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유네스코 물 안보 및 지속가능 물 관리
국제연구교육센터

XVIII
World Water Congress
International Water Resources Association (IWRA)

The Effect of Urban Conditions, External Influences, and O&M Efficiency on Urban Water System from the Nexus

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XVIII
WORLD WATER CONGRESS
Water for All
Harmony between
Humans and Nature
第18届
世界水资源大会
水与万物:
人与自然和谐共生

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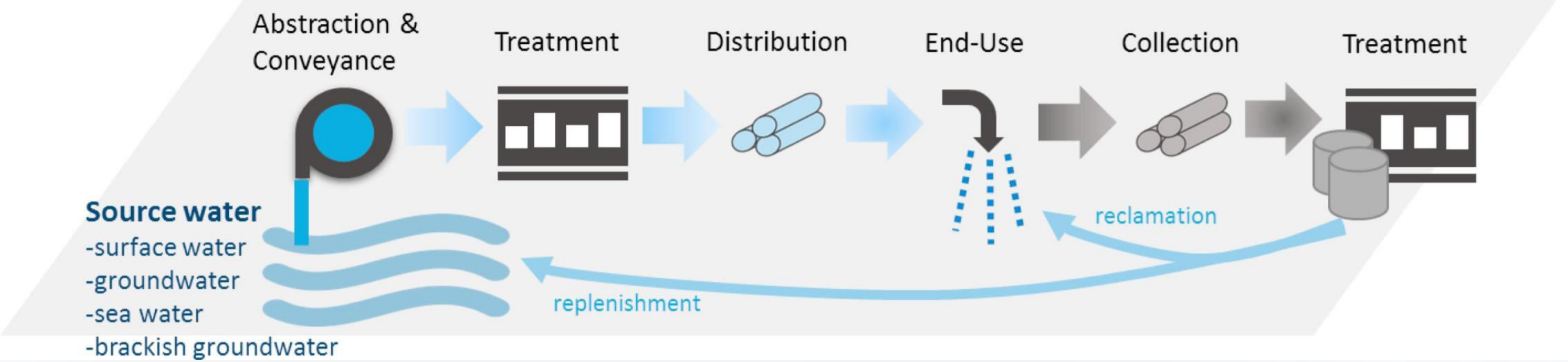
Current Challenges

Population Growth	The world population has exceeded 7 billion and the total world population will be 8.1 billion in 2025 and 9.7 billion in 2050 *(UN, 2019)*
Energy Demand	From 2011 to 2030, the world's main energy consumption is increasing 1.6% every year and it is predicted to increase by 36% until 2030
Water Demand	If the efficiency improvement is not realized under the current growing trend, it is forecasted that the water demand will increase from 4.5 trillion m^3 to 6.9 trillion m^3 *(UN-Water, 2019)*
Urbanization	Above 50% of world population live in cities and urbanization acceleration leads to industrialization, which implies more water demand *(UN, 2018)*
Food Demand & Changing Meals	The meat intake of world population is projected to increase by 14% by 2030 comparison to baseline 2018-2020. Under this situation, around huge proportion of grain production shall be converted to animal feeds *(OECD-FAO,2021)*

Urban Water System

- **Urban water system** is an artificial process for using water resources in urban areas
- Even though, the close and complex relationship between water and energy exist, conventional water and energy management in urban area tends to focus on individual management, rather than a holistic approach
- A comprehensive approach to analyze the relationship between water and energy is essential



