WASTEWATER RECYCLING AND REUSE IN EU COUNTRIES: Necessity for Establishing EU Legislation

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Presentation Topics

- **Introduction**
- **Trends in Water Reuse: The paradigm of Southen California**
- **European Water Resources and Wastewater Status**
- **Wastewater Recycling and Reuse in EU**
- **Quality Criteria of Wastewater Reuse in EU**
- **Conclusions**

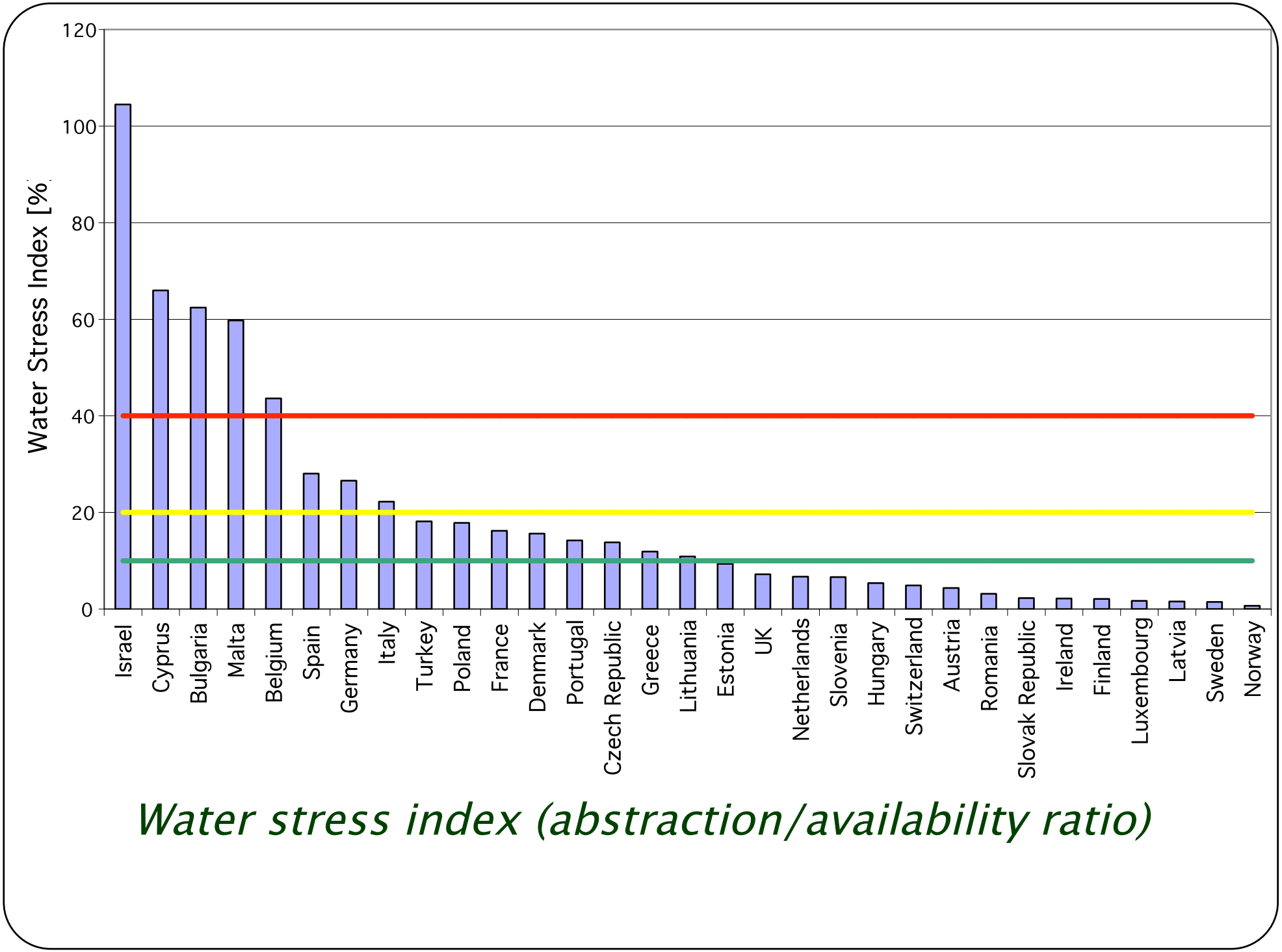
Presentation Topics

üIntroduction

Hydor' (Water) is the beginning of everything;
Thales from Melitus (ca. 636-546 B.C.)

