WATenERgy CYCLE
Urban water full cycle: from its source to its end-users and back to the environment

WP5 Joint Pilot Actions

Joint Del. 5.4 Ex-Ante Energy recovery evaluation

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PP3 - Municipal Enterprise for Water Supply and Sewerage of Kozani

PP4 - University of Thessaly-Special Account Funds for Research-Department of Civil Engineering

PP2 - General Secretariat for Natural Environment and Water

Project co-funded by the European Union and National Funds of the participating countries

WP5: Joint Pilot Actions

- Responsible partners:
  - **PP3 - Municipal Enterprise for Water Supply and Sewerage of Kozani**
  - **PP4 - University of Thessaly-Special Account Funds for Research-Department of Civil Engineering**
  - **PP2 - General Secretariat for Natural Environment and Water**

- Partners involved: ALL

- Budget: 885,021.23 €

Project co-funded by the European Union and National Funds of the participating countries

WP5: Joint Pilot Actions

WP5 includes Joint Pilot Actions

- Evaluation of the pilot case prior to the pilot actions. General presentation and description of the pilot case and the pilot action; identification of problems; water and energy audit (Water Balance and Pis); conclusion

- Evaluation of the pilot case after the pilot actions. Description of the pilot action implementation; water and energy audit after the implementation of the pilot action; discussion related to the new PIs values; problems encountered during the pilot action implementation; costs estimation; conclusions

- Summary report on the implementation of the pilot action (per partner).

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WP5: Joint Pilot Actions

Beneficiary		Pilot action	Equipment	Water Use Efficiency	Energy Efficiency
LP	DEYA Larissas (Greece)	Purchase & Installation of Energy Recovery System (three IE3 High Energy Efficiency Motors 250 KW two Inverters, one Softstarter: & Installation Service) at the Central Pumping Station for Larisa Water Utility	three IE3 High Energy Efficiency Motors 250 KW two Inverters, one Softstarter: & Installation Service		√
PP3	DEYA Kozanis (Greece)	Purchase of Energy Recovery System (ENR) and Automated Meter Reading (AMR) (700 AMR, 2 mobile reading systems, software, 3 ENRs DN150 & 2 ENRs DN200, training) for Kozani Water Utility	700 AMR; 5 small hydroturbines	√ Apparent losses	√
PP5	UKKO (Albania)	Water leak detection car (equipped with facilities), Leak detection equipment flow analysis, aquaphone, analysis secorr 300. Water losses measurement database and decision support system. Korça City Zone Pressure no. 3 will represent the UKKO JSC study area that will be our pilot action area	Leak detection car with incorporated Water Leak detection Equipment	√ Real losses	
PP6	WBN (Cyprus)	Purchase of equipment for water pressure management (PRVs) and smart water meters SCADA, PILLAR, software including training of personnel. Monitor operating parameters (pressure, flow, quality parameters). Water Balance calculation	· 700 AMR in DMA25 · PRV installation in DMA 15 · Electronic sensors for water quality monitoring · Electronic power generators	√ · Apparent losses · Real losses	√
PP7	BWA (Bulgaria)	Purchase of leak detection, monitoring and sewerage network inspection equipment. Training purposes	Water leak detection equipment to be used for training & educational purposes	√ Horizontal training	
PP8	Prilep (N. Macedonia)	Purchase of leak detection system and measuring equipment, GIS software for "Water supply and drainage". Water losses measurement database and decision support system	GIS software and leak detection system and measuring equipment	√ Real losses	

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WP5: Joint Pilot Actions – Water or Energy Efficiency?