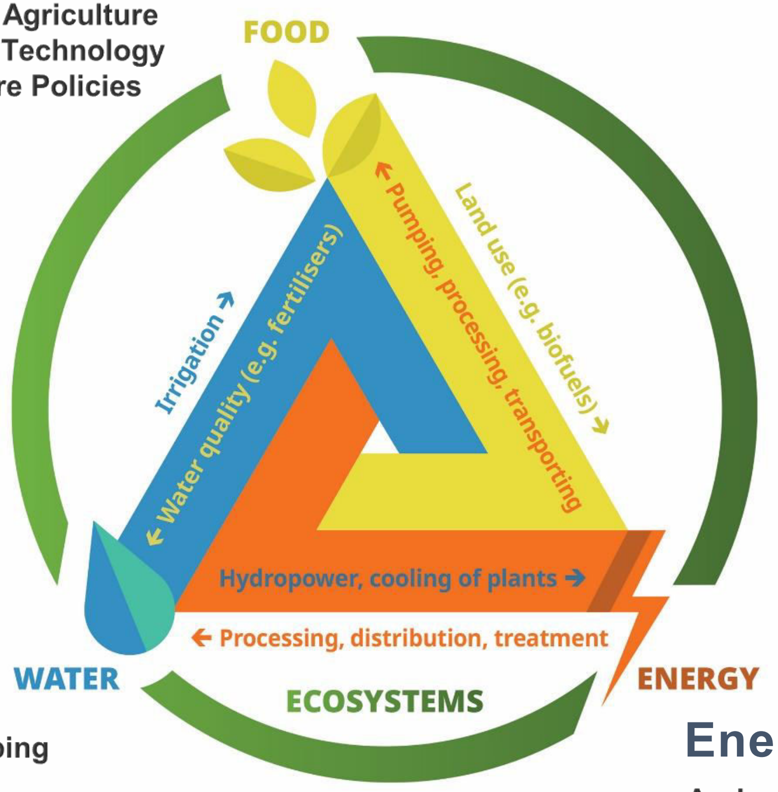
Urban Water Systems

The Nexus Approach

- The **Nexus** approach analyzes *interlinkages, synergies, and trade-offs* between sectors
- It aims to identify solutions, fostering water-energy-food security and efficiency, and reducing impacts and risks on water-dependent ecosystems

Water-Food

- Water for Agriculture
- Irrigation Technology
- Agriculture Policies



Water-Energy

- Water Heat Energy
- Water Production, Pumping
- Seawater Desalination
- Wastewater Treatment
- Hydroelectric Power Generation
- Cooling Water of Power Plant

Energy-Food

- Agricultural Product Facilities
- Biofuels
- Irrigation Pumping
- Food Production

Water-Energy-Food Nexus Framework

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Research Objectives

To establish guidelines, strategy, and action plan for urban water system

- Build an energy intensity matrix by urban water system process
- Analysis on energy intensity by water (total water use, revenue water, real water)
- Water-Energy Nexus assessment and guidelines
- Analysis of Water-Energy Nexus by urban conditions, external influences, and o&m efficiency on urban water system

Methodology

- **Model used**: system dynamics
- **Data used**: Energy intensity of urban water system
  - ✓ Desalination, abstraction (groundwater), conveyance, water treatment, transmission & distribution, reuse, wastewater collection, wastewater treatment, discharge
- **Urban Water System Variables**
  - ✓ External impact variables: population, groundwater usage, energy intensity condition
  - ✓ Operation and management variables: lpcd, energy intensity condition, water loss rate

Methodology

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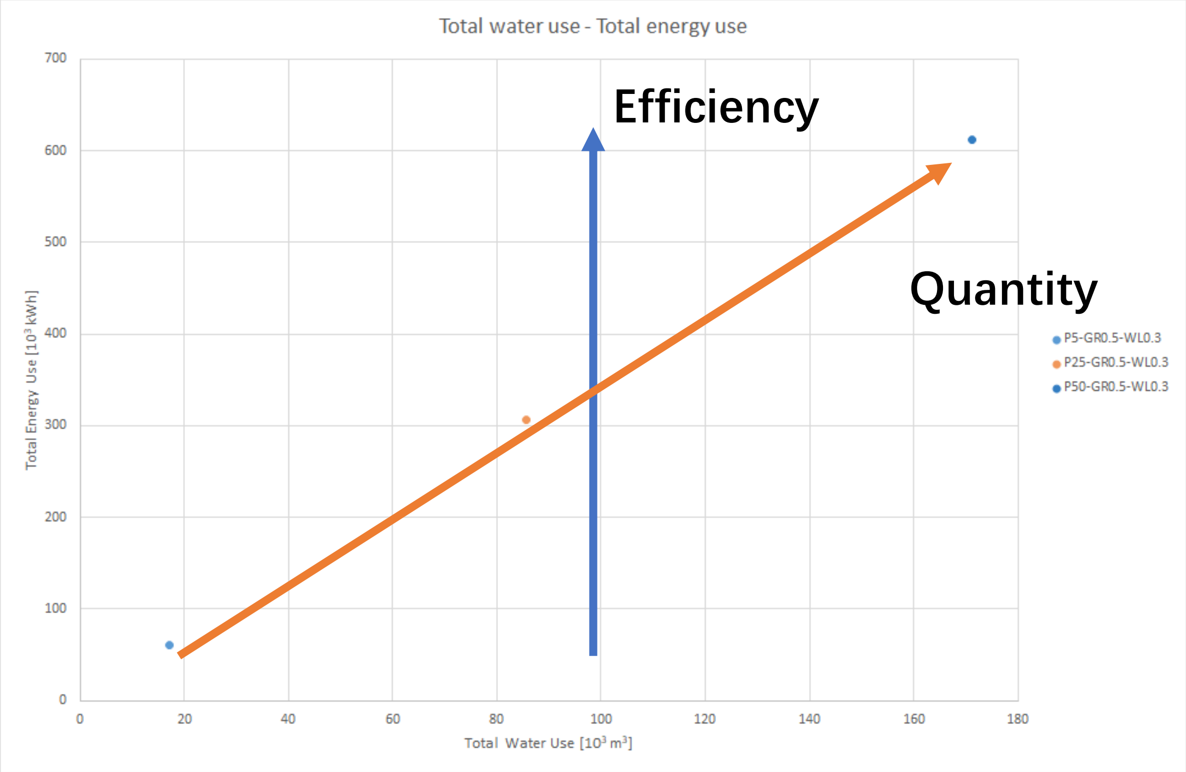
Energy intensity trends can be diagnosed