Climate

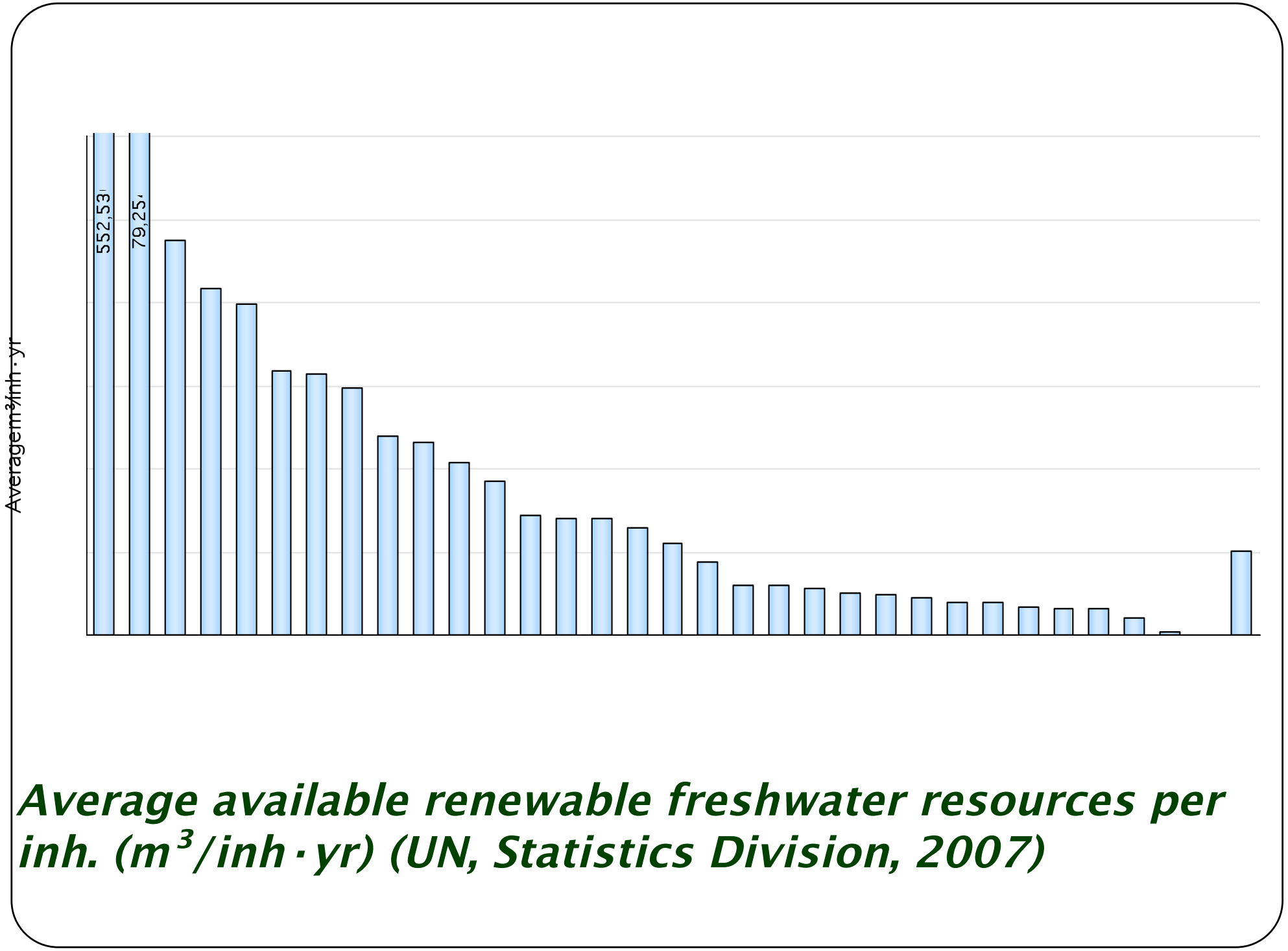
- EU is characterized by a severe water imbalance, particularly during the summer months, due to low atmospheric precipitation and, at the same time, increased demands for irrigation, potable water use due to tourism, and industry.
- The climate is sub-humid in south-eastern EU countries with humid and relatively cold winters and dry and warm summers.
  In the central and north-western EU countries the climate becomes more continental, with colder winters and warm summers.
- Average precipitations ranging from 400 mm/yr (in Malta) to 850 mm/yr (in France and Belgium) and to over 1000mm/yr in some northern countries.



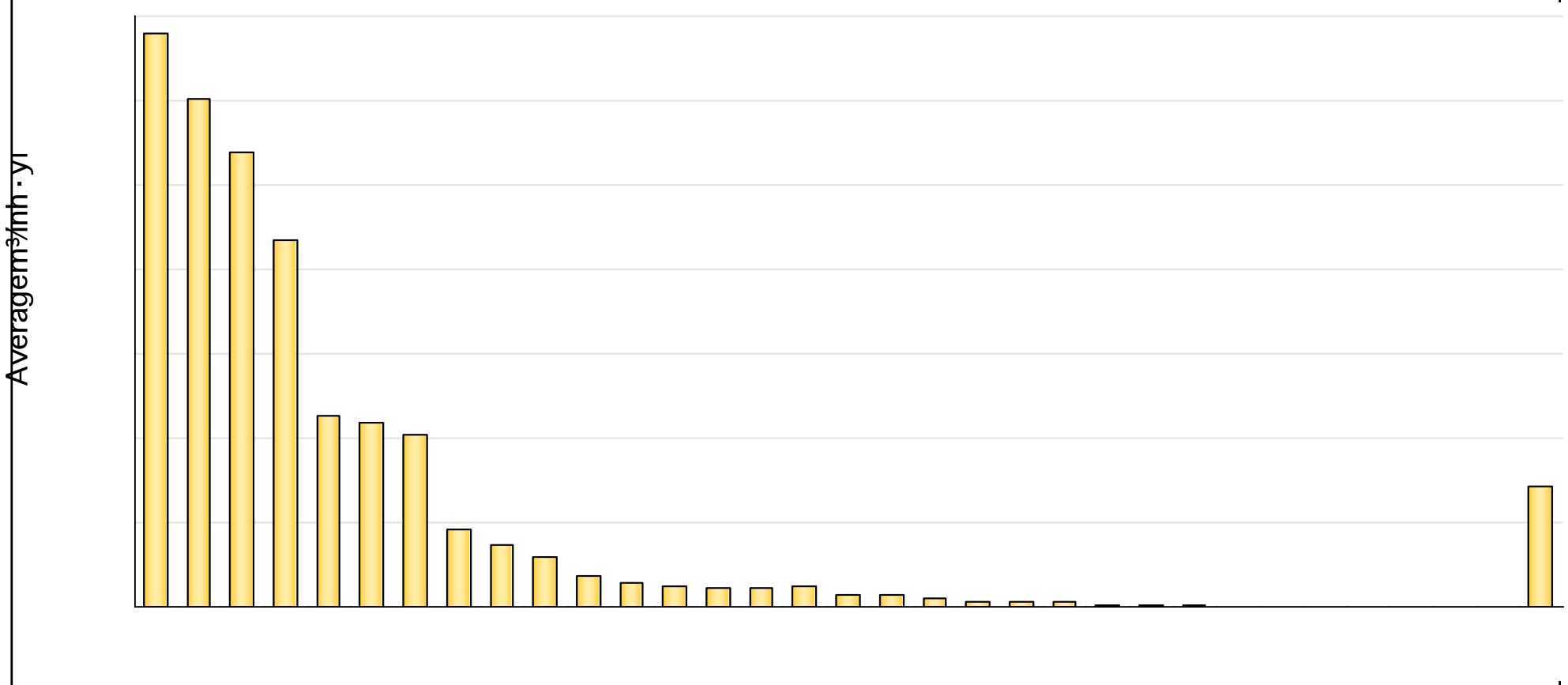
Water stress index (abstraction/availability ratio)

