Drivers, Successes, Challenges and Opportunities for Onsite Industrial Water Reuse: a Path Forward for Collaboration and Growth (WateReuse-13-04)

Joan Oppenheimer, Mohammad Badruzzaman, Carla Cherchi, Jason Weakley, Jonathon Pohl

About WateReuse

The WateReuse Research Foundation is a nonprofit charitable organization that conducts research to improve the treatment, distribution, and acceptance of water reuse.

More Information

www.watereuse.org/foundation

Research Reports

www.watereuse.org/foundation/publications

A Few Notes Before We Get Started…

- Today's webcast will be 60 minutes.
- There is one Professional Development Hour available.
- A PDF of today's presentation can be downloaded when you complete the survey at the conclusion of this webcast.
- If you have questions for the presenters, please send a message by typing it into the chat box located on the panel on the left side of your screen.
- If you would like to enlarge your view of the slides, please click the Full Screen button in the upper right corner of the window. To use the chat box, you must exit full screen.

Today's Presenters

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MWH Global

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MWH Global

Erin Augustine
Kellogg Company

WateReuse Research Foundation (WRRF) Industrial Reuse Projects

External Reuse

Supply by the external reuse water producers, mainly utilities

WRRF-08-12
Requirements and Opportunities for Water Reuse in Energy and Biofuels

WRRF-09-04
The Value of Water Supply Reliability in the CII Sector

WRRF-12-03
Analysis of Technical and Organizational Issues in the Development and Implementation of Industrial Reuse Projects

Internal Reuse

Water is being used, treated, and reused onsite

WRRF-13-04
Drivers, Successes, Challenges and Opportunities for Onsite Industrial Water Reuse: a Path Forward for Collaboration and Growth

WRRF-14-04
Framework of Onsite Industrial Reuse

WRRF-14-05 White Paper on Hydraulic Fracturing

WATEREUSE

Acknowledgements

- Project Officer - Justin Mattingly
- Technical Advisory Committee
  - Jimmy Yu (PepsiCo)
  - Anthony Lau (IDI)
  - Greta Zornes (ConocoPhillips)
  - Richard Cisterna (Natural Systems Utilities)
- Active Industry Participants
  - Boeing, Coca-Cola, Dow, Duke Energy, GE, Gold Fields, Kellogg, Jackson Family Wines, Newmont Mining, Perrigo, Veolia

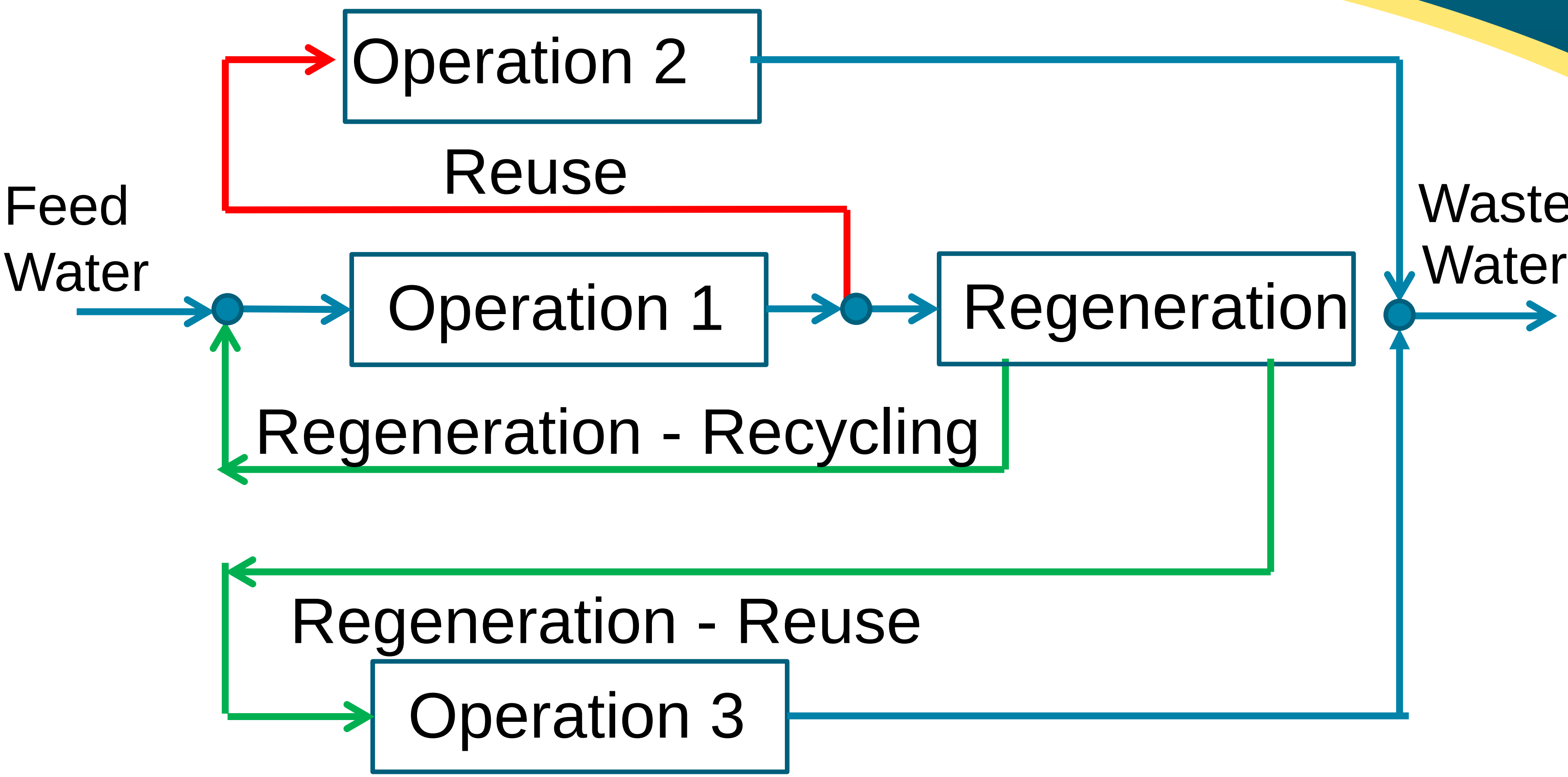
Definition of “Onsite / Internal” Water Reuse

Retention of water within a given facility that has served a useful purpose

&

then using the same water again for a beneficial purpose within the same facility.

Types of Onsite Water Reclamation



Klemeš, J.J. Industrial water recycle/reuse. Current Opinion in Chemical Engineering (2012), 1:239.

Conservation vs Reclamation

- Cooling Towers recirculate water to cool equipment
  - Evaporation (temp differential)
  - Drift (drift rate)
  - Blowdown or Bleed-off (COC)

Where Cycles of Concentration (COC) = $\frac{TDS_{(Blowdown)}}{TDS_{(Makeup)}}$

Make-up = Evaporation + Blowdown + Drift

So while improving COC is a conservation measure, reuse makeup water can enhance COC

Project Objectives

- Identify Drivers – economic, regulatory, social
- Understand on-site industrial reuse/recycling factors
- Explore roadblocks/impediments to onsite reuse
- Summarize gaps – knowledge, tools, technologies
- Assess future expansion opportunities

Project Approach

Task 1: Desktop Study

- Lit Review
- Vendor Outreach
- Trade Associations
- Public/Private Partnerships
- Regulations

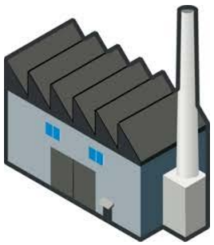
Task 2: Survey

- Water Needs
- Scarcity Issues
- Tools
- Current Reuse
- Drivers/Needs
- 10 of 21 Companies
- 17 Facilities

Task 3: Workshop

- 2 Workshops
- 8 of 21 Companies
- Research Roadmap
- Knowledge Gaps

Industrial Reuse Differs from Municipal Reuse



- Larger diversity of industrial facility processes
- Proprietary nature of industrial corporations
- More diverse and exotic variety of constituents
- Greater need for rapid return on investment
- Historically fewer subsidized economic incentives
- Less technology performance data from installations

North American Industry Classification System (NAICS)

Code	Definition	Code	Definition
21	Mining, Quarrying, O&G	325	Chemical Manufacturing
22	Utilities (Power)	326	Plastics & Rubber Manufacture
311	Food Manufacture	327	Nonmetallic Mineral Manufacture
312	Beverage/Tobacco Manufacture	331	Primary Metal Manufacture
313	Textile Mills	332	Fabricated Metal Manufacture
314	Textile Product Mills	333	Machinery Manufacture
315	Apparel Manufacture	334	Computer/ Electronic Manufacture
316	Leather Manufacture	335	Electrical Equipment Manufacture
321	Wood Product Manufacture	336	Transportation Manufacture
322	Paper Manufacture	337	Furniture Manufacture
323	Printing & Support Activities	339	Miscellaneous Manufacture
324	Petroleum/Coal Manufacture		

Eight General Water Use Categories

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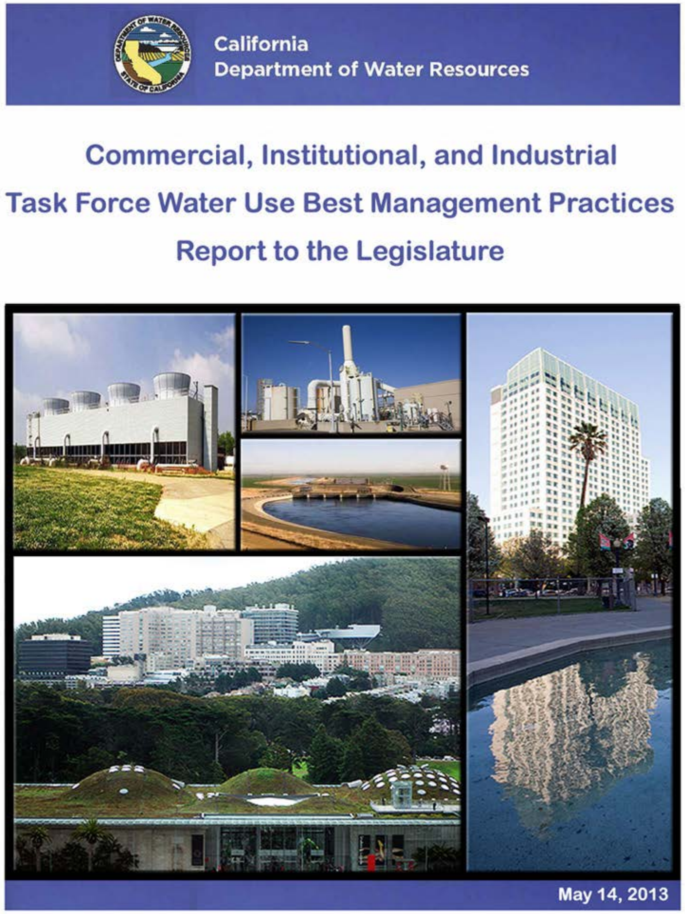
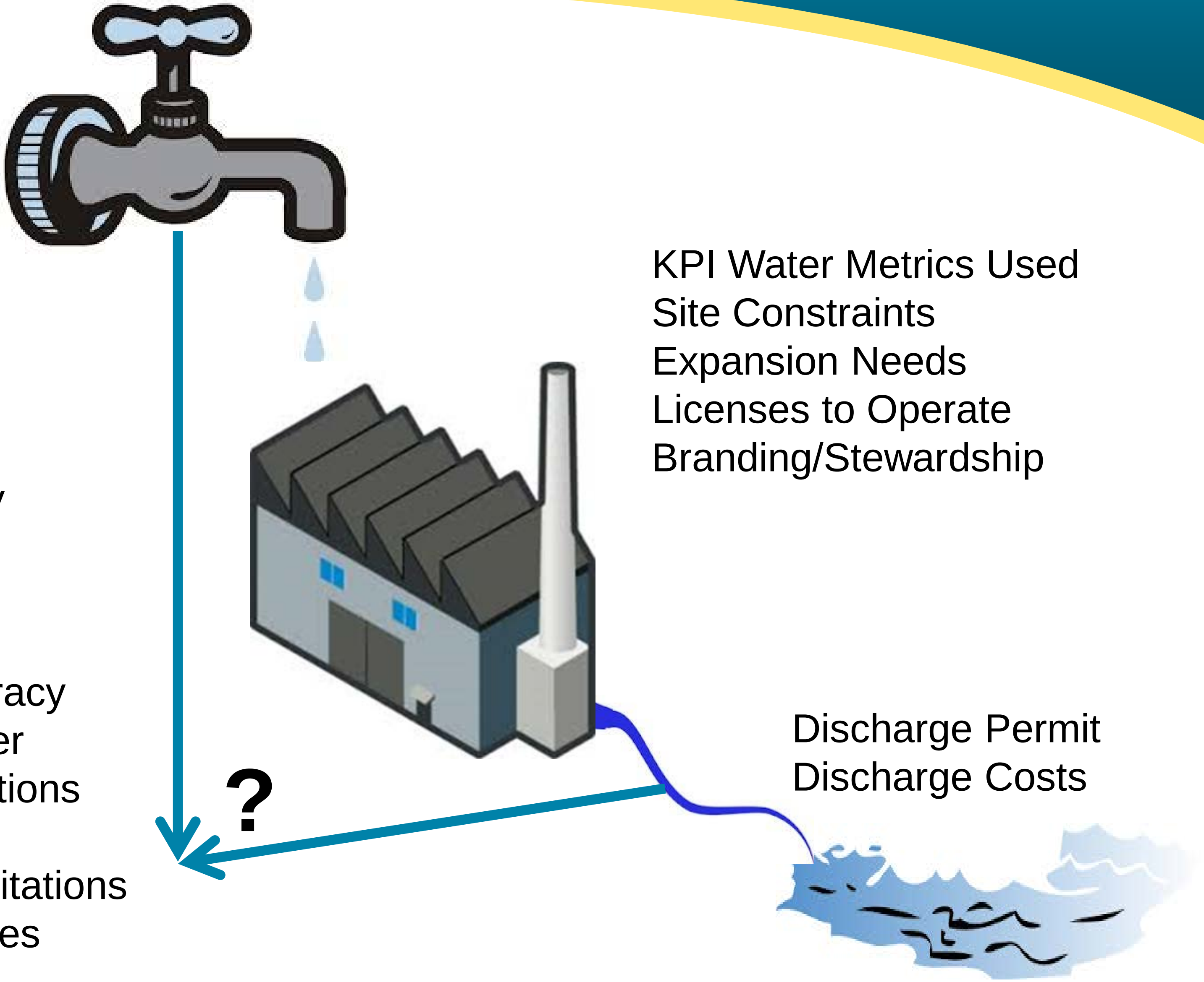