- Efficiency: same water use, less energy use
- Quantity: both water and energy use increase



Variables	Total water EI	Revenue water EI	Real water EI
Population ↑	Quantity (↑)	Quantity (↑)	Quantity (↑)
Abstraction ↑	Efficiency (↑)	Efficiency (↑)	Efficiency (↑)
Energy Intensity Condition ↑	Efficiency (↑)	Efficiency (↑)	Efficiency (↑)
Water Loss ↑	Quantity (↑), Efficiency (↓)	Efficiency (nearly ↑)	Efficiency (↑)

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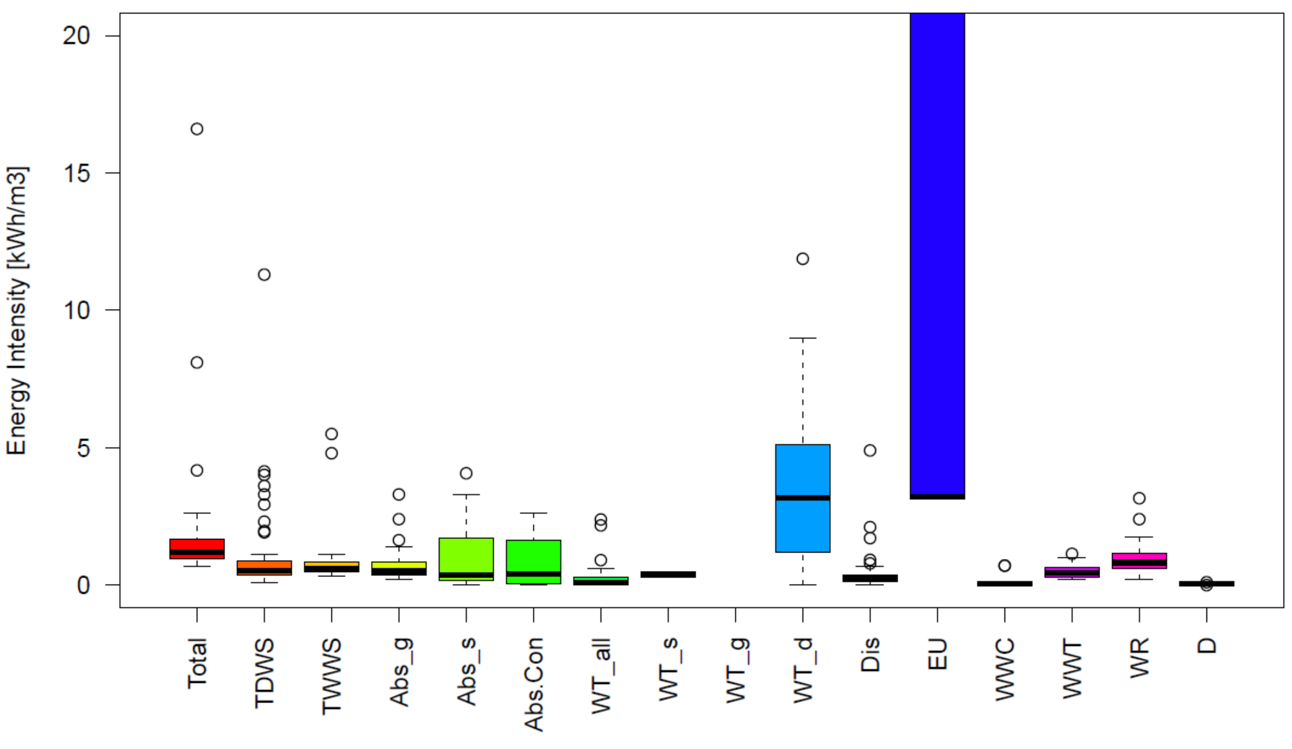
Results – Energy Intensity Matrix