Presentation Topics

- **European Water and Wastewater Status**



Average available renewable freshwater resources per inh. (m^3/inh·yr) (UN, Statistics Division, 2007)



Average water abstractions (m^3/ inh. yr) for agriculture (EUREAU, 2008; UN, Statistics Division, 2007; Eurostat, 2005)

Water Uses in EU[a]

Water availability

Atm. precipitation	**400–1000mm**
Total fresh water resources	**2270km³/yr**
Abstracted	**13.2%**

Water use

Total water use:	**299 km³/yr**
Urban (20%)	**60 km³/yr**
Industry	**31 km³/yr**
Energy (42.5%)	**127 km³/yr**
Irrigation water use: (a) agriculture:	**75 km³/yr**
[(b) landscape:	**6 km³/yr]**
Irrigation water (%):	**27**

[a]Adapted from EU EAA 2008 and Aquarec, 2006

Presentation Topics

- **Trends in Water Reuse: The paradigm of Southern California**

The Global Water Challenge

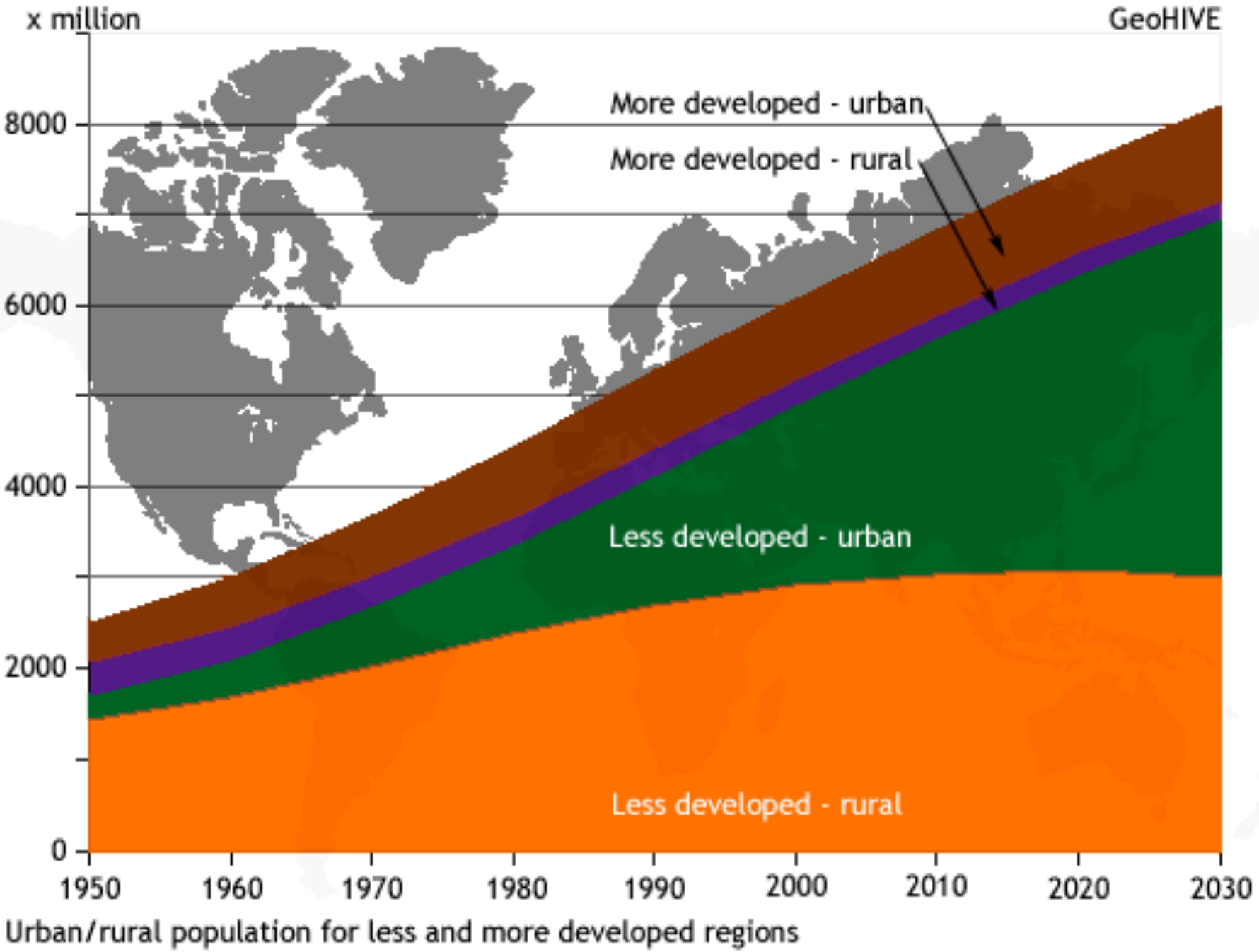
The World in 2050

2 billion more people (~145,000 per day)

90% of this growth in developing countries

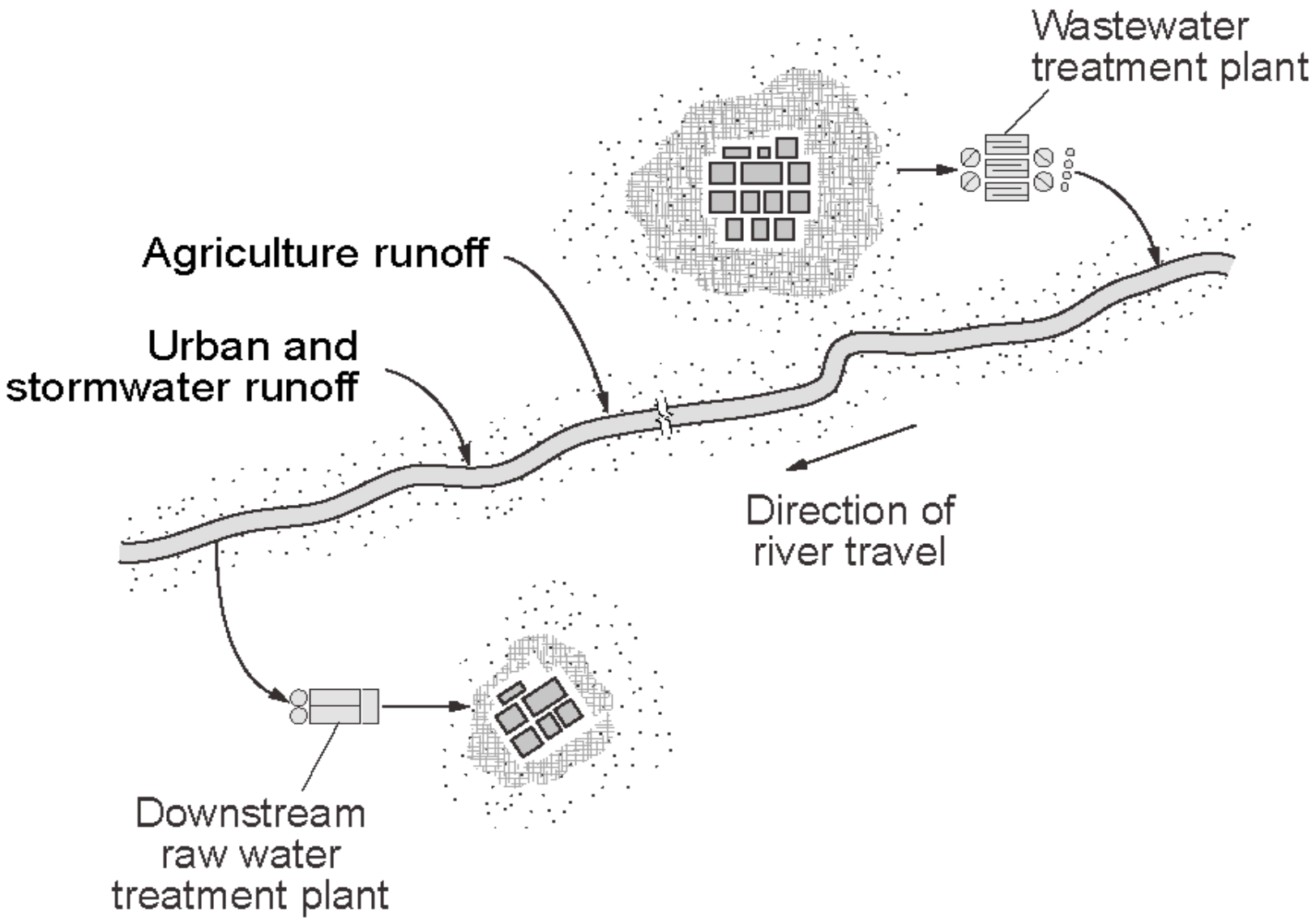
80-90% of this growth in urban areas

2/3 of countries with water scarcity (1/3 in 2000)



Urban/rural population for less and more developed regions

De Facto and Indirect Potable Reuse
(Existing in fact, whether recognized legally)