- Cooling & boilers
- Cogeneration/energy recovery
- Process
- In-plant conveyance
- Cleaning
- Environmental controls
- Sanitation
- Irrigation of landscape

Factors Creating Drivers / Challenges

Water Scarcity
Supply Costs



KPI Water Metrics Used
Site Constraints
Expansion Needs
Licenses to Operate
Branding/Stewardship

Volume Ratios
Technology Parity
Technology Risk
Regulatory Parity
Production Risks
Water audit Accuracy
True Cost of Water
Stakeholder Relations
Permitting Clarity
Infrastructure Limitations
Financial Incentives

Discharge Permit
Discharge Costs

Factors Creating Drivers / Challenges

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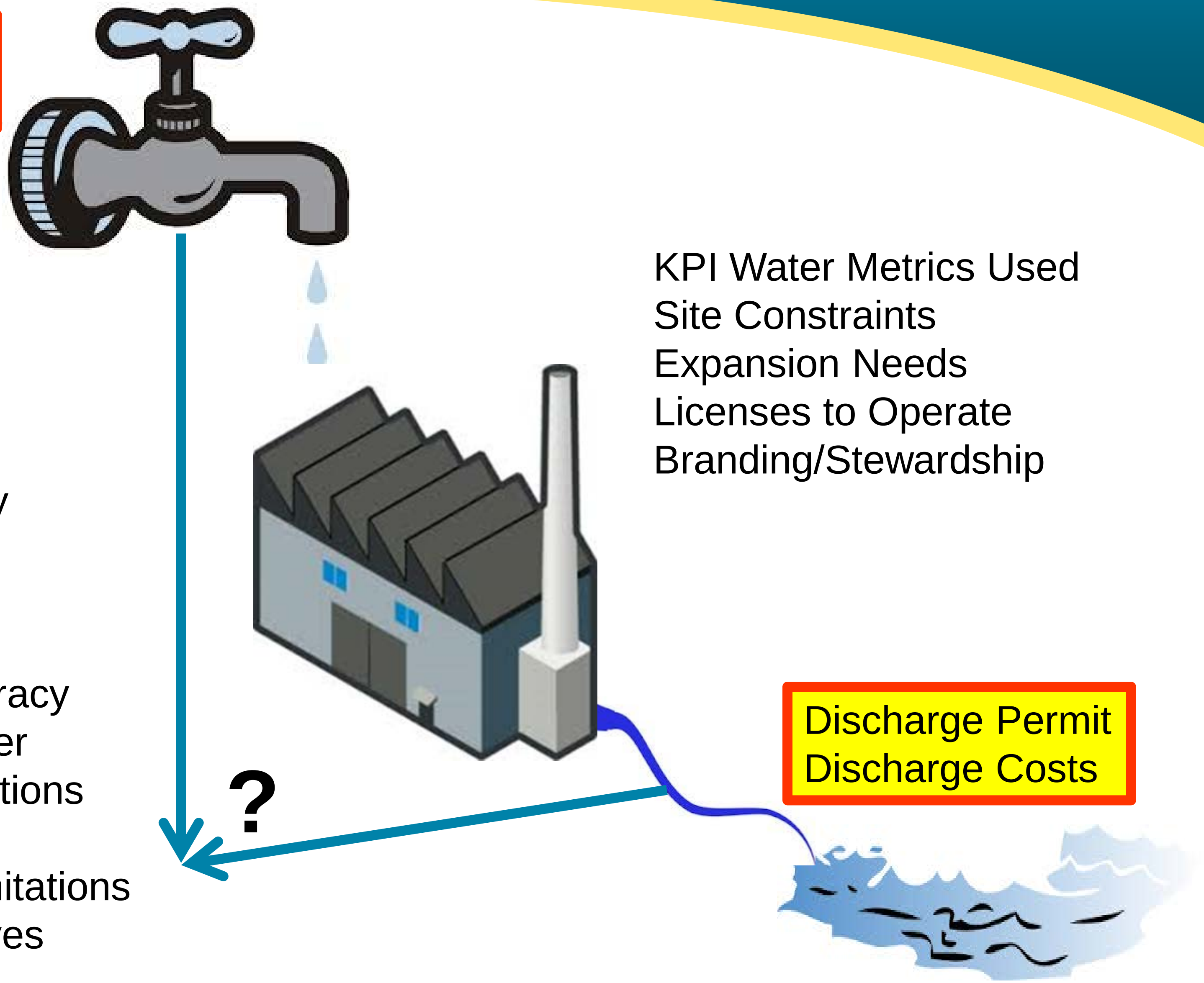

Volume Ratios
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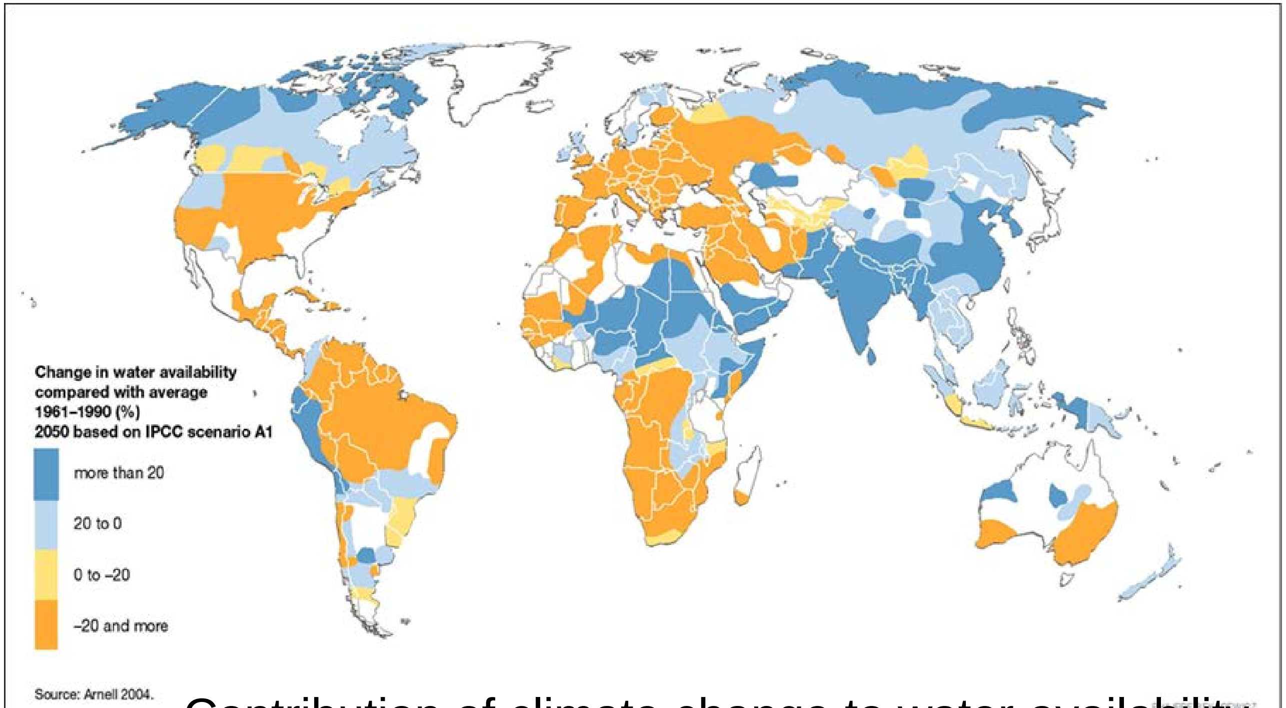
Physical Water Risk – Regional Stress

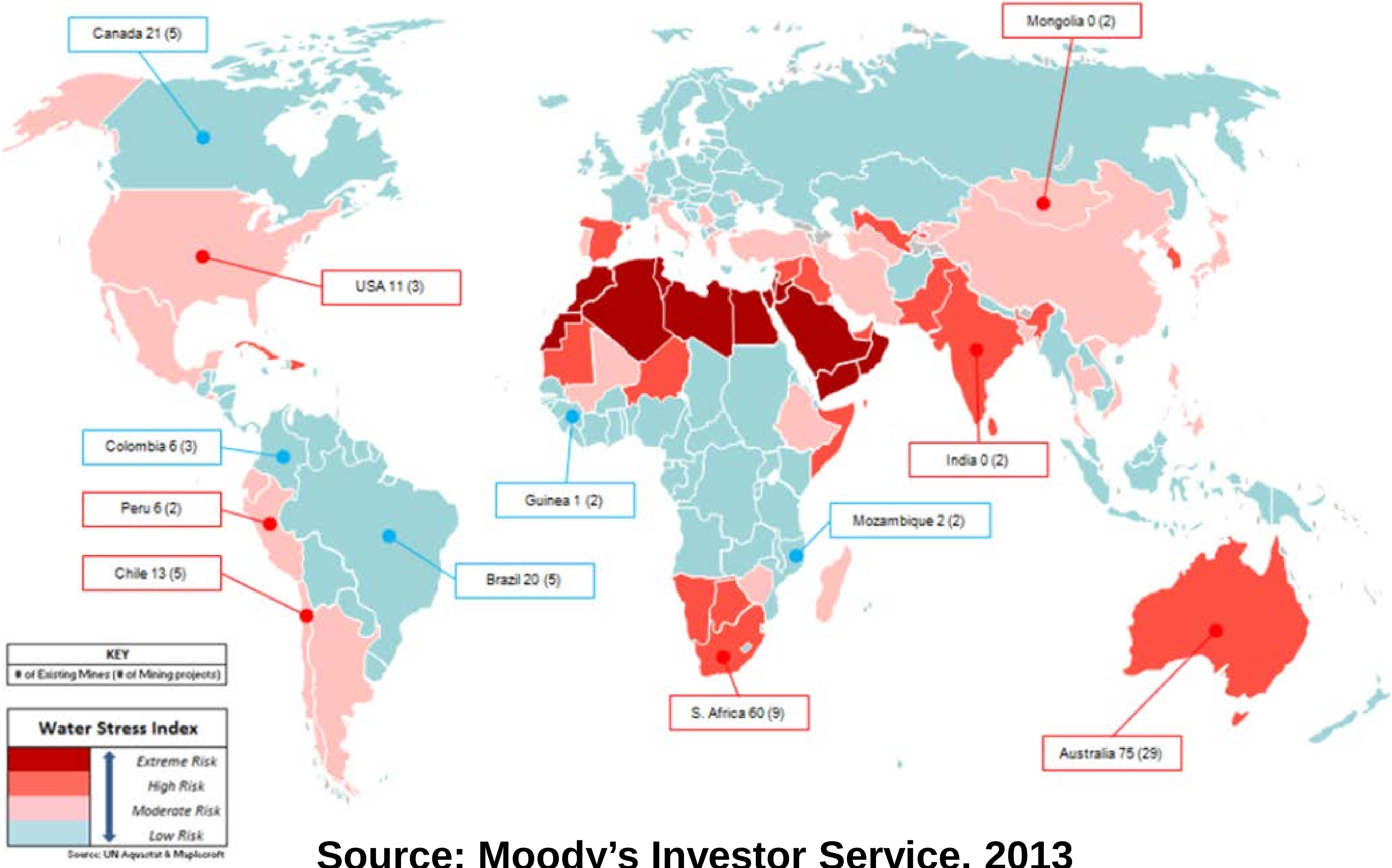
- Inadequate Local Supplies
  - Increasing population / community development needs
  - Climate change altering regional distribution
  - Pollution