- Developed energy intensity matrix by urban water system by using 367 literatures
- The energy intensity median value of total water system, water treatment system, and wastewater system are 1.210 kWh/m^3, 0.519 kWh/m^3, 0.580 kWh/m^3 respectively
- End use > desalination & reuse > water treatment & wastewater treatment, conveyance > wastewater collection & discharge



Results – Energy Intensity Matrix

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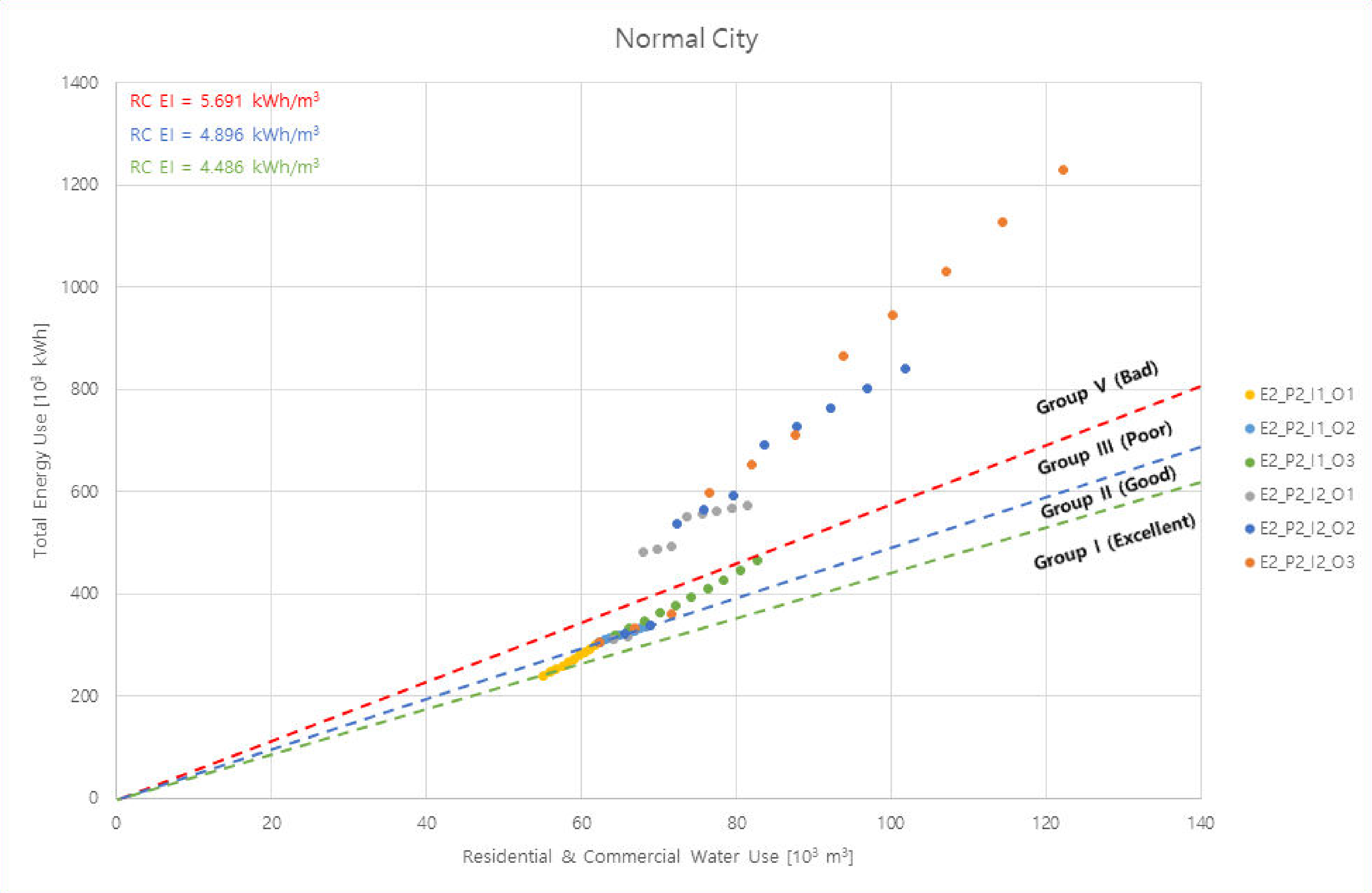
Category	Total			Abs.	Con.	Abs. Con	WT				Dis.	EU	WWC	WWT	WR	D
	Total	TDWS	TWWS	Abs_g	Con_s	Abs. Con	WT_all	WT_s	WT_g	WT_d	Dis	EU	WWC	WWT	WR	D
Mean	2.334	1.029	1.024	0.822	0.910	0.820	0.294	0.382	-	11.963	0.439	54.491	0.181	0.494	1.072	0.053
Errors	0.728	0.212	0.277	0.178	0.211	0.185	0.099	-	-	4.691	0.110	51.297	0.080	0.044	0.238	0.014
Median	1.210	0.519	0.580	0.505	0.370	0.396	0.090	0.382	-	3.170	0.255	3.211	0.061	0.440	0.820	0.054
Mode	1.155	0.850	0.840	0.415	0.832	0.040	0.029	-	-	3.170	0.100	-	0.710	0.410	0.820	0.055
1st quartile	0.865	0.357	0.470	0.372	0.150	0.048	0.029	-	-	1.197	0.136	3.161	0.037	0.300	0.588	0.038
3rd quartile	1.690	0.903	0.840	0.874	1.813	1.636	0.298	-	-	5.450	0.385	157.10	0.140	0.711	1.445	0.068
Std. Dev.	3.492	1.646	1.327	0.794	1.099	0.927	0.560	-	-	30.761	0.762	102.59	0.264	0.246	0.860	0.034
Variation	12.191	2.708	1.760	0.630	1.208	0.860	0.314	-	-	946.22	0.580	10525	0.070	0.060	0.739	0.001
Kurtosis	13.661	26.006	8.237	4.636	1.513	-0.647	9.415	-	-	12.528	25.992	4.000	1.853	0.495	1.969	2.448