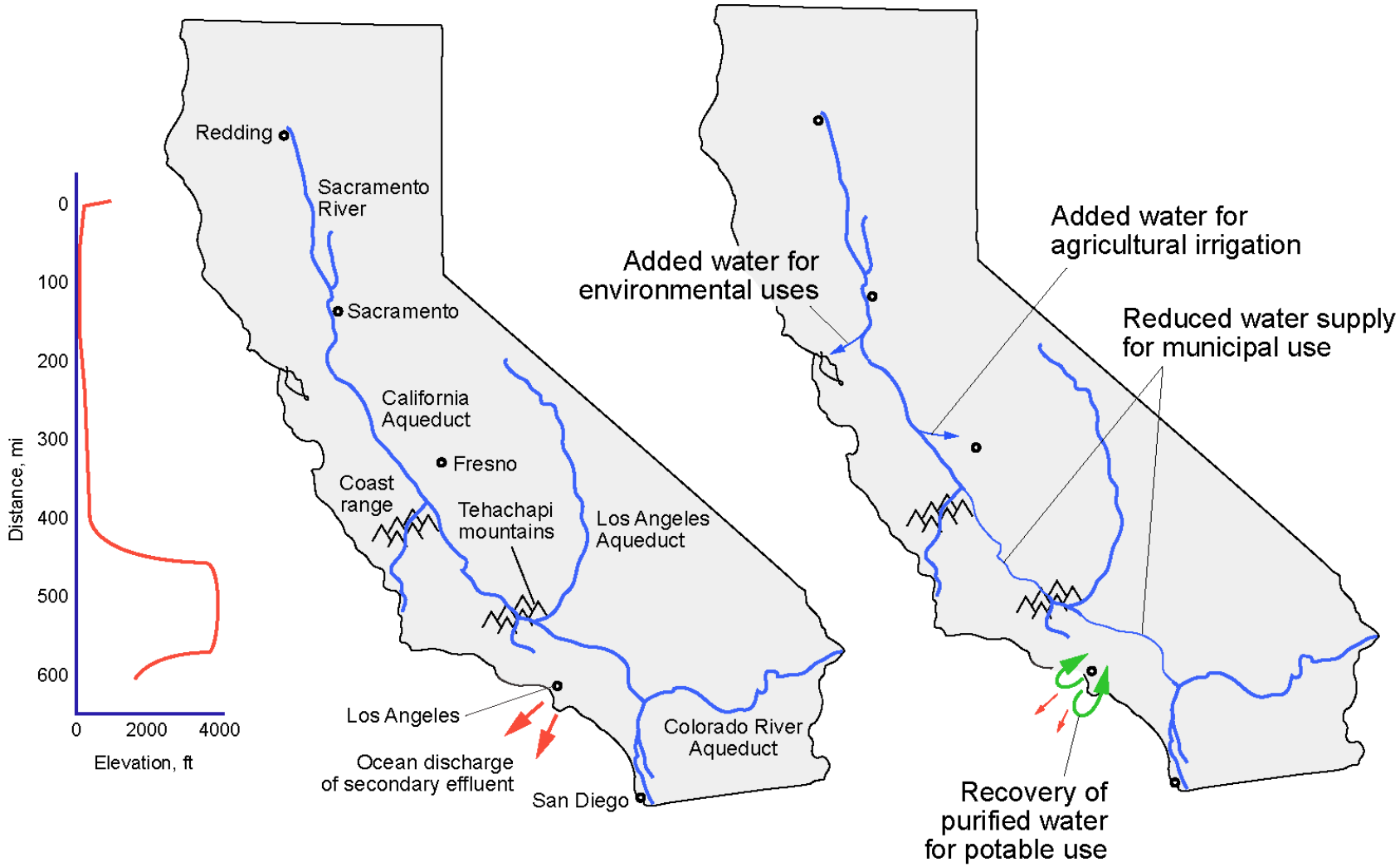
Water Use By County in Southern CA

Item	Quantity, ML/d				
	Los Angeles	Orange	San Diego	Riverside	San Bernardino
Population, 1000's	9,935	2988	2933	1946	1964
Groundwater	1253	185	284	326	291
Surface water	5785	1268	1347	1321	1086
Total	**7038**	**1453**	**1631**	**1647**	**1377**

Electric Power Consumption in Typical Urban Water Systems

System	Power consumption, kWh/ML	
	Northern California	Southern California
Supply and conveyance	40	2350
Water treatment	25	25
Distribution	315	315
Wastewater treatment	660	660
Total	**1,040**	**3350**

Opportunities for the Future: The Southern California Example



Benefits of the Southern California Example

- ü Reliable alternative source of supply, more secure from natural disasters
- ü Lower cost and reduced energy usage
- ü More water available for agricultural use, especially during drought periods
- ü Environmental benefits for bay delta habitat restoration

Factors Limiting Nonpotable and Indirect Potable Reuse

Agricultural Irrigation

- Large distance between reclaimed water and agricultural demand
- Need to provide winter storage

Landscape Irrigation

- Dispersed nature of landscape irrigation
- Cost of parallel distribution system

Indirect Potable Reuse

- Most communities lack suitable hydrology for groundwater recharge
- Availability of nearby suitable surface storage

So What is the Answer?

If a significant amount of wastewater is to be recycled from large cities without the availability of suitable environmental buffers (either groundwater or surface water), then direct potable reuse, with adequate protective measures will have to be implemented

Presentation Topics

- **Wastewater Recycling and Reuse in EU**

Water Reuse Potential Categories In EU

üAgricultural irrigation (widely practiced, high social and low economic value, etc.)
üIndustry: cooling, boiler or process water (widely practiced, high economic value, increasing interest for recycled urban effluents)
üNon-potable urban uses and landscape irrigation (widely practiced, high economic value)
üRestoration of water bodies and wetlands (emerging, high environmental value, etc.)
üAquaculture (widely practiced, high economic value, etc.)
üIndirect reuses: aquifer recharge, drinking water augmentation, etc. (emerging).