Contribution of climate change to water availability

Source: www.unep.org/dewa/vitalwater/jpg/0407-runoff-scenario-EN.jpg

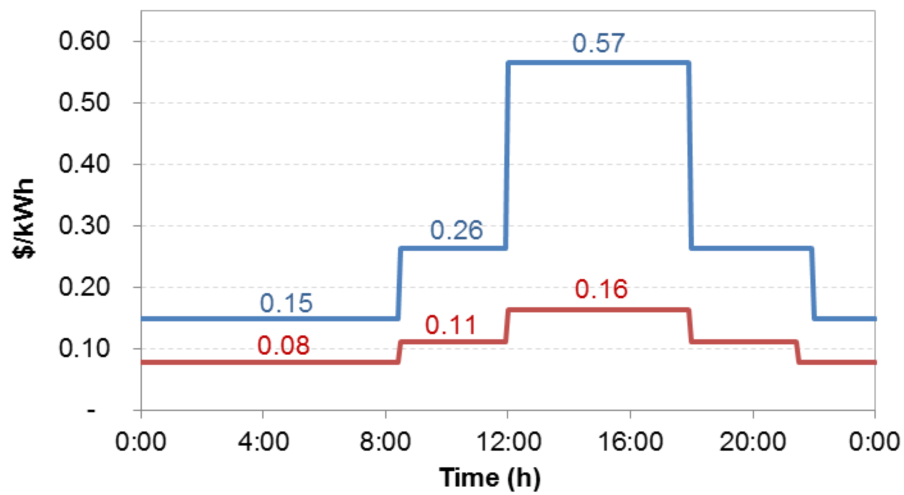
Water Stress for Mining Regions



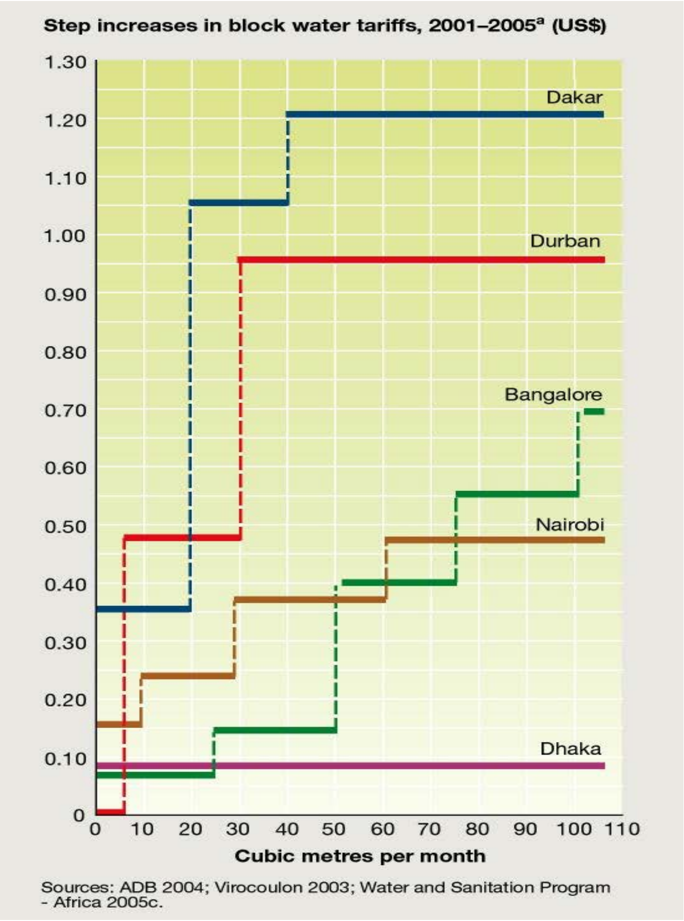
Source: Moody's Investor Service, 2013

Regulatory Water Risks

- <u>Government Use Restrictions</u>
  - Pricing of supply & discharges
  - Licenses to operate (permitting)
  - Water rights
  - Quality standards



Example of electricity TOU tariff



Example of block water tariff

Cost of Water by OECD Nation

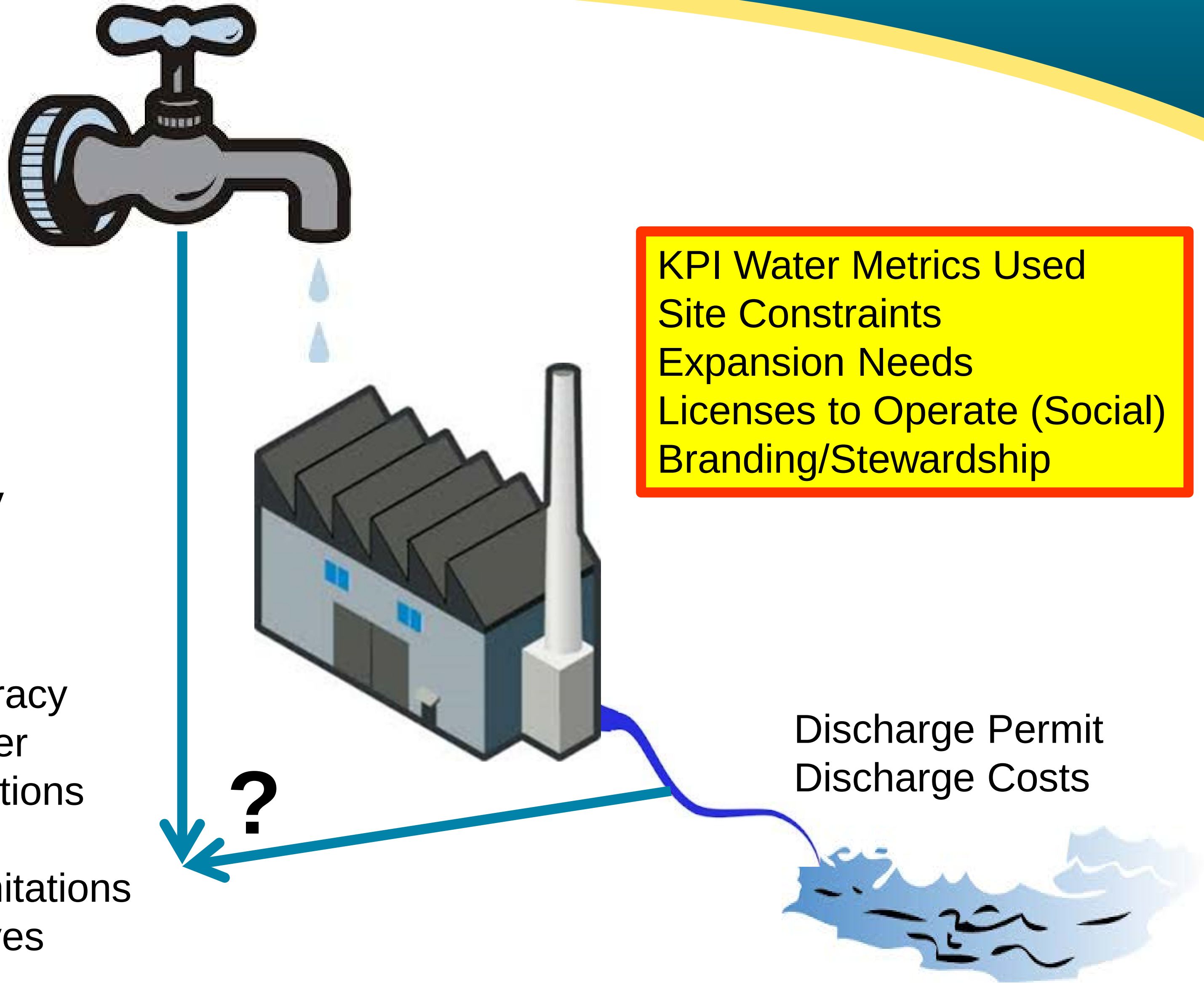
OECD Nation	Household ($US/1000 gal)	Industrial & Commercial ($US/1000 gal)	Irrigation & Agriculture ($US/1000 gal)
Netherlands	12	4.1	5.4
Austria	4.0	4.0	3.8
France	12	3.6	0.30
Greece	4.3	4.3	0.19
USA	4.7	1.9	0.19
Hungary	1.7	5.8	0.011
UK	8.6	6.4	0.076
Australia	6.2	6.2	0.076
Canada	2.6	6.0	0.038

(http://reliefweb.int/report/world/united-nations-world-water-development-report-2014-water-and-energy)

Project Survey Mean Cost was $2.88 (n=14)

Factors Creating Drivers / Challenges

Water Scarcity
Supply Costs



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Permitting Clarity
Infrastructure Limitations
Financial Incentives

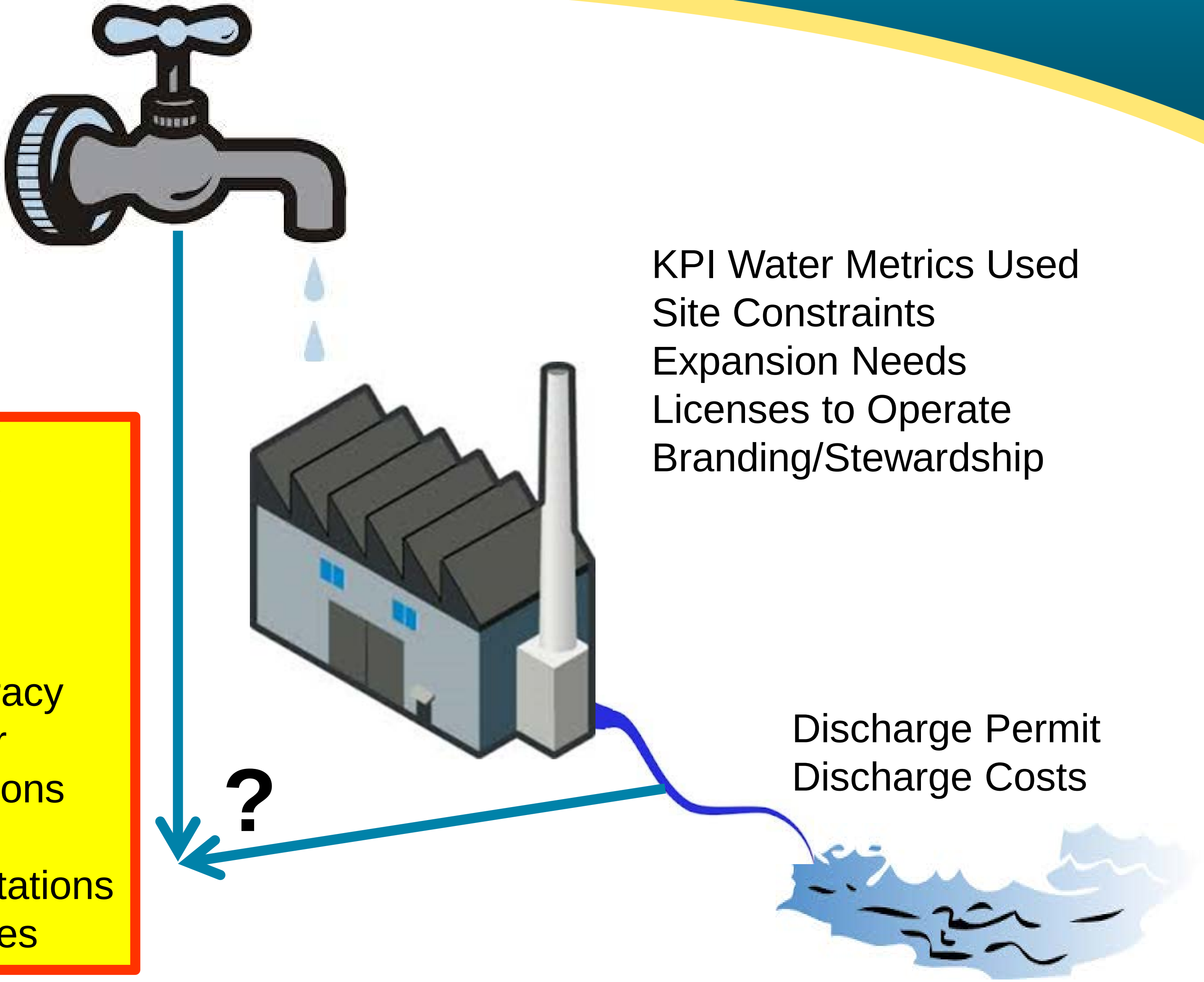
Discharge Permit
Discharge Costs

Water Risks - Reputational

- Prevent tarnishing of brand or image
  - Negative ecological impacts
  - Negative public health impacts
  - Appropriating more than “fair share”
  - Exporting water away from local users