Water use efficiency

- PP3-DEYAK
- PP5-UKKO
- PP6-WBN
- PP7-BWA
- PP8-JKP ViK Prilep

Energy efficiency

- LP/PP1 - DEYAL
- PP3 - DEYAK
- PP6-WBN

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Energy characterization of a water system (Cabrera et al., 2014)

1st stage

- ***Basic diagnostic***
- *from basic data (energy and water injected into the system, water demands, pressure required and physical and topographical characteristics of the system), to do a diagnosis of the system*

2nd stage

- ***Water audit***
- *If the diagnostic say that the PWS is efficient, it is not necessary to go further. But not, it is urgent to know why and where energy is lost and how to reverse the situation. To do this, a water audit of the system, is required. Water is the energy carrier. From this point of view leaks are both water and energy losses.*

3rd stage

- ***Energy audit.***
- *The destination of the energy entering into the control volume that bounds the system must be identified. It is equal to the sum of the energy supplied to users and the energy losses (pump and motor drive inefficiencies, pipe's friction, valve's dissipation and, in some urban water networks, the energy lost in domestic tanks where water is depressurized).*

4th stage

- ***Analysis of operational actions.***
- *energy consumption can be reduced by improving the system's operation. In the urban case adjusting the pressure to requirements can be used. Either with variable speed pumps or with pressure reducing valves, that does not reduce energy costs but, as it reduce leaks, results in a final saving. Last pumps must work at their highest performance or when energy cost are lower.*

5th stage

- ***Analysis of structural actions.***

6th stage

- ***Label the energy efficiency of PWS***

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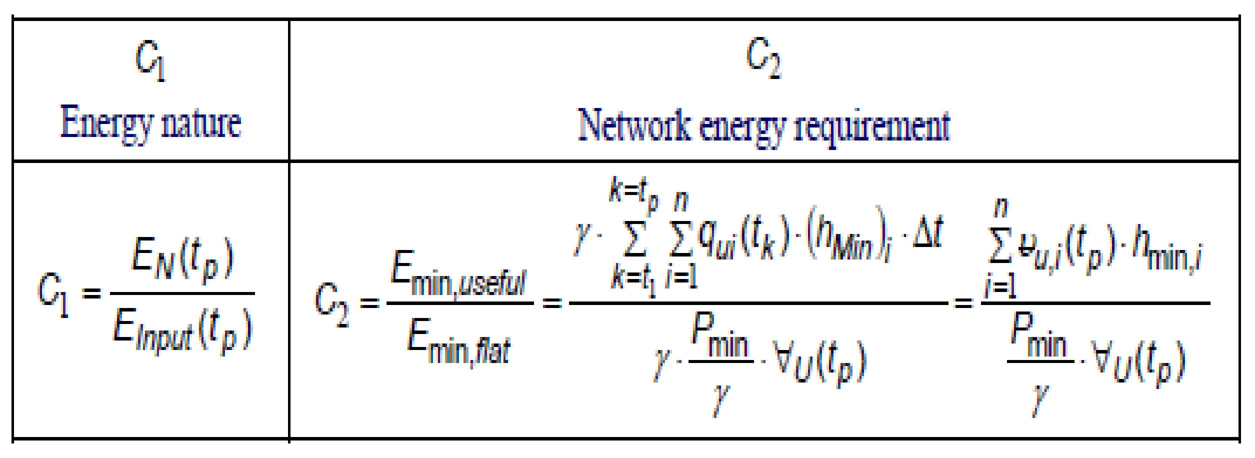
Basic energy indicators (1/3)

- *The first "context indicator" C1 shows which portion of the energy delivered to the system is natural and ranges from 0 to 1, with the maximum being reached when all the injected energy is gravitational, being provided by a high water source.*
- *The second context information c2, considers how demanding from an energy point of view the network is. As the ratio between the minimum useful energy defined in each node from the minimum required head and a theoretical minimum required energy (for a flat, leak free and frictionless network). Since this ideal network corresponds to a flat layout with all nodes located at the same maximum height z_{max}, the best possible value of c2 is one.*

(Cabrera et al, 2010)