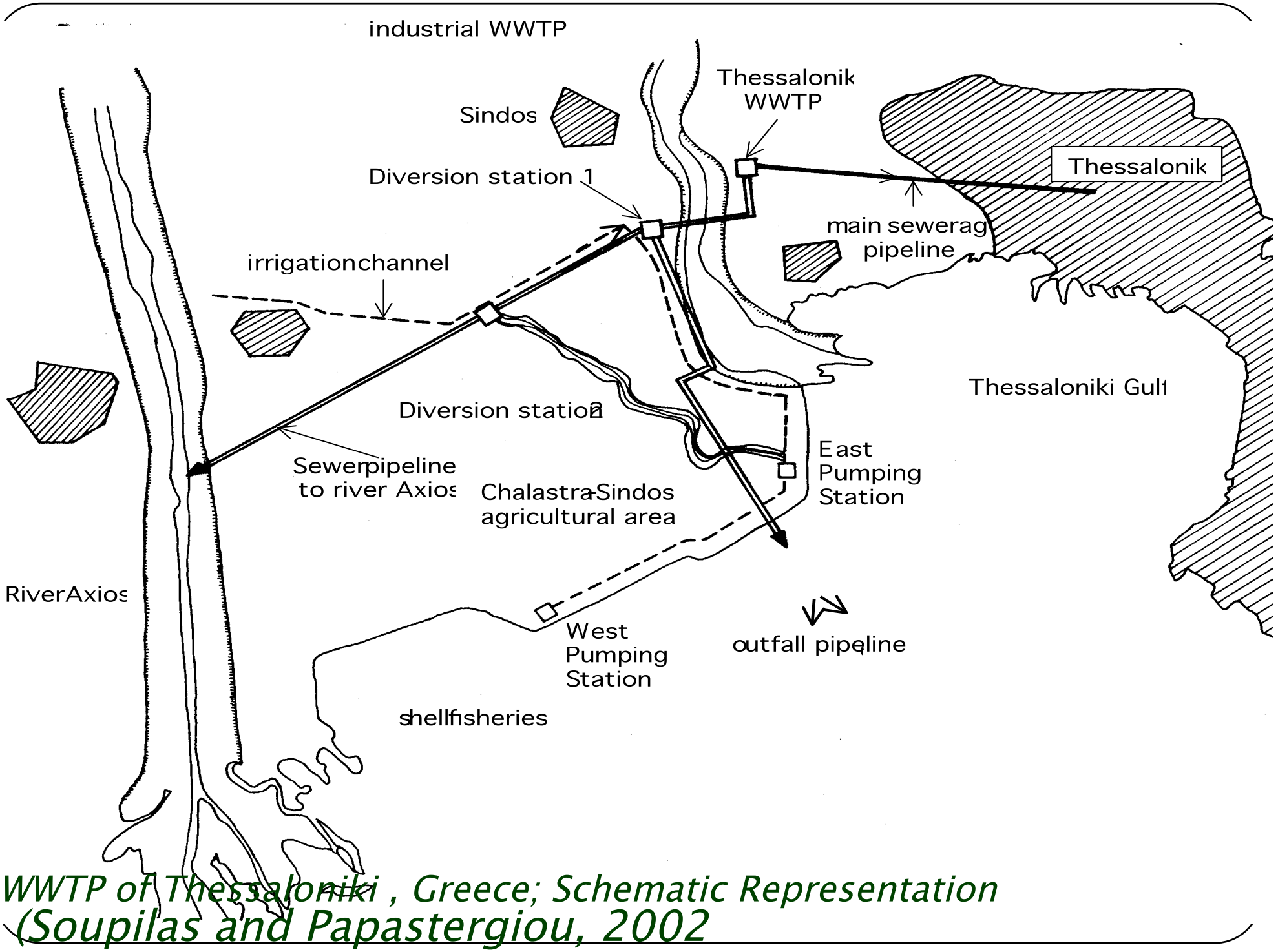
Major Reuse Projects in Greece

Project	Region	Capacity (m^3/d)[a]	Irrigated area (ha)	Crops
Irrigation of agricultural land				
Thessaloniki (Sindos)	Central Macedonia	165,000	2500	Corn, sugar beets, rice,etc.
Levadia	Central Greece	3,500		Cotton, corn
Amfissa	Central Greece	400		Olive trees
Nea Kalikratia	Central Macedonia	800	150	Olive trees
Chersonissos	Crete	4,500	100	Olive trees
Archanes	Crete	550	1450	Grapes and olive trees
Kos	North Aegean	3,500	500	Olive trees, citrus, etc.
Others		10,000		Various
Irrigation of other land (parks, forest, etc.)				
Chalkida		4,000	50	
Chersonisos		500	8	
Agios Costantinos	North Aegean	200	10	
Kentarchos	Crete	100	5	
Kos	North Aegean	500	10	
Karistos	North Aegean	1,450	30	
Ierissos	South Aegean	1,500	25	
Others	North Aegean	2,000		
Indirect reuse				
Larissa	Thessaly	25,000		Cotton, corn, etc
Karditsa	Thessaly	15,000		Cotton, corn, etc.
Lamia	Central Greece	15,000		Cotton, olive trees, corn, etc.
Tripolis	Peloponissos	18,000		
Others		35,000		
Total		310,000		