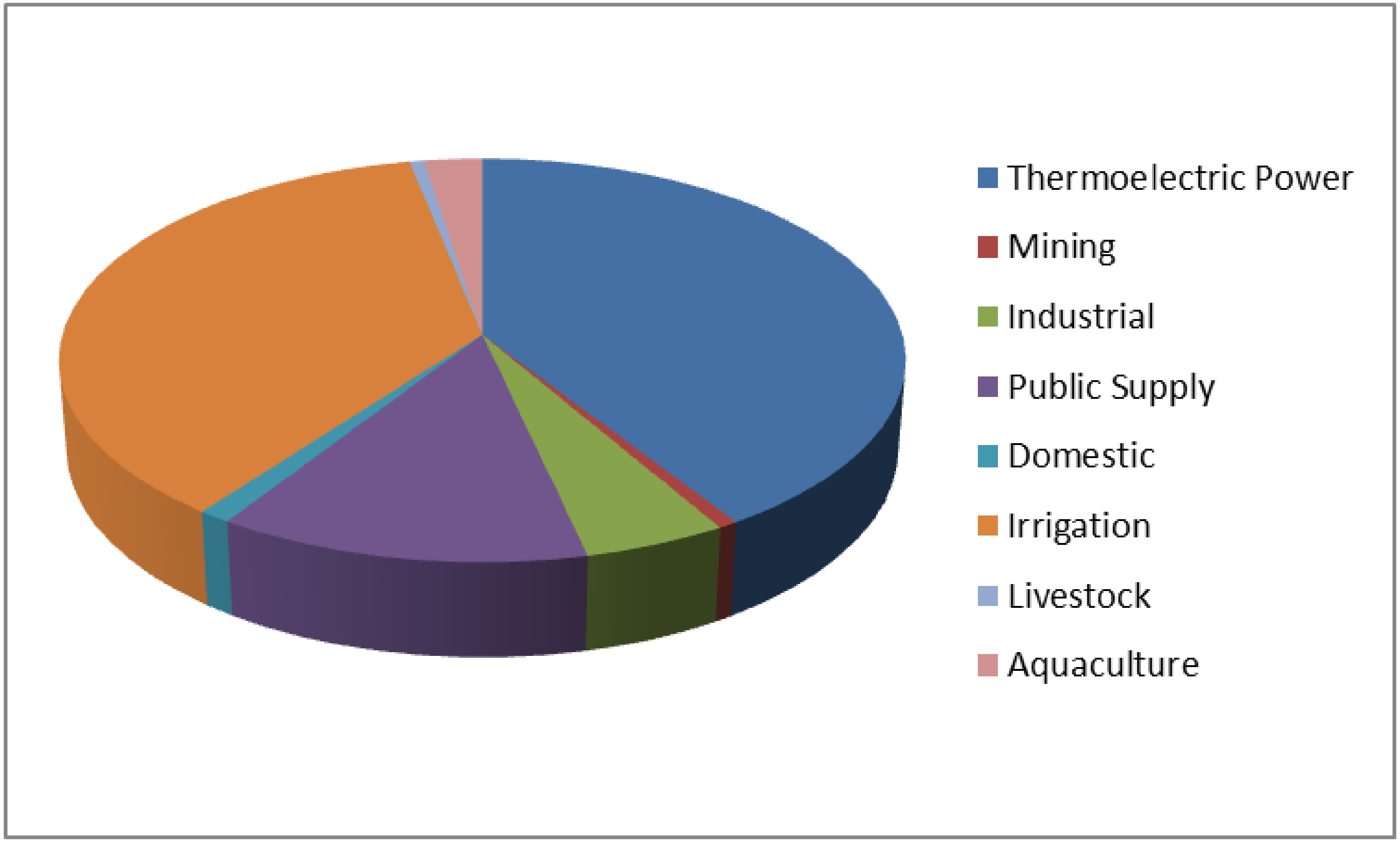
Factors Creating Drivers / Challenges

Water Scarcity
Supply Costs



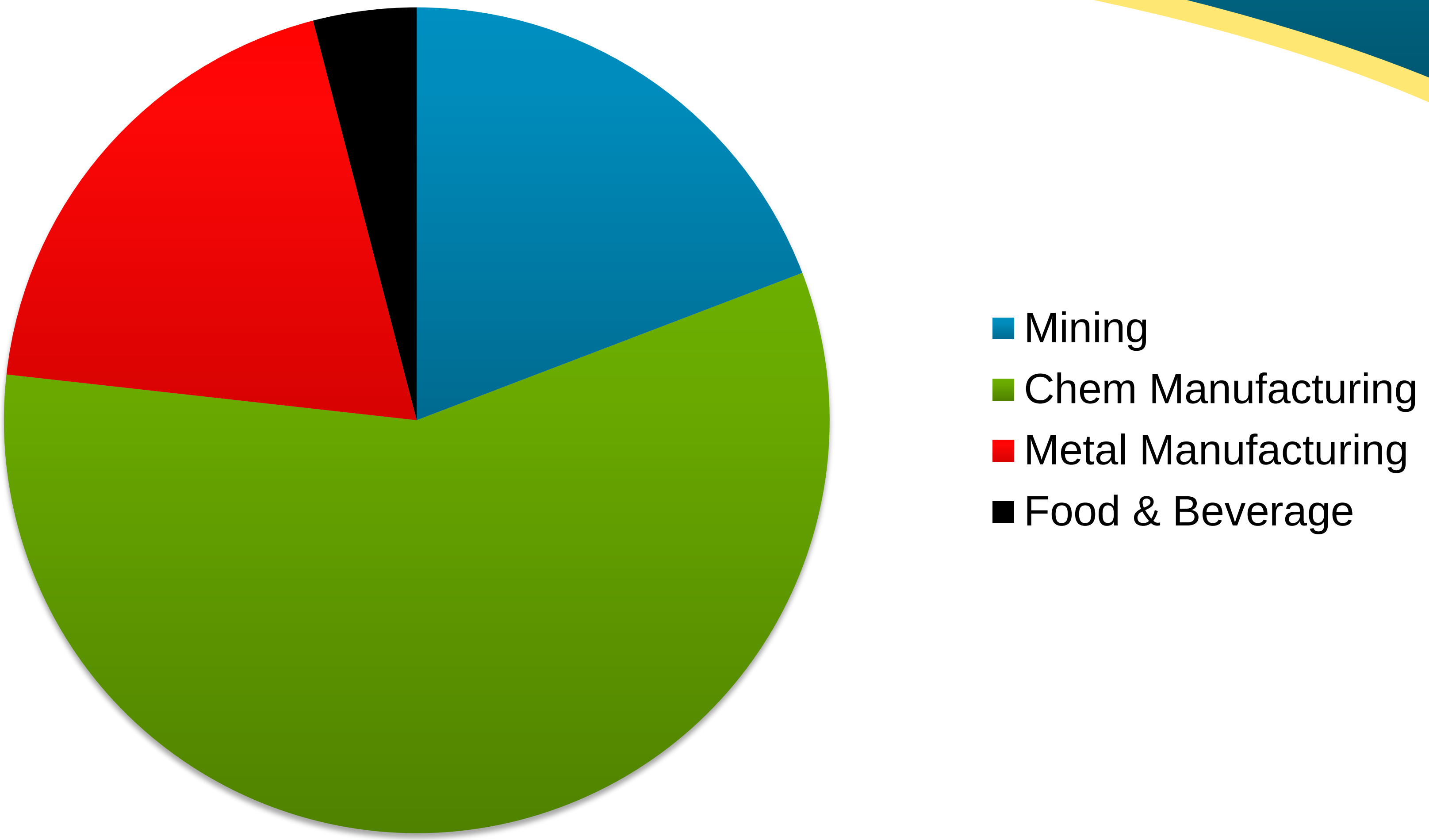
Volume ratios
Technology parity
Technology risk
Regulatory parity
Production risks
Water audit accuracy
True cost of water
Stakeholder relations
Permitting clarity
Infrastructure limitations
Financial incentives

Water Use in United States (Year 2005)



Adopted from USGS: (http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf)

Water Use in Norway by Industry (Year 2003)



Adapted from: 2006 Final Report to Eurostat, Agreement No. ESTAT 200471401002, Statistics Norway, 31. May 2006

Generic Use by Industry Data for Norway

NACE Code	Total Use (Mgal)	Sanitary (%)	Processing (%)	Cooling Water (%)	Water in Products (%)	Leaks & Evap-oration (%)	Other Use (%)
11	86,097	<1	<1	22	<1	<1	69
13	10,534	<1	99	<1	<1	-	<1
15	19,382	2.8	40	49	2.8	<1	4.5
21	45,937	0.40	40	57	<1	1.6	<1
24	166,641	<1	8.6	90	<1	<1	<1

11 = upstream oil and gas
13 = mining of metal ores
15 = food and beverage manufacturing
21 = pulp, paper and paperboard manufacturing
24 = chemicals and chemical product manufacturing

Unit or Annual Basis Industrial Water Use

Industry	Vol/unit produced (from literature)	Mgal/Yr (Facility) (from survey)	Bgal/Yr (Corporate) (from survey)
Mining	5 – 54 gal/lb Cu [1]	212 - 4980	8 - 82
Power	0.1 – 1.1 gal/kWh [2] 8 gal/kWh [3]	118	-
Food & Beverage	**0.07 – 2 gal/lb [4]** 1.39 L/L [5] 2 L/L [6] 8.06 L/kg [7] 0.50 L/kg [8]	85 - 318	3.5 - 66
Chem Manufacturing	15 – 100 L/kg [9]	-	732
Metal Manufacturing		12 - 70	-

[1] (Singh, 2010), [2](Feely III, 2008 for thermoelectric power plants), [3](Torcellini et al., 2003 for hydroelectric power plants), [4](State of California, 2013), [5](IBWA, 2013 for bottled water), [6](IBWA, 2013 for carbonated soft drinks), [7](BIER, 2011 for water consumption for aluminum can body and lid), [8](BIER, 2011 for glass container and steel cap), [9](Rupp, 2011 for textile dyeing),

Food and Beverage Wastewater Production

Food Processing	Wastewater Effluent Production (m^3/ton)	References
Dairy (Milk)	0.2 - 10	Vourch et al., 2005
Seafood	11	Afonso and Borquez, 2002
Meat (HSCW)	3 - 10	Sampson et al., 2005
Fruits & Vegetables	1.2 - 5	Muro et al., 2012
Sugar	1.5	Chavez-Rodriquez et al., 2013
Fats (Olives)	0.25 – 1.24	Valta et al., 2013
Beverage Processing	**Wastewater Effluent**	**References**
Beer	3 - 10	Simate et al., 2011
Wine (grapes)	3 - 5	Mosse et al., 2013
Alcohol Distilleries (alcohol)	10 - 20	Simate et al., 2011

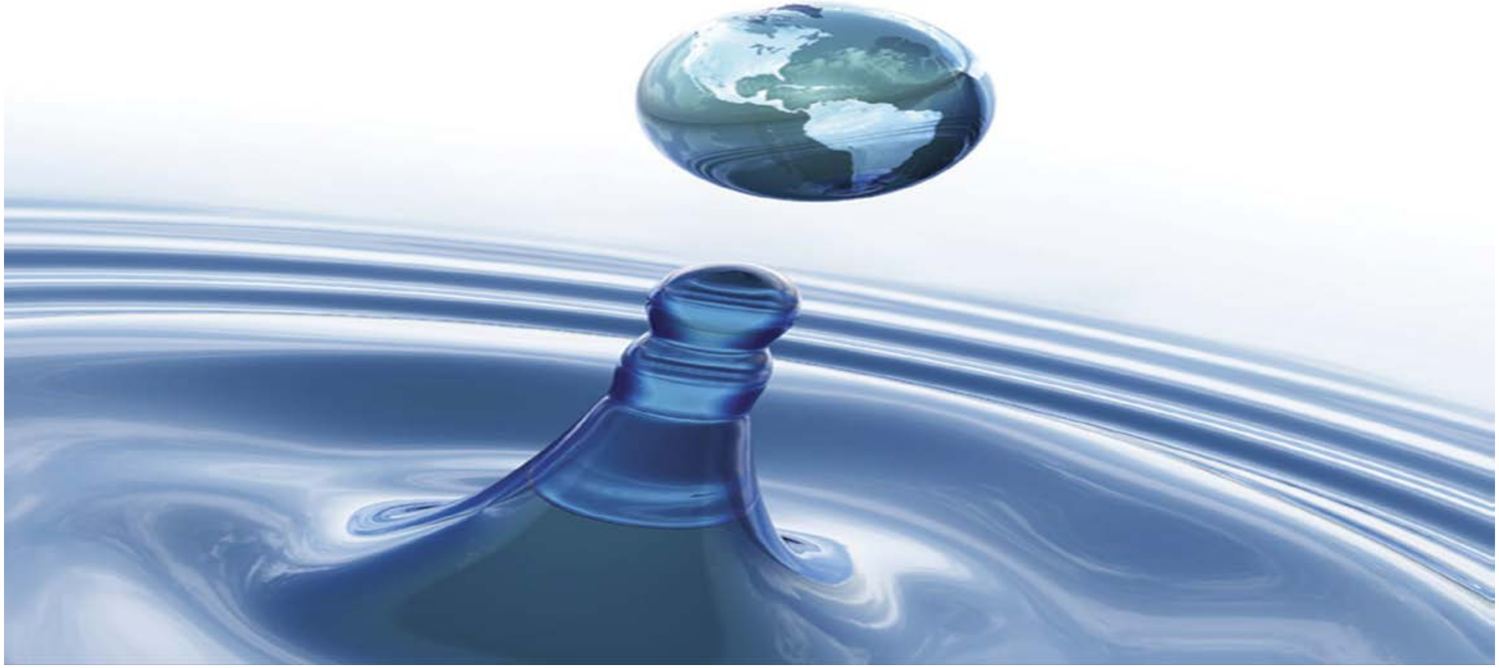
Approximate range of 0.53 – 15 m^3/ton water use from previous slide.