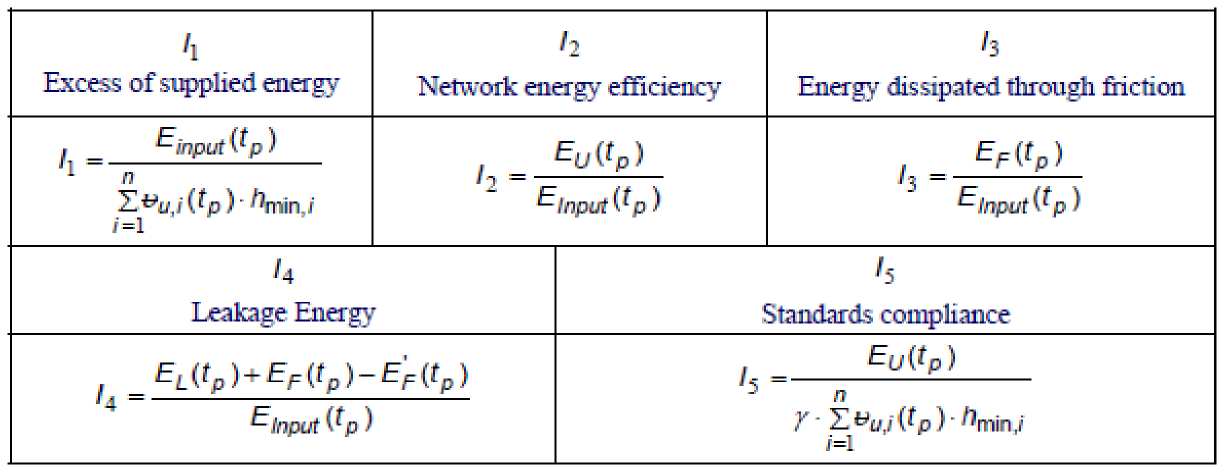


C_1 Energy nature	C_2 Network energy requirement
$C_1 = \frac{E_N(t_p)}{E_{Input}(t_p)}$	$C_2 = \frac{E_{\min,useful}}{E_{\min,flat}} = \frac{\gamma \cdot \sum_{k=t_1}^{k=t_p} \sum_{i=1}^{n} q_{ui}(t_k) \cdot (h_{Min})_i \cdot \Delta t}{\gamma \cdot \frac{P_{\min}}{\gamma} \cdot \forall_U(t_p)} = \frac{\sum_{i=1}^{n} \vartheta_{u,i}(t_p) \cdot h_{\min,i}}{\frac{P_{\min}}{\gamma} \cdot \forall_U(t_p)}$

Basic energy indicators (2/3)

- *The first indicator, I_1, is the ratio between the real energy entering the system and the minimum useful energy.*
- *I_2, is a measure of the efficiency of the use of the energy injected to the system (which fraction of the total energy input is useful).*
- *I_3 represents the hydraulic capacity of the network. A higher value indicates lower efficiency. Although this can be brought to values very close to zero, eliminating friction losses implies a very costly design. Target values depend on a balance between investment and running costs.*

(Cabrera et al, 2010)



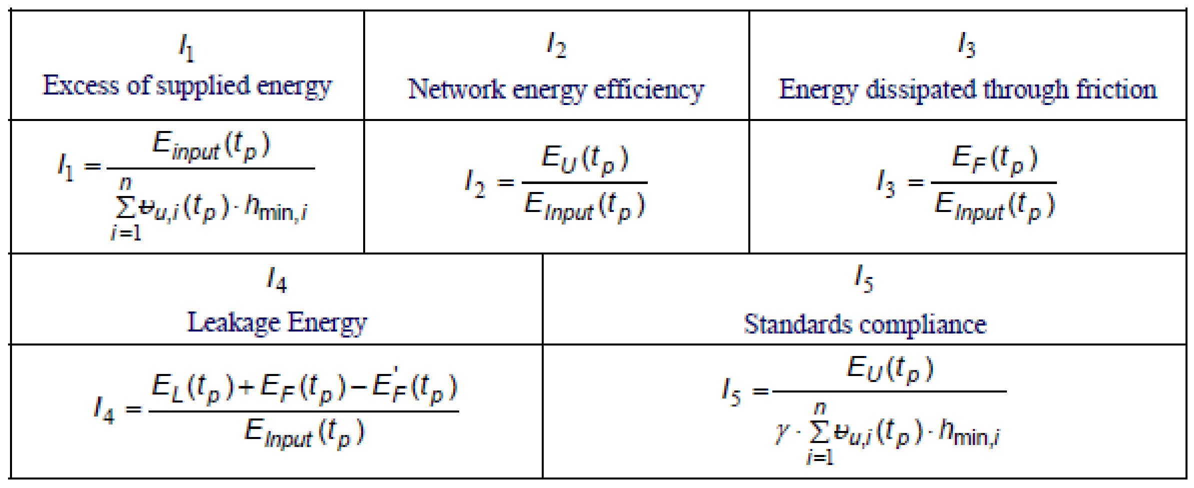
I_1 Excess of supplied energy	I_2 Network energy efficiency	I_3 Energy dissipated through friction
$I_1 = \frac{E_{input}(t_p)}{\sum_{i=1}^{n} \vartheta_{u,i}(t_p) \cdot h_{\min,i}}$	$I_2 = \frac{E_U(t_p)}{E_{Input}(t_p)}$	$I_3 = \frac{E_F(t_p)}{E_{Input}(t_p)}$