Reuse of wastewater effluent in Chalkida

Sugarbeets experimental fields irrigated with wastewater effluent at Sindos, Thessaloniki

Rice fields irrigated with wastewater effluent at Sindos, Thessaloniki



WWTP of Thessaloniki , Greece; Schematic Representation (Soupilas and Papastergiou, 2002

Irrigation canal and mixing point of Thessaloniki's WWTP effluent with the Axios river water

Distribution of major crops in the irrigated area

Crops	Area (ha)	Percentage (%)	Water requirements (max and min in m^3/ha)
Cotton	104	4.26	54–66
Corn	559	22.8	62–76
Alfalfa	111	4.5	70–86
Rice	1677	68.5	100–222

Concentration of pathogens in wastewater effluent, Axios fresh water and the mixed water (25.08.11)

Type of water	TC (MPN/100mL)	*E. coli* (MPN/100mL)	Enterococci (no/100ml)	*Salmonella* species (MPN/100 ml)	IN (no of eggs/L)
WWTP effluent	<3	<3	<3	none	none
Axios	23	23	<3	none	none
Mixed	21	15	<3	none	none

Concentrations of chemical parameters in the WWTP effluent, fresh water of Axios and mixed water (Soupilas, 2011)

Parameter	Units	Effluent	Axios	Mixed
SS	mg/L	11	16	12
COD	mg/L	60	16	18
BOD5	mg/L	3	2	2
pH		7.27	7.71	7.6
EC	μS/cm	5130	560	700
Ca	meq/L	5.33	3.07	3.09
Mg	meq/L	7.84	0.73	0.75
Na	meq/L	49.74	1.35	1.61
SAR		19.25	0.98	1.16
Cl-	mg/L	1250	50	75
$N\text{-}NH_4$	mg/L	0.33	0.18	0.26
$N\text{-}NO_3$	mg/L	9.66	1.1	1.2
TKN	mg/L	10.6	1.4	1.4
$P\text{-}PO_4$	mg/L	3.6	<0.5	0.81
K	meq/L	0.35	0.06	0.08
HCO_3	meq/L	5.46	3.32	3.82
Chlorides	meq/L	60.4	1.01	1.08
SO_4	meq/L	2.5	0.3	1.0

*Qualitative Criteria in Mixed water (4:1) of Axios River Water and Treated Wastewater Effluent (**CMD 123805/05**)*

pH	6,5 – 8,5
EC	< 3,0 dS/m
BOD_5	< 20 mg/L
COD	< 80 mg/L
TSS	< 30 mg/L
Residual Cl^-	< 0,5 mg/L
IN (no of eggs/L)	< 1
B	< 2 mg/L
TKN	< 30 mg/L
FC	< 1000MPN/100 mL

Poplar plantation irrigated with recycled water and amended with sludge in Vall-Llobrega, Girona, Spain

"Port Aventura" golf course in Spain irrigated with recycled water

In Costa Brava, Spain: 3.000.000 m^3/yr reclaimed water (of denitrified, Title-22) is used for groundwater recharge (Tordera) since 2003.

Long term effects on crops and soil have been investigated at the University of Bari, Italy

Field of fennels irrigated with membrane filtered municipal wastewater at CERIGNOLA, Bari, Italy

Golf course irrigated with recycled water in the island of Porto Santo (archipelago of Madeira), Portugal

Water use (in Mm^3/yr) including reuse of treated wastewater in EU-Mediterranean countries

Country	Total water withdrawal	Agric. Use	Treated wastewater	Wastewater reuse (2005)	Wastewater reuse (2025)
Cyprus[a]	270	182	17	1	85
France	32,600[b]	2,800[b]	7,000[c]	15	120
Greece	8,150	6,900	700	6	60
Italy	45,000	22,000	5,500[d]	250	550
Malta	60	14	10	4	15
Portugal	7,500[e]	6,550[e]	480[f]	5	70
Spain	40,000	25,000	3,375[g]	350	1350
Total	133,580	63,444	17,082	631 (3.7%)	2250

[a]These data relate only to the Government Controlled areas; [b]IFEN (2007); [c]FEN (2008); [d] APAT (2005)
[e]Programa Nacional para o Uso Eficiente da Água (2002); [f]INSAAR (2009);
[g]Versión Preliminar del Plan Nacional de Reutilización de Aguas (2010)

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Irrigation water (%):	27

Wastewater recycling and reuse

Reuse in 2005	650Mm³/yr
Potential of reuse in 2025	2,250Mm³/yr
Reuse in US in 2005	2,450Mm³/yr

[a]Adapted from EU EAA 2008 and Aquarec, 2006

Presentation Topics

- **Criteria (Regulations or Guidelines) in EU**

In EU increased recycling of waters can have two distinct advantages:

üRecycling can provide additional sources of water for various purposes, which currently are supplied by Europe's limited freshwater resources

üRecycling can reduce discharge of wastewater and stormwater into receiving environments and of course nutrients and other pollutants

Historical development data of the water quality for Irrigation (Paranychianakis et al., 2010).