Skewness	3.584	4.594	3.008	2.197	1.448	0.968	3.098	-	-	3.595	4.764	2.000	1.846	1.037	1.608	-0.022
Range	15.900	11.210	5.190	3.110	4.070	2.624	2.385	0.000	0.000	142.49	4.890	205.22	0.689	0.942	2.947	0.106
Minimum	0.700	0.090	0.310	0.190	0.000	0.000	0.005	0.382	0.000	0.015	0.010	3.160	0.022	0.198	0.215	0.000
Maximum	16.600	11.300	5.500	3.300	4.070	2.624	2.390	0.382	0.000	142.50	4.900	208.38	0.710	1.140	3.162	0.106
Observations	23	60	23	20	27	25	32	1	0	43	48	4	11	31	13	6

Results - Guidelines

- We distinguished urban water system by Excellent, Good, Poor, and Bad according to energy intensity matrix
- The guideline (classification) can be a useful benchmarking tool for determining the level of the city by comparing it with other cities in terms of the efficiency of the Nexus perspective of the urban water system

	Total water energy intensity	Revenue water energy intensity	Real water energy intensity
Excellent	~ 3.274	~ 4.678	~ 4.486
Good	3.274 ~ 3.574	4.678 ~ 5.106	4.486 ~ 4.896
Poor	3.574 ~ 4.154	5.106 ~ 5.935	4.896 ~ 5.691
Bad	4.154 ~	5.935 ~	5.691~

Results – Scenario Analysis



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Conclusions

- With energy intensity matrix and developed guidelines, we were able to analyze resources usage in urban Water-Energy Nexus perspective
- The results shows how external impact variables and operation & management variables affect to energy intensity in urban water system
- This study allows to provide scientific evidence on energy intensity to support policy-makers and researchers

Thank You

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