWh/m^3)
Energy used to collect wastewater		
	Waste Water Pumping	0.04-0.19
	Waste water collection	0.003-0.04
	Primary Waste Water Treatment	0.01-0.37
Secondary Waste Water Treatment		
	lagoons	0.09-0.29
	activated sludge	0.1-0.6
	oxidation ditch	0.3-2
	Membrane Bio Reactors	0.1-1.5

Membrane bioreactors are designed to operate at comparatively high suspended solids concentration compared to activated sludge processes

The energy intensity of the processes will decrease with increase in size of the plant

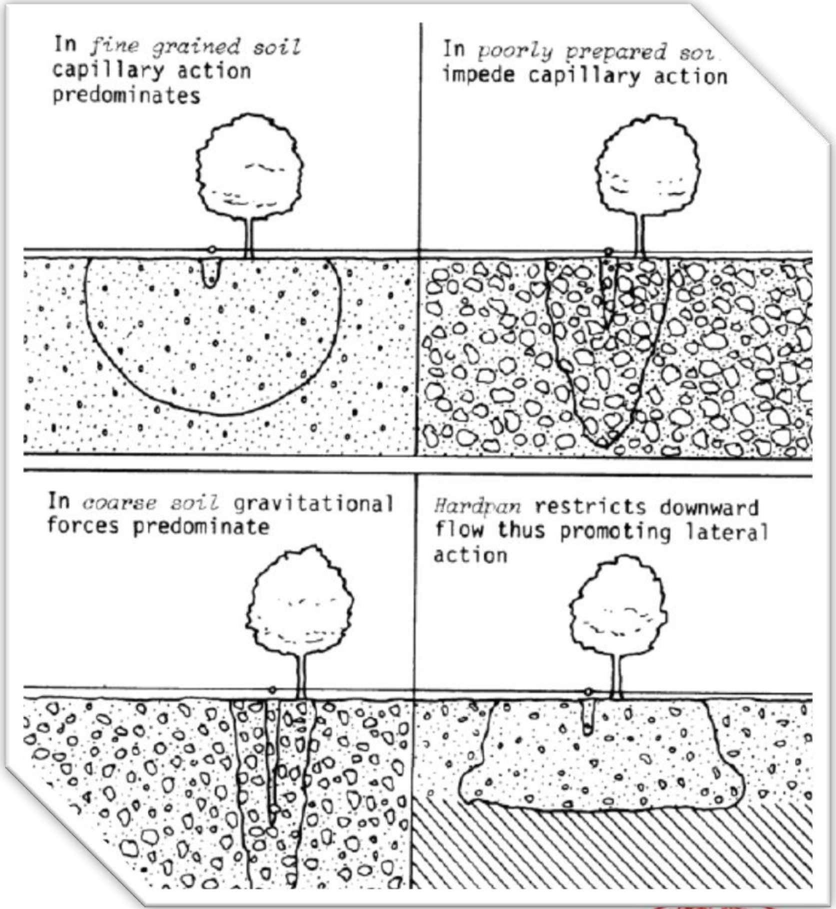
Reference: Plappally A K and Lienhard V, J H Energy Requirements for Water Production, Treatment, End Use, Reclamation, and Discharge, Renew. Sustain Energy Reviews, Vol 16 ,2012

ENERGY FOR AGRICULTURE WATER USE

HOW ENERGY IS EXPENDED TO GROW CORN: Case Study of US and INDIA

Equivalent Electrical Energy Intensity (kWh/hectare)		
Inputs	US Corn	Indian Corn
Labor	179.07	453.48
Machinery	394.57	71.7
Bullock	0.00	503.87
Diesel	156.98	
Nitrogen	961.24	465.11
Phosphorus	127.13	56.2
Potassium	106.20	
Manure	0.00	372.48
Lime	122.09	
Seeds	201.55	46.89
Irrigation	124.03	
Herbicides	240.31	
Insecticides	108.53	
Electricity	13.18	
Transport	65.50	
Total Energy Used	3189	1970
Output (kg/hectare)		
Corn Yield	9400	1721

Type of Soil- Water Percolation



Source: Plappally et al, 2012, Pimental, 2009, Brown, L C, 2008, The OSU.

Which is the Best Energy Efficient irrigation Systems for India: Manage Water – Manage Energy

Electricity use and Costs for drip and surface irrigation of crops grown in India

	Electricity Consumption (kWh/ha)		Quantity of water (m^3/ha)		Productivity (10^5 kg/ha)		Irrigation Cost ($/ha)		Percent cost savings (%)
Crops	Drip	Surface	Drip	Surface	Drip	Surface	Drip	Surface	Over Surface
Sugarcane	**1325**	2385	**9400**	21500	**0.14**	0.11	**98.2**	176.7	55.5
Grapes	**2483**	3959	**2780**	5320	**0.24**	0.20	**183.9**	293.3	62.7
Banana	**5913**	8347	**9700**	17600	**0.68**	0.52	**438**	618.4	70.8