Year	Data and quality criteria
	Before 1918 wastewater reuse for irrigation was practiced in various regions since the Minoan Era, but there no any criteria
1918	California State Board of Public Health set up the "First regulations for use of sewage for irrigation purposes
1952	First regulations of Israel
1973	WHO 100 FC/100 mL, 80% of samples
1978	California State of wastewater reclamation regulations: 2.2 TC/100 mL
1978	Israel regulations: 12 FC/100 mL in 80% of samples: 2.2 FC/100 mL in 50% of samples
1983	World Bank Report (Shuval et al., 1986)
1983	Florida: No *E. coli* detection in 100 mL
1984	Arizona: Standards for virus (1 virus/40 L) and Giardia (1 cyst / 40 L)
1985	Report of Feachem *et al.,* 1983
1985	Engelberg report (IRCWD, 1985)
1989	WHO Recommendations for wastewater reuse: 1000 FC/100 mL; and <0.1 nematode egg/L
1990	Texas State: 75 FC/100 mL
1991	Sanitary French recommendations: Based on WHO
1992	US EPA Guidelines for water reuse: No FC detection in 100 mL (7 d median. No more of 14 FC/100 mL in any sample)
2000	State of (Title 22) was revised
2003	WHO State of the Art Report on Artificial Recharge of Groundwater with Recycled Water (Aertgeerts and Angelakis, 2003)
	Italian quality criteria
2004	Cyprus regulations
2005	Revised US EPA Guidelines for Water Reuse
2006	WHO guidelines for wastewater reuse, revised
2006	Australian guidelines for water recycling and reuse (managing health and environmental risks)
2006	Portugues Standard NP 4434
2007	Spanish Reuse of Reclaimed Water: Quality Criteria
2010	Greek regulations (Common Ministerial Decision)
2011	Malta criteria (under preparation)
2011	

Existing Situation in EU Countries

ü **Countries with Regulations or Guidelines:**
Cyprus, France, Greece, Italy, Portugal, and Spain.

ü **Countries Contemplating Regulations or Guidelines:**
Belgium, Bulgaria, Germany, Hungary, Malta, Poland, Romania, and UK.

ü **Countries with no Regulations or Guidelines:**
Austria, Czech Republic, Denmark, Estonia, Finland, Iceland, Ireland, Latvia, Lithuania, Luxembourg, Norway, Slovenia, Slovakia, Sweden, Switzerland, and The Netherlands.

Comparison of EU-Med Countries for unrestricted irrigation with those of major worldwide philosophies

Organization, Country or State	Indicators	Targets (log reduction)	Comments
WHO (1989)	FC: ≤1000 cfu/100 mL Helminth eggs: ≤1.0 /10 L	-	
WHO (2006)	*E. coli*[a]: 10-10^5 cfu/100 mL	Rotavirus: 7 *Cambylobacter* *Cryptosporidium*	A QMRA approach is applied based on the Stockholm Framework methodology.
Australia (2006)	*E. coli* ≤1.0 cfu/100 mL	Rotavirus: 6.0 *Campylobacter*: 5.0 *Giardia*: 5.0	A QMRA approach is applied to assess but lacks a Monte Carlo Analysis.
California (Title 22, 2000)	TC ≤ 2.2 cfu/100 mL	-	Based on "zero risk approach"
Cyprus	FC: ≤5[d] cfu/100 mL Helminth eggs: ≤0 /L	-	Irrigation of leaved vegetables, bulbs, and corns eaten raw and ornamental plants is not allowed
France	*E. coli* ≤ 250 cfu/100 mL	Bacteriohages ≥ 4 *Enterococcus* ≥ 4 A.S.B.[b] ≥ 4	Maximal distances between irrigation areas and some activities such as water bodies have been enforced
Greece	*E. coli* ≤5[e] cfu/100 mL and/or TC ≤2[f] cfu/100 mL	-	Another 64 parameters (of heavy metals, metalloids and priority substances) are included
Italy[d]	*E. coli* ≤10 cfu/100 mL	-	Another 53 parameters are included
Malta	No set	-	
Portugal[c]	FC ≤100 cfu/100 mL Helminth eggs ≤1.0 /L	-	Not recommended in soils with slopes >20% and in karstic geological formations
Spain[c]	*E. coli* ≤100cfu/100mL[g] Helminth eggs: <1/10L	-	In some cases are included up to 60 parameters are considered and monitoring at the point of use

Overall the EU-Med regulations can be separated into three major categories:

- These of France which are based on the revised WHO and Australian guidelines.
- The Cyprus, Greece, and Italy regulations which are more or less based on the California regulations.
- These of Portugal and Spain with an intermediate, compared to the previous two, philosophy and with no clear limits for unrestricted irrigation.

The establishment of such EU regulations and/or guidelines and best management practices will contribute to:

ü Avoid useless restrictions and disadvantages of national regulations (monitoring 65, 72 and 55 parameters for Greece, Spain, and Italy, respectively is required)

ü Improve the management of water resources and increase the protection of public health and environment in a sustainable way as mandated by WFD

ü Eliminate the cost of effluent reuse projects and encourage the use of alternative water sources, and finally

ü Enhance the agricultural productivity and the quality of produce all over the EU

Presentation Topics

- **Conclusions**

Closing Thoughts

(a) In EU there is relatively high water availability with uneven distribution

(b) Technology is now available to produce water for any reuse even for direct (and indirect) potable reuse

(c) In EU water reuse is inevitable and will represent an essential element of sustainable water resources management.

(d) To promote water reuse in EU

- ü Must think of wastewater differently.
- ü The public support is necessary.
- ü Clearer institutional arrangements, economic instruments, and water reuse guidelines or regulations are urgently needed
- ü The profession must speak with a unified vocabulary: Words and Context are Important


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Thank you for listening

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