Water Consumption by Categorical Use

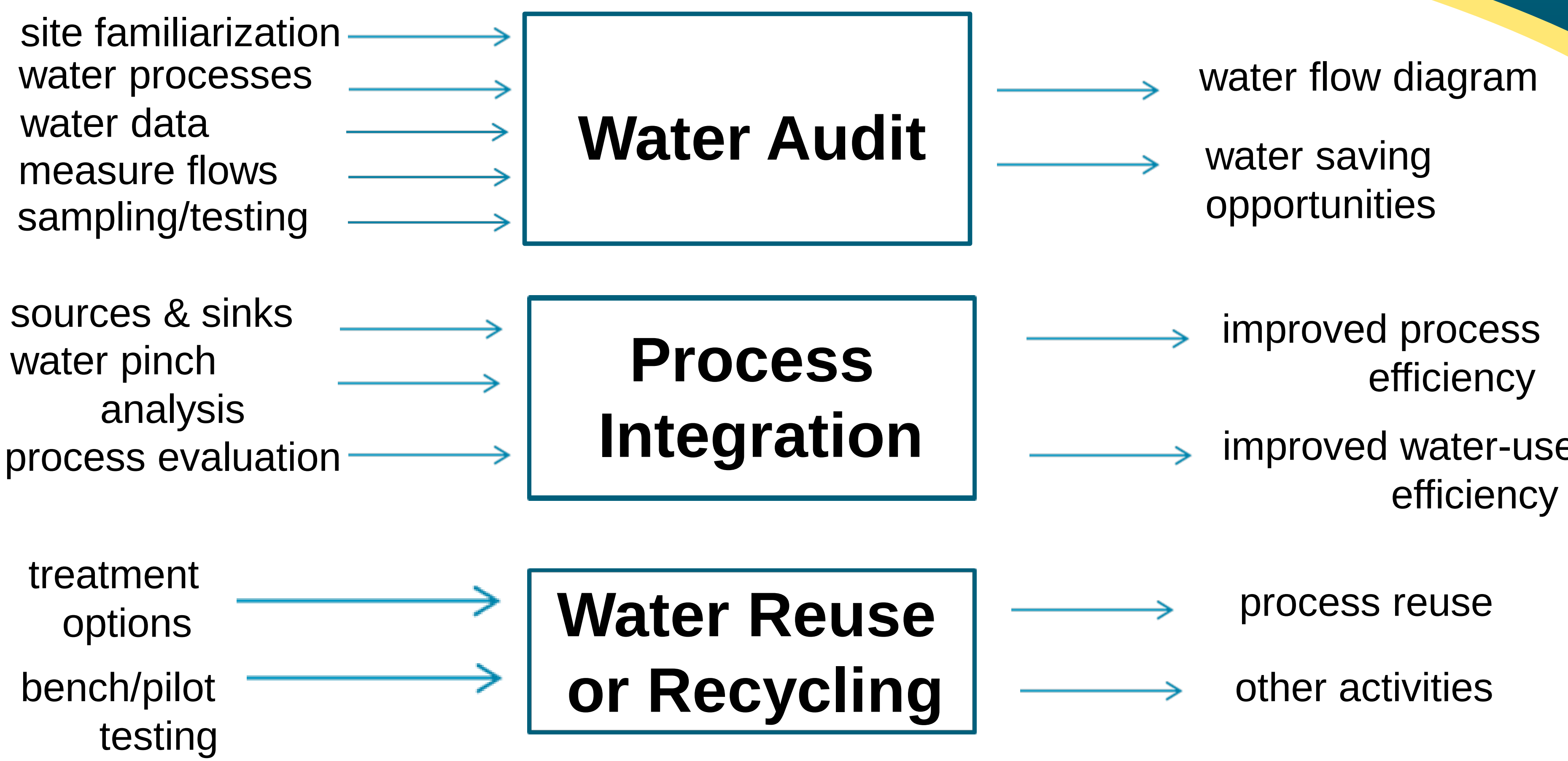
Generic Category	Percentage of Water Consumed
Cooling tower	60 - 85
Boiler	65 - 95
Process	5 - 90
Process cleaning	10 - 50
Sanitation	2 - 7
Irrigation	>95

State of California (2013) Commercial, Industrial, and Institutional Task Force Best Management Practices Report to the Legislature Volume I, October 21, 2013. (http://www.water.ca.gov/legislation/docs/CII%20Volume%20II%20july%202014.pdf).

Evaluation of Water Use and Reuse/Recycling Opportunities



Steps Towards Water Reuse & Recycling



Adapted from Agana, B.A. et al. / Journal of Environmental Management 114 (2013) 446

Take a Water Walk…

Identify all water-consuming equipment, high-use areas, meter locations and where sub-meters are needed

Observe shift clean-ups & process changeovers

Note the water quality used in each process step

Note all water losses, evaporative losses, excessive water pressure & leaks

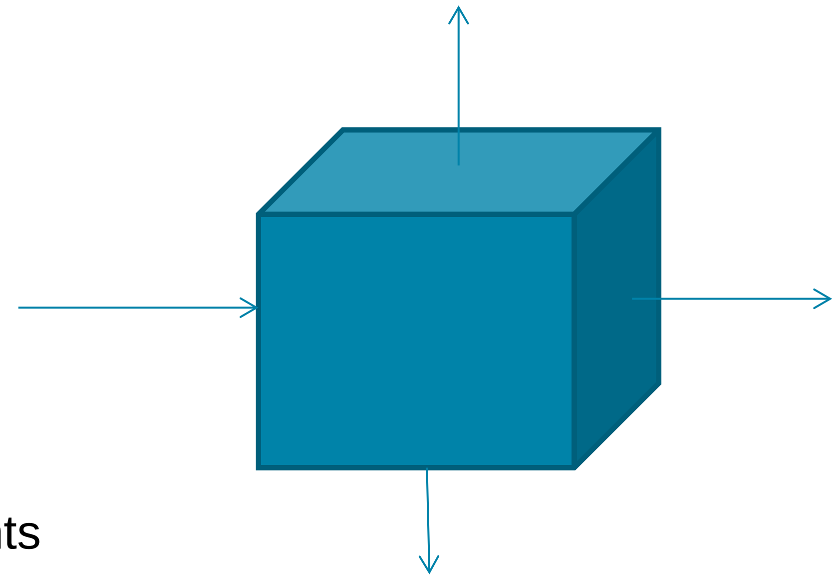
Quantify water flow rates & usage

Determine water quality needs for each process & quality of wastewater discharged

The Water Balance – How To Determined Water Usage

Water Evaporated, gallons/year
- Engineering Calcs.
- Equipment Specifications
- Mass Balance

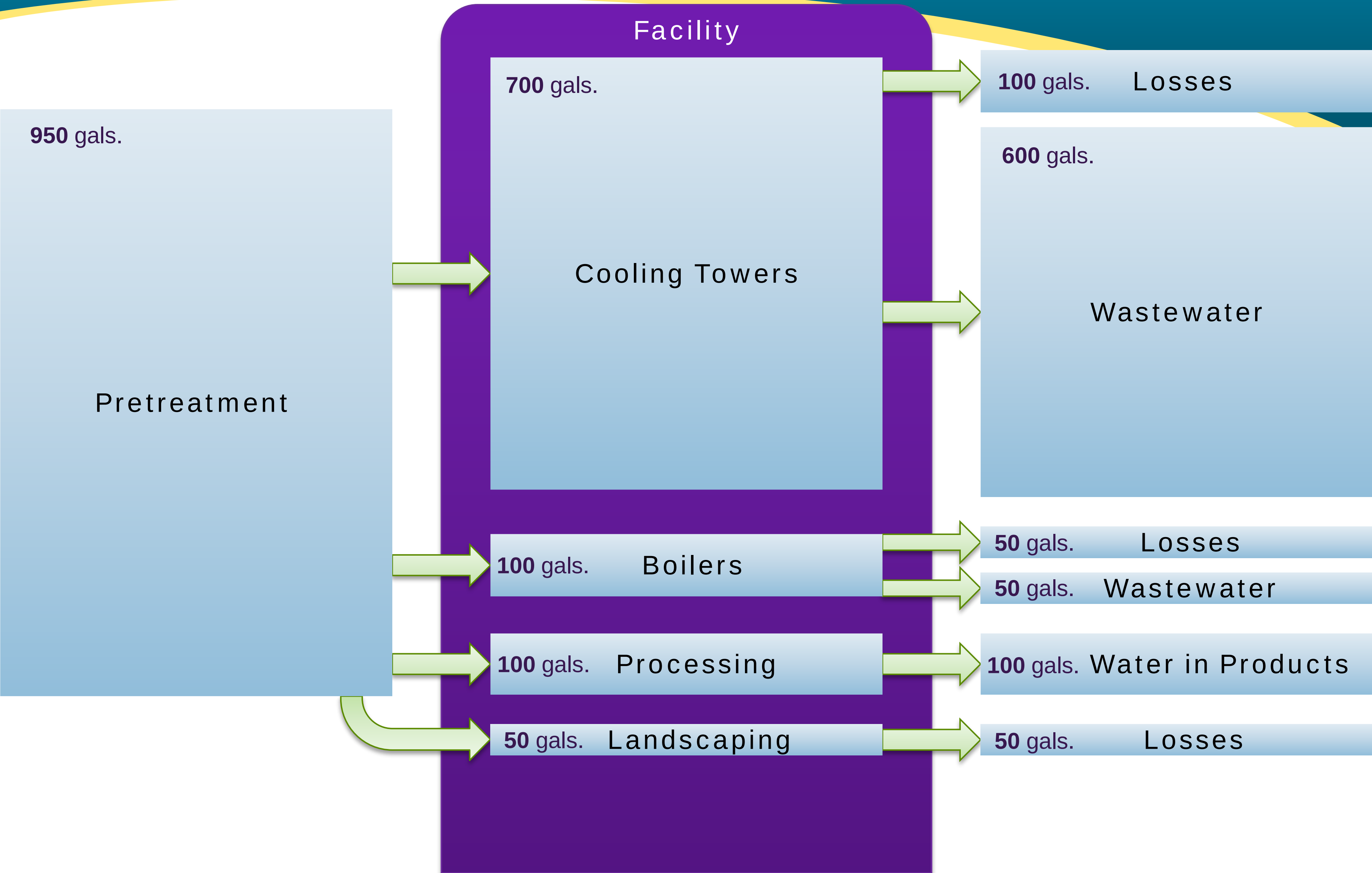
Water Used, gallons/year
- Utility bills
- Flow Meters
- Engineering Calcs.
- Measurements



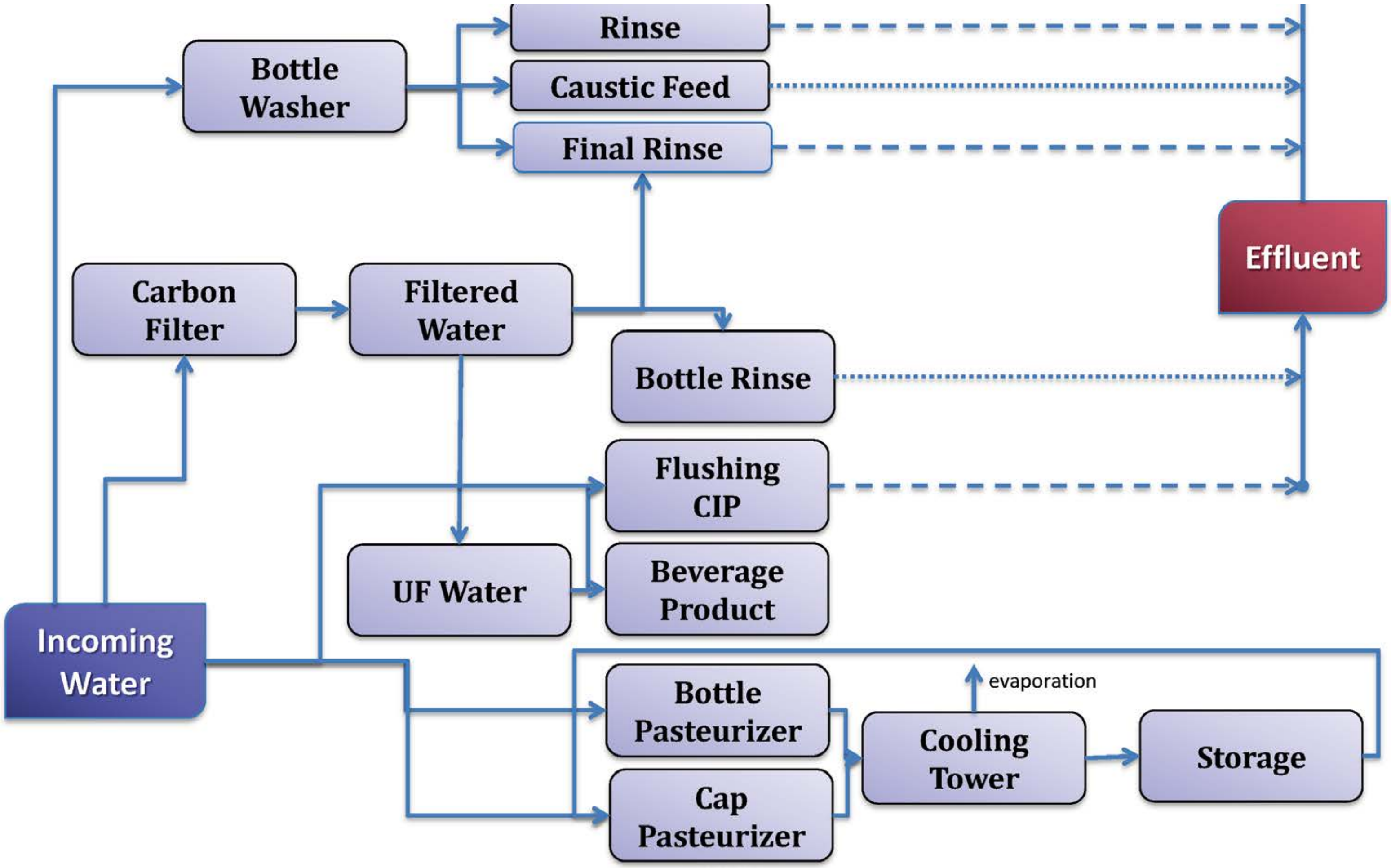
Wastewater discharged, gallons/year
- Flow Meters
- Engineering Calcs.
- Measurements
- Permit Information