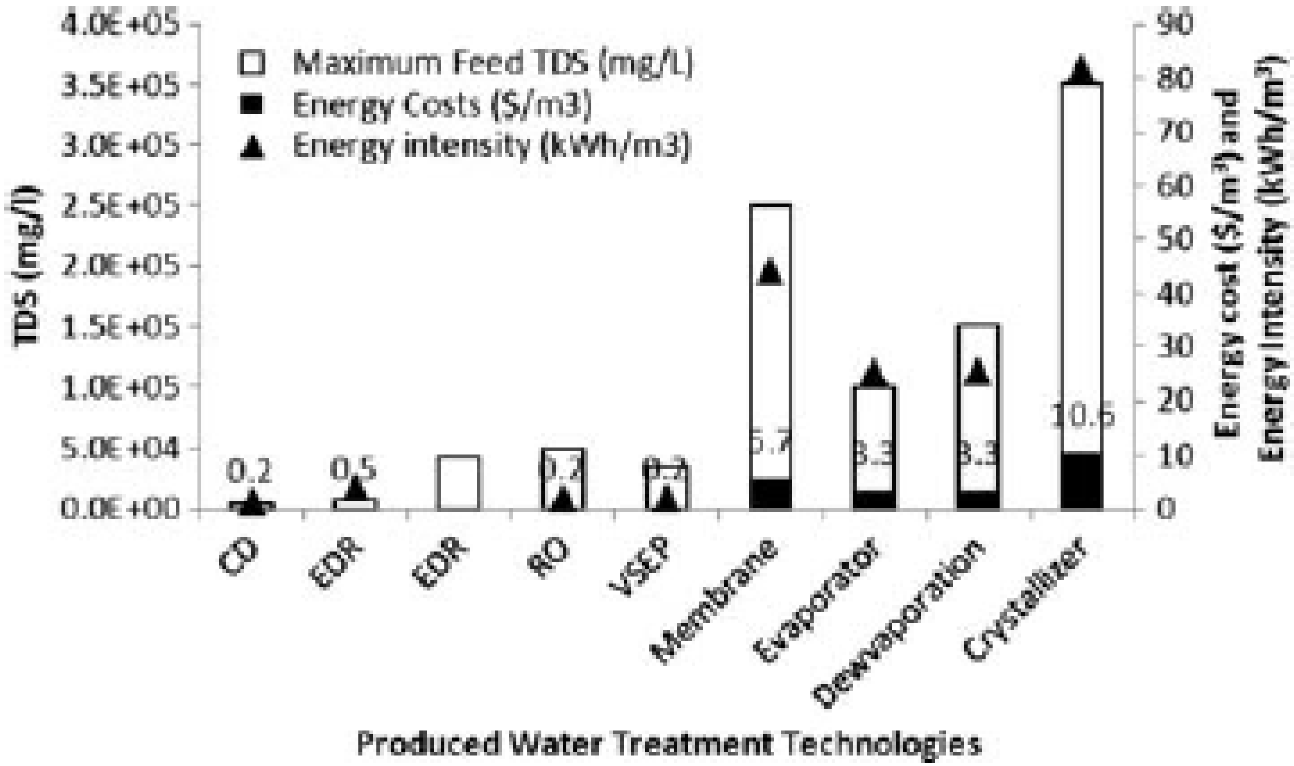
Source: Plappally A K and Lienhard J H, Renew.Sustain Energy Review, 2012

The energy expended to irrigate a field is dependent on
the amount of water pumped,

- area of the field,
- soil characteristics of the location,
- geology,
- slope,
- crop varieties or cropping patterns,
- precipitation or climate at the location,
- temperature,
- type of irrigation,
- irrigation scheduling,
- application effectiveness,
- pumping system type,
- pressure requirement at the point of use and
- energy cost

Source: Plappally A K and Lienhard J H, RSER, Vol 16

FOOD OF THOUGHT FOR PETROLEUM INDUSTRIES FOR WATER TREATMENT AND MANAGEMENT



Energy Consumption of Water Treatment for the Petroleum Industry

- A possibility in Rajasthan with the largest shale reserve in India

Reference: Plappally A K and Lienhard V, J H Energy Requirements for Water Production, Treatment, End Use, Reclamation, and Discharge, Renew. Sustain Energy Reviews, Vol 16 ,2012

Recent observations in India including Rajasthan

People may not realize that in completing basic tasks, such as washing hands or brushing teeth, they could be using more water and water-related energy than is needed.

Also, nearly 25% people accepted that on an average, they spend more than 12 minutes in the shower.

Peak consumption range of refrigerated drinking water is reported to be 2-4 litres at Mandi near to the Himalayas in summer while a consumption of 9-10 litres is reported from Jodhpur near the Thar desert.

There is rampant consumption of bottled water at Jodhpur while it is negligent at Mandi.

Approximately 40% people do not even think about storing rainwater for household use, in spite of facing regular water shortage during the summer months. People are ignorant of the water policies by the government and personal interaction with them revealed that most of them were not familiar with common terms such as flat tariff for water.

Source: A. Hasija et al 2013, WATECH 2013, Feb 13-14, WATECH ASIA

Situation at Home, Jodhpur Rajasthan (Puraram et al 2013, WATECH, 2013, WATECH ASIA)

20-30% of the general public was found to be ignorant of their household expenses related to electricity and water.

Toilets were found to be the location of maximum daily water consumption.

People preferred cold water to bath and to wash clothes. Hand washing of clothes was more preferred than machine wash.

Most of the respondents were ignorant about the technical differences and efficiencies of drum as well as vertical washing machines.

About 70% of the water filtration market in Jodhpur is controlled by reverse osmosis and ultra violet filtration systems put together.

Females exhibited comparatively more awareness towards water use and related energy consumption at home.

The appliance aesthetics and respondents mindset overshadows their knowledge on effectiveness of the technology and efficiency features of the appliance used on or for water.

This impairs the basic aim of water management and conservation in households.