Wastewater dispose off-site, gallons/year
- Shipping records
- Site records
- Mass Balance

Develop a Water Flow Balance



ILSI Example Process Flow Diagram for Water Bottling Facility

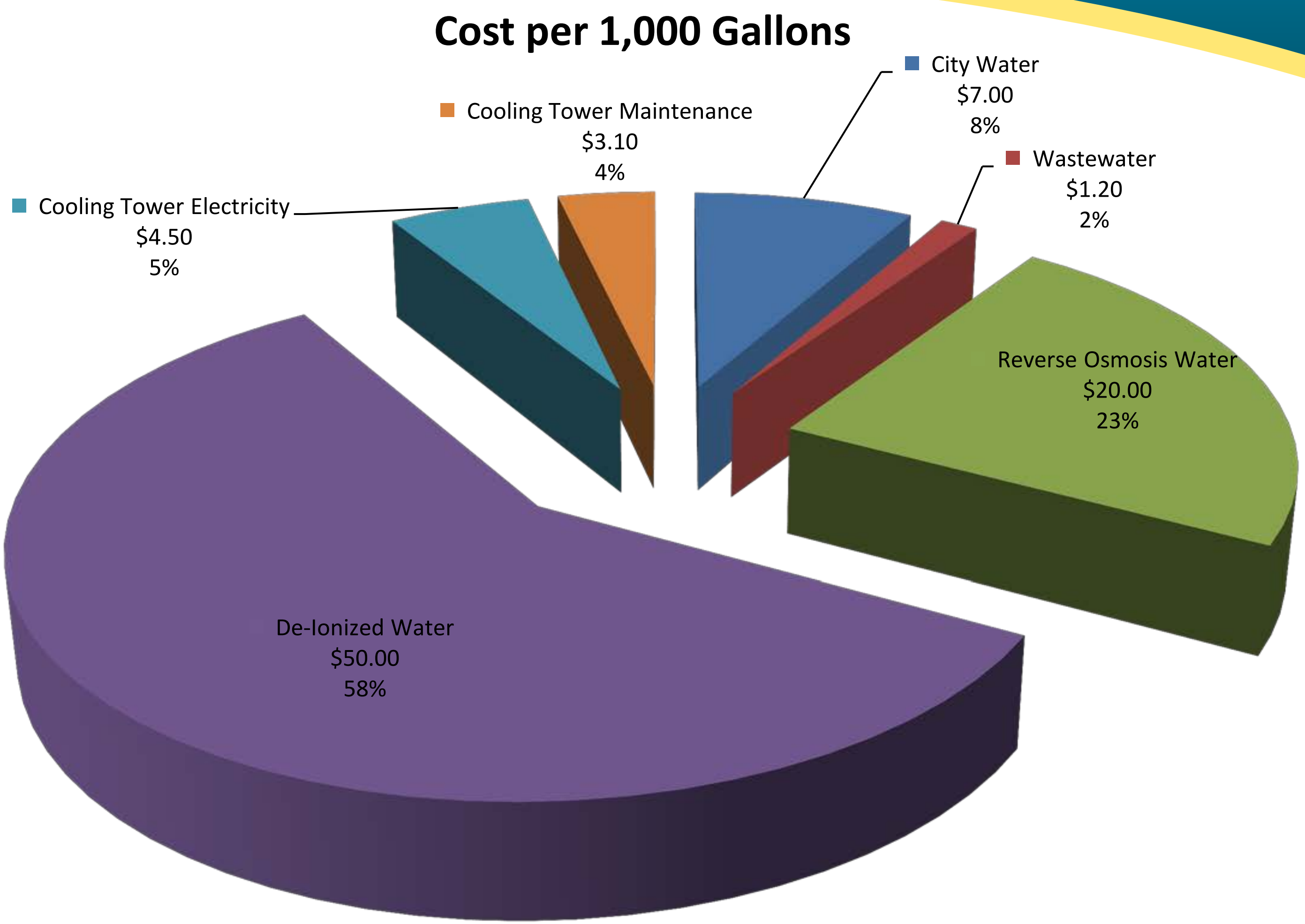


What is "True Cost"?

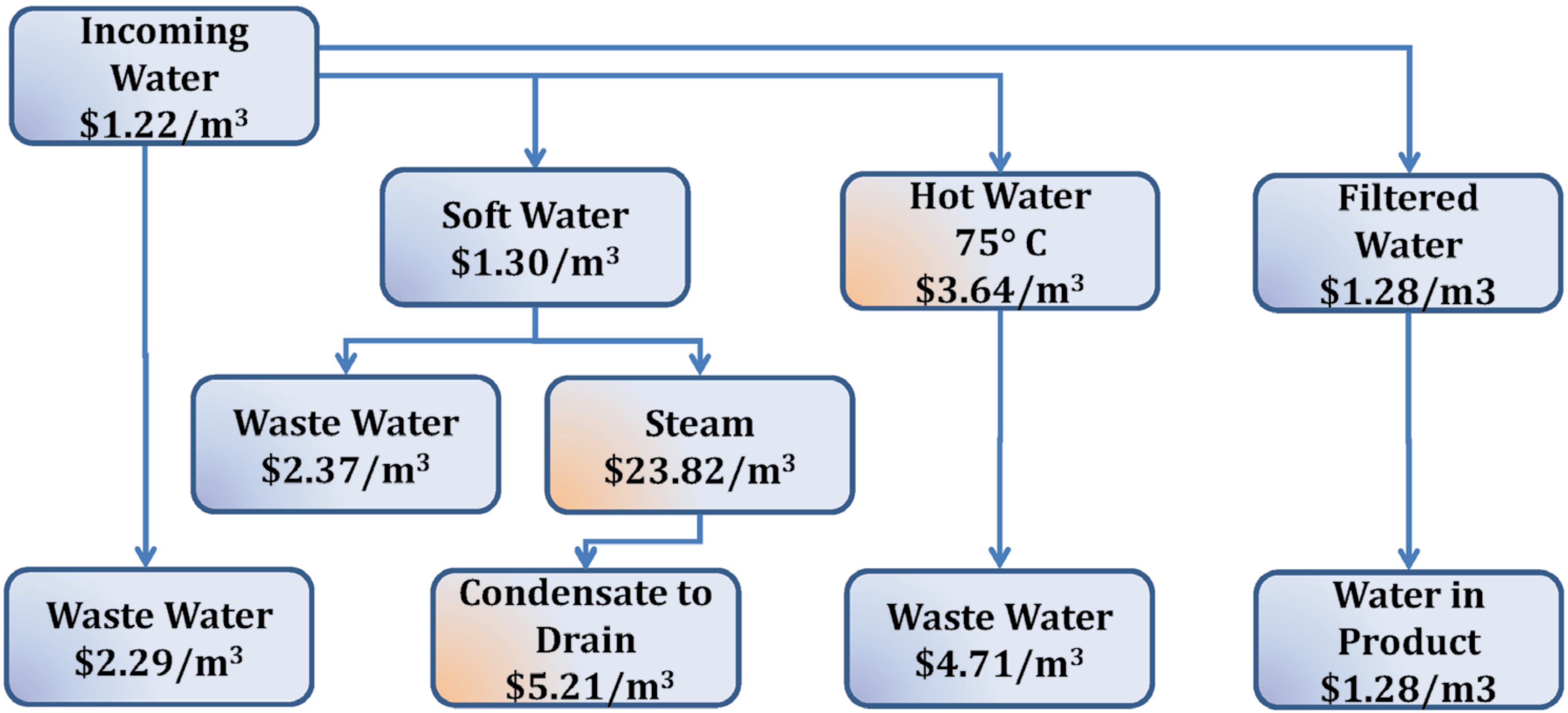
The less visible costs of receiving, distributing & treating water include:

- Licensing
- Maintenance
- Chemical addition
- Analytical costs
- Pumping costs (power & maintenance)
- Pre-Treatment
- Effluent treatment costs
- Sludge treatment & disposal
- Softening chemicals
- Backwash water/RO reject water effluent treatment costs
- Pumping
- Labor
- Water treatment costs
- Cooling tower legionella control
- Borehole abstraction costs
- Power

Example of True Cost of Water



Food & Beverage Example – True Cost (ILSI, 2013)



Potential Reuse/Recycle Streams

Membrane Filtration Concentrate	➢ Water concentrated with material rejected by the membrane that is continuously (reverse osmosis) or periodically (low pressure) wasted.
Cooling Tower	➢ Cooling water used for applications
Pump Seal Water	➢ Water used to flush mechanical seals on pumps.
Continuous Monitoring Flows	➢ Sidestream flows to water quality measuring devices, including chlorine analyzers & turbidimeters.
Chemical Feed Systems	➢ Batching/dilution water used in the generation of chemical solutions.
Product Final Rinse	➢ Final rinse water used in washing of equipment
Flue Gas Scrubbing	➢ Water used in process to remove particulates from flue gas.
Miscellaneous Facility Cleaning	➢ Miscellaneous facility water from facility hose stations & for conveyor washing.
Vehicle Wash Water	➢ Water used in for cleaning vehicles.

Advanced Technologies for Reuse/Recycle

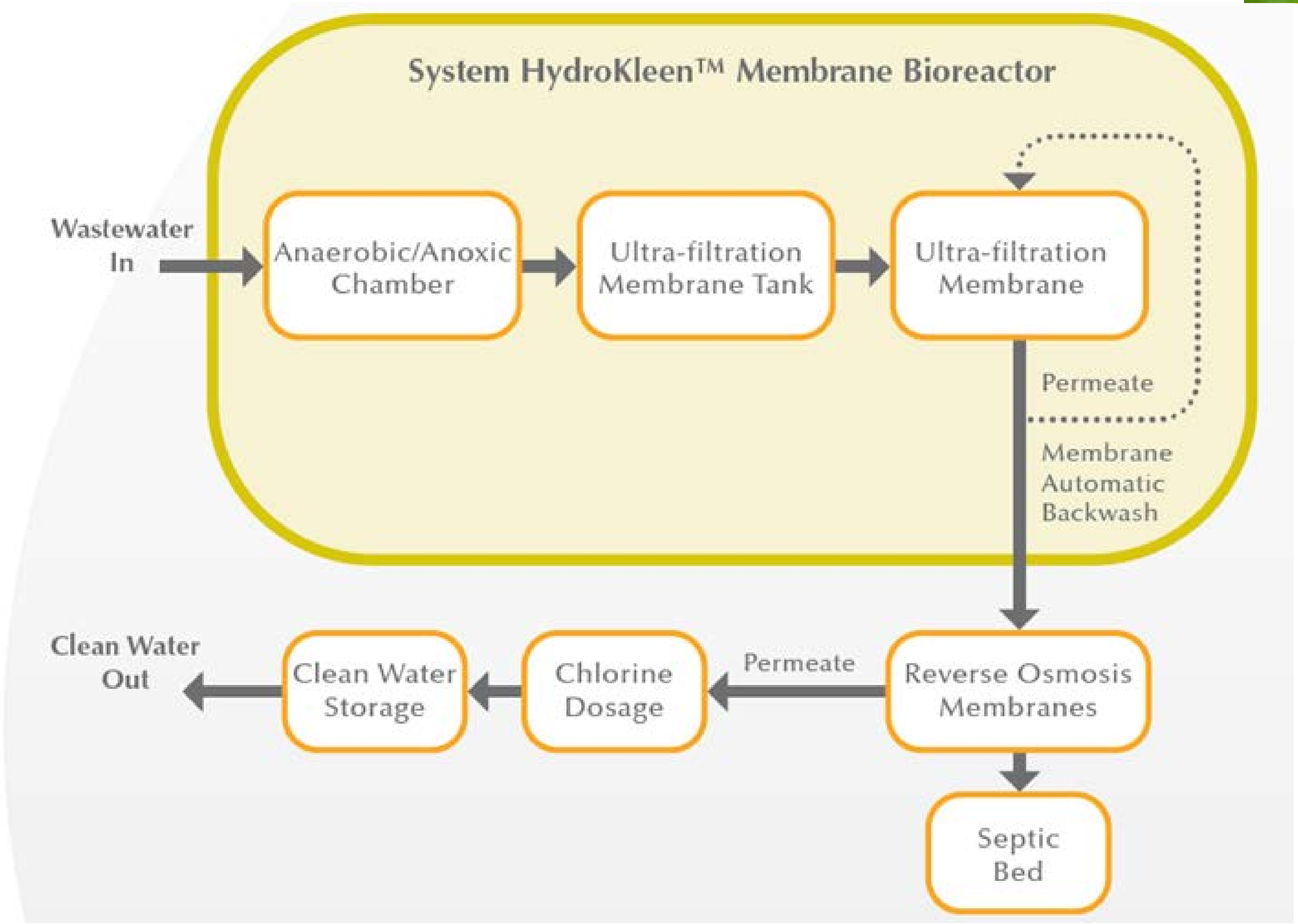
Membrane Bioreactor	Combines ultrafiltration with biological treatment in a small footprint	Excellent solids removal & low sludge production
Ultrafiltration	Uses pressure-driven barrier to remove compounds	Removes suspended solids, bacteria, other pathogens
Reverse Osmosis	Forces water through membranes under high pressure	Removes dissolved chemicals & other compounds to produce water with high purity
Ozonation	Oxidizes the water with ozone	Destroys bacteria & other microorganisms
Ultraviolet Light	Exposes water to UV light for disinfection	Inactivates any trace micro-organisms, providing 4-log reduction of microbes

Reuse Assessment Options

Direct Reuse Sources	Cooling Water for Bottle/Container Filling	Chemical Feed Systems	Flue Gas Scrubbing	Sanitary (Toilet Flushing)	Evaporative Cooling Tower Feed	Boiler Pre-Treatment	Production Pump Seal Water	Miscellaneous Facility Cleaning	Non-Contact Cooling Water	WWTP Utility Water	Vehicle Wash Water	Landscape Irrigation
	Potential Direct Reuse Application											
Membrane Filtration Permeate	2	2	2	2	2	3	1	1	1	1	1	1
Cooling Water	2	n/a	2	2	2	2	2	1	1	1	1	1
Filler Cool Down Water	2	2	2	2	2	2	2	2	1	1	1	1
Cooling Tunnels	2	2	2	2	2	2	2	2	1	1	1	1
Granular Media Backwash	5	5	4	4	5	4	4	4	4	4	4	4
Continuous Monitoring Flows	5	4	4	4	4	4	5	5	4	4	4	4
WTP Sludge Thickener Supernatent	5	5	5	5	5	5	4	4	4	4	4	4
WTP Sludge Dewatering Filtrate	5	5	5	5	5	5	4	4	4	4	4	4
WWTP Effluent	5	5	5	5	5	5	5	5	5	5	5	5

- Group 1 - Applicable for Direct Reuse at full volume assuming minimum water quality parameters of source stream are met
- Group 2 - Disinfection may be necessary to blend at full volume
- Group 3 - pH adjustment may be necessary to blend at full volume
- Group 4 - Sedimentation/Disinfection may be necessary to blend at full volume
- Group 5 - Full treatment including filtration may be necessary to blend at full volume

Reclaimed Juice Processing WW



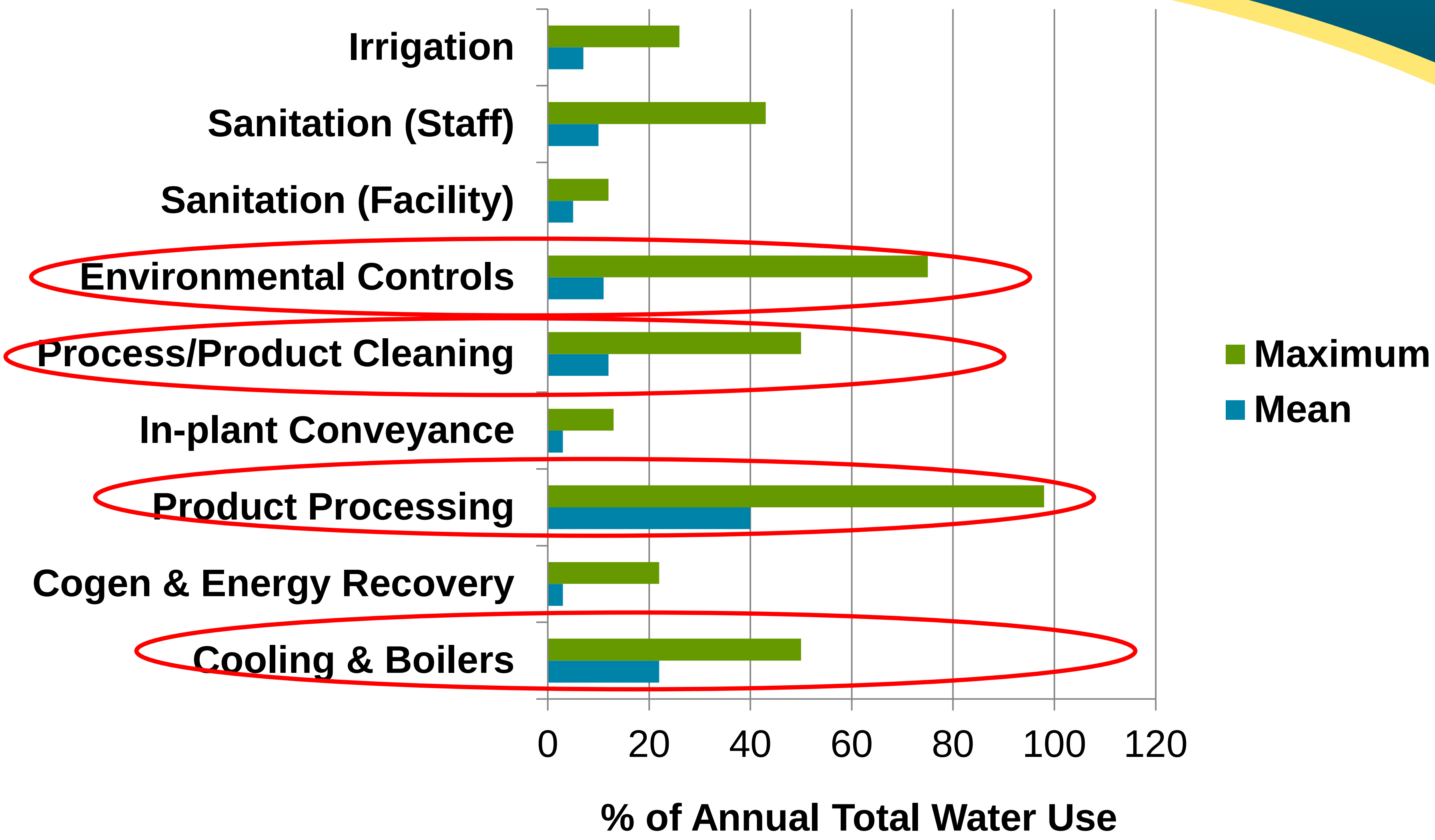
Algoma Orchards treats wastewater to potable water standards for reuse in process equipment sanitation.

Reuse/Recycling Implementation Issues

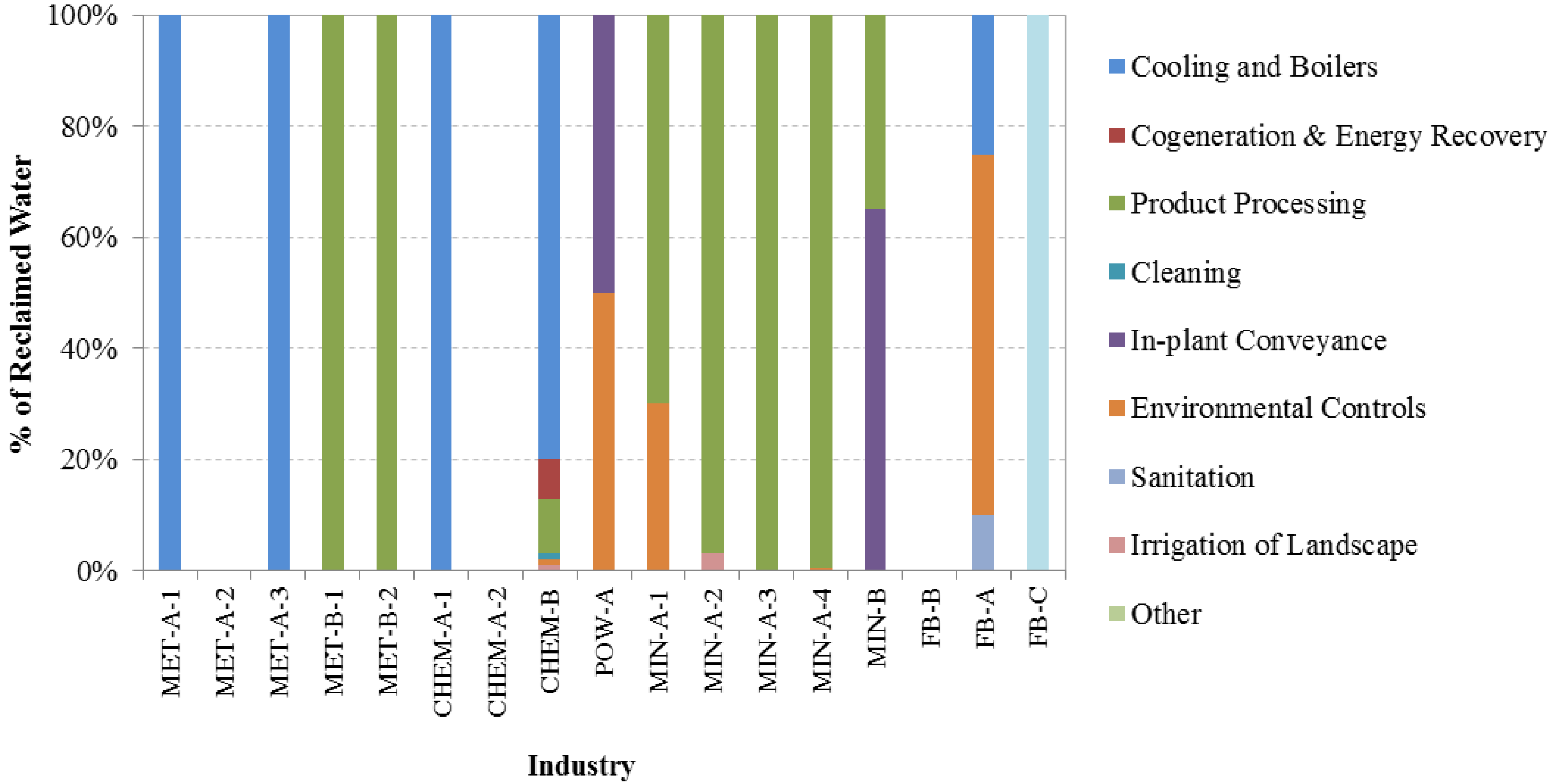
- Material and water balance
  - *Insufficient flow meters and water quality sensors*
  - *Limited knowledge on flow and quality variability*
- Treatment options
  - *Identifying suitable technologies for specific wastewater*
  - *Identifying use for various water quality sources and demands*
  - *Site constraints (available space, infrastructure upgrades, etc.)*
- Economics
  - *Identifying options that provide a suitable ROI*
  - *Identifying other factors that offset ROI*

Survey and Workshop Findings

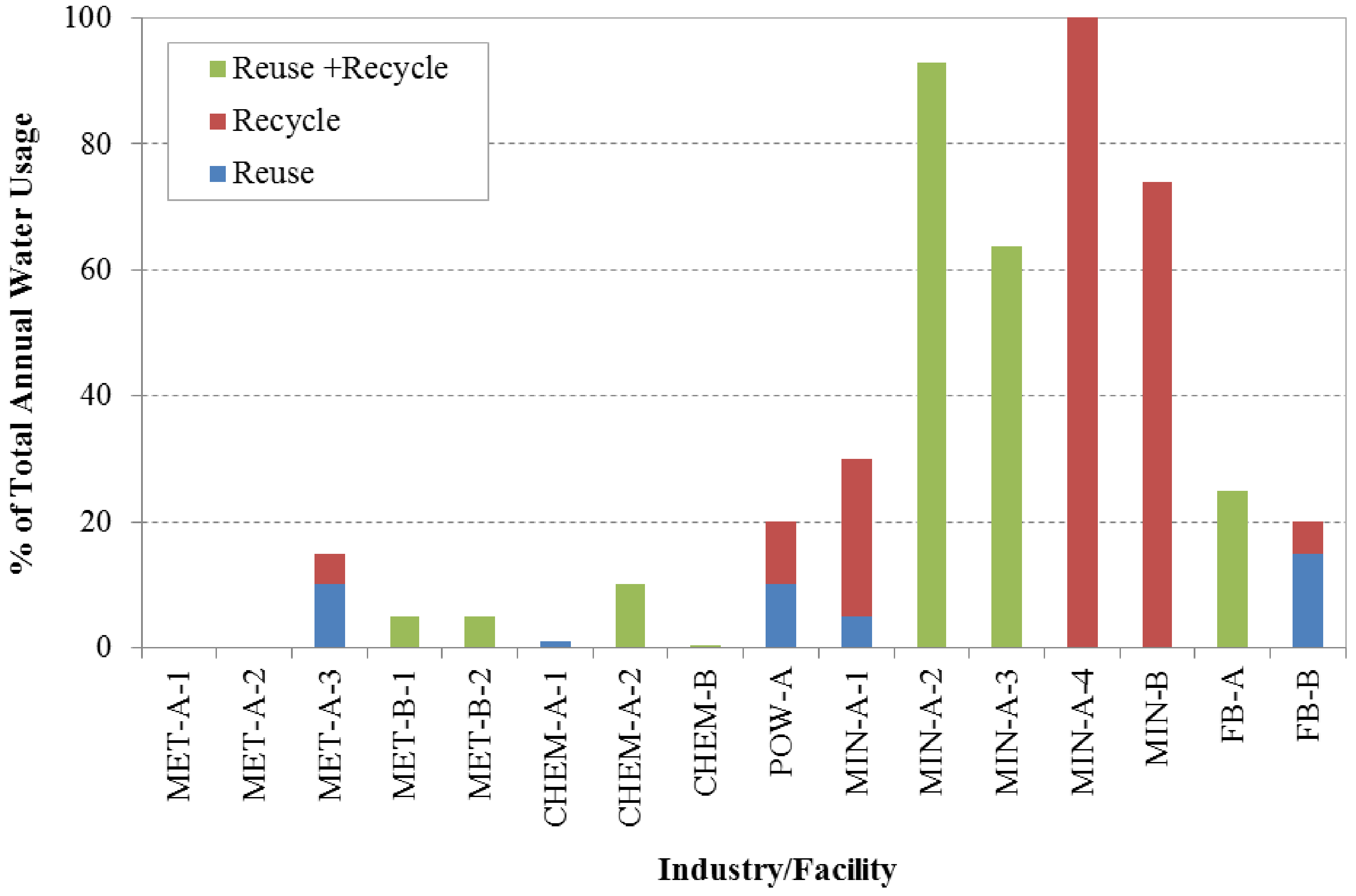
Water Use on % Basis (from survey)



% Distribution Reclaimed Water Volume



Reuse / Recycle as % Total Annual Water Use



Ease of Implementation (Workshop Responses)

Reuse Category	Mining	Mining	Food & Bev	Food & Bev	Power	Manufac-turing	Mode (N=6)
Irrigation	1	2	1	1	2	1	1
Cooling & Boilers	5	3	2	2	1	3	2.5
Environ-mental	1	1	7	6	4	2	3
Convey-ance	1	4	3	7	8	4	4
Sanitation	1	6	4	8	3	5	4
Product & Process Cleaning	5 / 8	5 / 7	5 / 6	2 / 4	5/ 6	7 / 8	5 / 6.5
Cogen & Energy Recovery	7	8	8	5	7	6	7

1= easy; 8 = hard

Reuse/Recycling Benefits & Cost Savings – Food Industry

Sub-sector	• Reuse/Recycle	Benefits	Cost Savings
Dairy	• Pasteurization cleaning water used for first rinse of tanks • Tank rinse water used for cleaning	30% reduced water consumption	$73K/yr
Dairy / Fruit Juice	• Milk processing steam reuse • Once through cooling water recaptured for washing	19,000 L daily reduction of water consumption	$6.3K rebate $9K/yr
Brewery	• Reclaimed bottle/can pasteurizer water (excess holding capacity)	Reduced discharge & water consumption	$60K/yr (10 month payback)
Brewery	• Pasteurization overflow & bottle washer final rinse to keg and floor washing	Reduced water consumption	$37.5k/yr (2 yr payback)

Workshop Identified Solutions to Challenges

- Promote circular economy training for management
- Establish accreditation program (similar to LEED)
- Create active database of case study projects
- Provide tools for calculating true cost of water
- Develop fouling resistant membranes
- Assess recalcitrant compound biological catalysts
- Develop chemical fate and transport tools
- Enhance process modeling
- Improve facility metering and sensing

Major Research Topic Needs

- **Financial**
  - Develop ROI calculator based on true cost of water
- **Technology**
  - Develop salt handling, recalcitrant organics
  - Compile latest developments, applicability, benefits
  - Develop cost-effective ZLD applications
- **Communication**
  - Create knowledge sharing platforms for industrial groups with similar needs
  - Continually compile case studies in publicly accessible format

Major Research Topic Needs (cont'd)

- <u>Guidance Development for:</u>
  - New facility design criteria promoting marginal water use
  - Existing facility auditing protocols promoting reuse/recycle
  - Treatment and residuals criteria
  - Model treatment schemes for different industrial sectors
  - Validation protocols for process train solutions
  - Reuse/recycling criteria for generic water use categories
  - Reuse/recycling integration within existing footprint tools

Tools to Increase Water Reuse

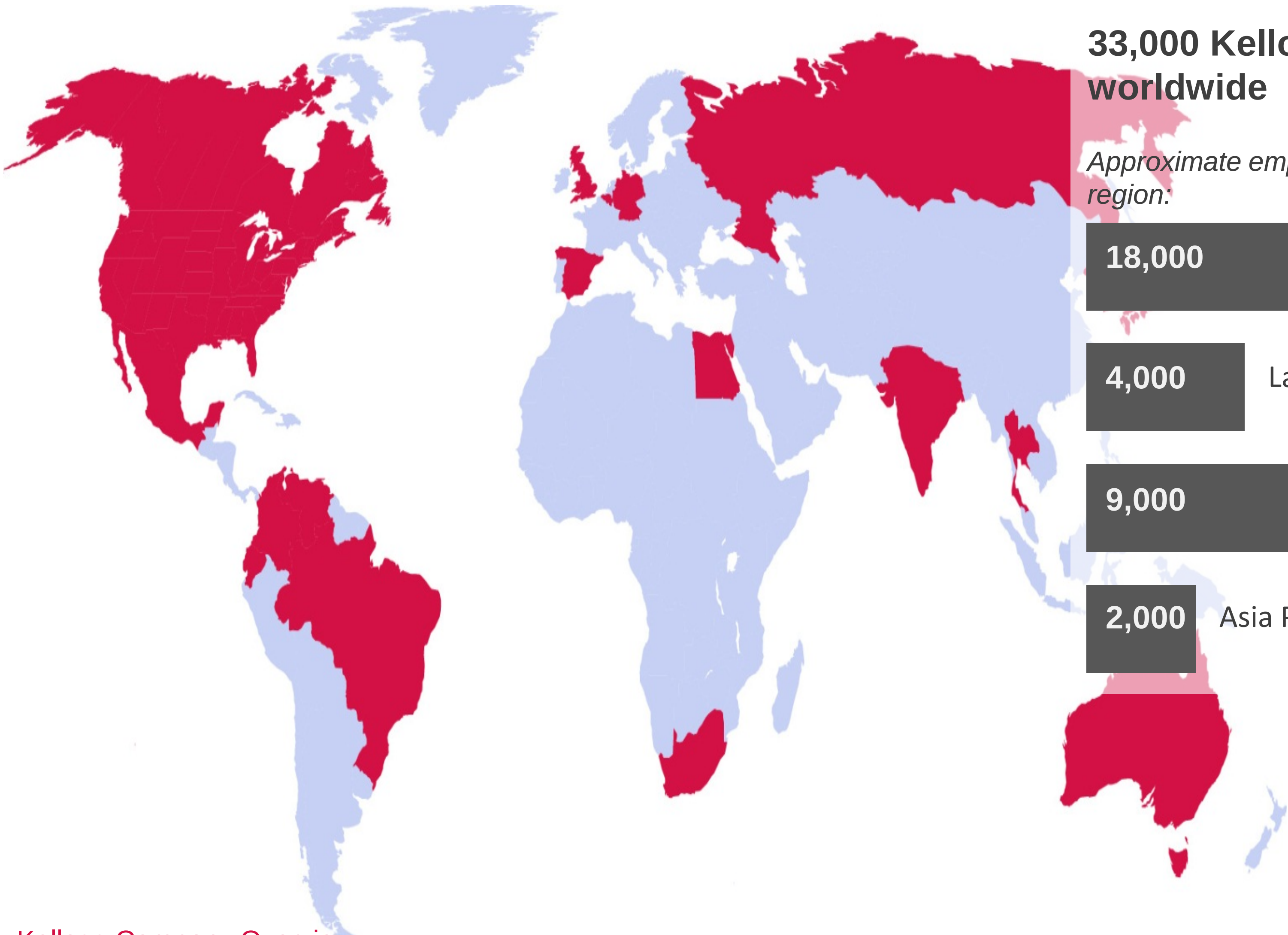
- Water audit benchmarking tools
- Process recycling optimization tools
- Monetization of non-economic factors
- Technology transfer (modular approach)
- Identifying “difficult” chemicals across industries

GLOBAL SUSTAINABILITY COMMITMENTS

RICE KRISPIES
CHEEZ-IT
Sultana Bran
Keebler
COCO POPS
Pringles
Kashi
The Seven Whole Grain Company
CORN FLAKES
Kellogg's
ZUCARITAS
pop. tarts
Special K
Eggo
MorningStar Farms
FROSTED FLAKES
RICE BUBBLES
Kellogg's mini MAX
CHOCO KRISPIS
TONY

Manufacturing Footprint

Kellogg's



33,000 Kellogg employees worldwide

Approximate employee numbers by region:

18,000	North America
4,000	Latin America
9,000	Europe
2,000	Asia Pacific

Why Sustainability Matters

Kellogg's GLOBAL SUSTAINABILITY COMMITMENTS

- Sustainability fits with our core values
- These types of commitments are very important for our consumers, improving the trust in our foods:
  - It strengthens the equity (integrity, trust, progress) in our brands
  - It drives relevance for our strategic categories
  - It builds corporate reputation
  - And it supports delivery of business results

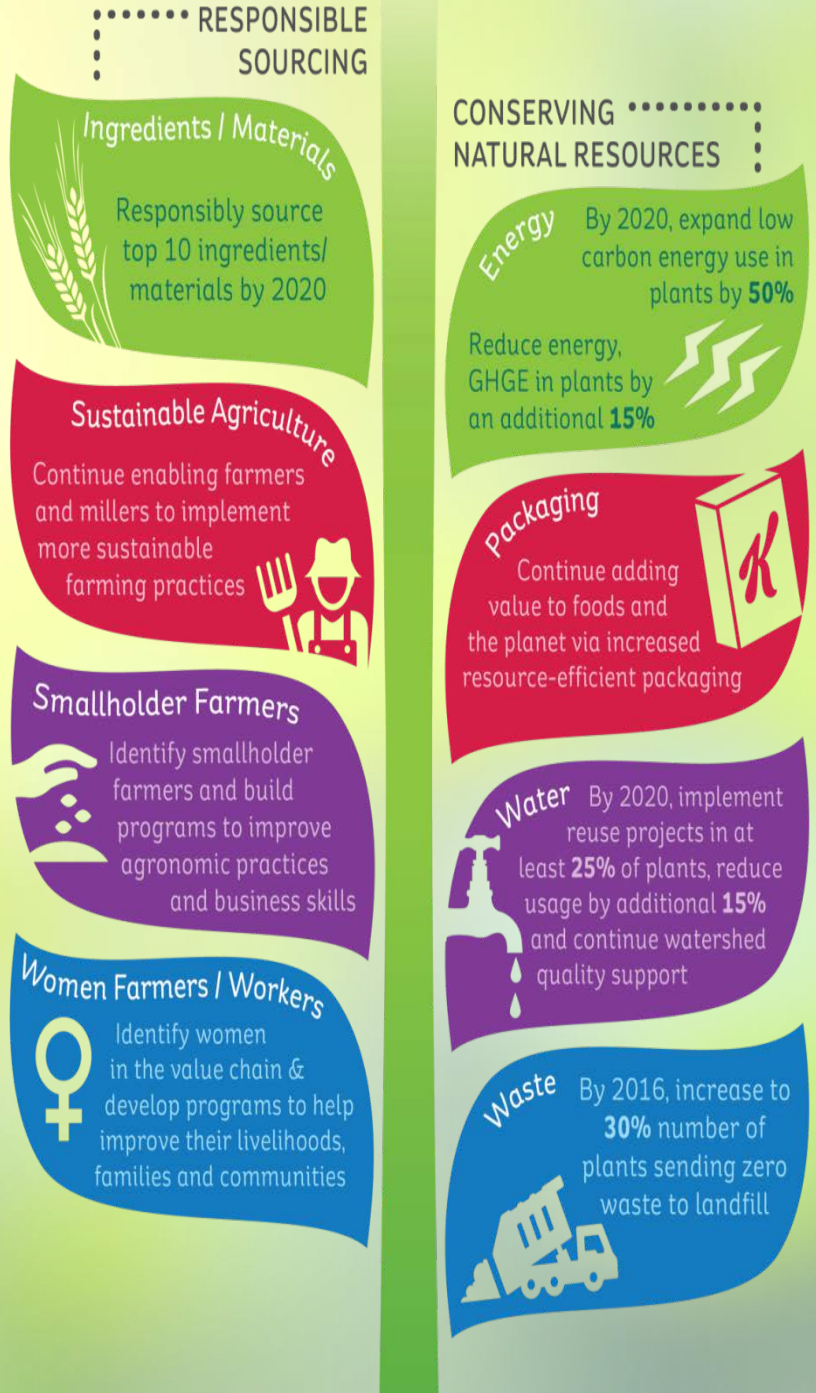
Kellogg's

GLOBAL SUSTAINABILITY COMMITMENTS

Supporting the livelihoods of individuals, families and communities that rely on us and on whom we depend.

Conserving natural resources where our ingredients are sourced and our foods are made.

Driving consumer demand by building trust and love for our foods.



Building on Our Success

- **By 2020, Kellogg is committing to :**
  - Expand our use of low-carbon energy in our plants by 50%
  - Reduce energy and GHG emissions by 15%*
  - Support watershed quality and reduce water use by additional 15%*
  - Increase to 30% number of plants sending zero waste to landfill
- (*Per metric tonne of food produced)

Water Reuse Opportunities and Challenges

Kellogg's GLOBAL SUSTAINABILITY COMMITMENTS

- Opportunities
  - – Reusing water within the same equipment/system
  - – Reusing water in nearby non-contact equipment
- Challenges
  - – Food safety is our #1 priority
  - – Cost of water is low

Water Reuse Success

Kellogg's GLOBAL SUSTAINABILITY COMMITMENTS

Partnering with water treatment chemical companies and neighbors, we have successfully reused water in

- Dust Collection Equipment
- Boilers
- Cooling Towers
- Landscape Irrigation

Questions?

Submit Your Questions Through the Chat Box

Joan Oppenheimer, BCES
MWH Global

Jon Pohl, P.E., LEED AP
MWH Global

Erin Augustine
Kellogg Company