I_4 Leakage Energy	I_5 Standards compliance
$I_4 = \frac{E_L(t_p) + E_F(t_p) - E_F'(t_p)}{E_{Input}(t_p)}$	$I_5 = \frac{E_U(t_p)}{\gamma \cdot \sum_{i=1}^{n} \vartheta_{u,i}(t_p) \cdot h_{\min,i}}$

Basic energy indicators (3/3)

- *The fourth indicator, I_4, measures the energy loss due to leakage, which results from the sum of energy loss through leaked water and the additional energy required to overcome friction with the increased flow rate needed to overcome leakage (difference between the actual energy dissipated in friction losses and the value of friction losses in a leak-free network,).*
- *I_5, is the direct ratio between the energy delivered to users and the minimum required useful energy. It is a network-level indicator that averages the overall condition of the system but may leave sector performance unnoticed (the average condition may be good while some sectors are performing poorly).*

(Cabrera et al, 2010)



I_1 Excess of supplied energy	I_2 Network energy efficiency	I_3 Energy dissipated through friction
$I_1 = \dfrac{E_{input}(t_p)}{\sum_{i=1}^{n} \vartheta_{u,i}(t_p) \cdot h_{\min,i}}$	$I_2 = \dfrac{E_U(t_p)}{E_{Input}(t_p)}$	$I_3 = \dfrac{E_F(t_p)}{E_{Input}(t_p)}$

I_4 Leakage Energy	I_5 Standards compliance
$I_4 = \dfrac{E_L(t_p) + E_F(t_p) - E_F^{'}(t_p)}{E_{Input}(t_p)}$	$I_5 = \dfrac{E_U(t_p)}{\gamma \cdot \sum_{i=1}^{n} \vartheta_{u,i}(t_p) \cdot h_{\min,i}}$

Performance Indicators (energy efficiency)

A/A	GROUP	PERFORMANCE INDICATORS	MEANING	FORMULA	MEASURED IN
Ph4	Pumping	Pumping utilisation	[Sum, for all installed pumps, of the number of operation hours of the maximum energy consumption day during the assessment period multiplied by the nominal power of the pump / (maximum nominal power that can be used simultaneously in the system x 24)] x 100	Ph4=[D2/(C7*24)]*100	%
Ph5		Standardised energy consumption	Energy consumption for pumping during the assessment period / Sum of the volume elevated during the assessment period multiplied by the pump head / 100	Ph5=D1/D3	kWh/m3/100m
Ph6	Treatment	Reactive energy consumption	Reactive energy consumption for pumping during the assessment period / total energy consumption for the pumping during the assessment period multiplied by the pump head x 100	Ph6=(D4/D1)*100	%
Ph7		Energy recovery	(Energy recovered by the use of turbines of reverse pumps during the assessment period / total energy consumption for pumping during the assessment period) x 100	Ph7=(D5/D1)*100	%
Op12	Electrical & signal transmission equipment inspection	Emergency power system inspection	[(Sum of the nominal power of the emergency power systems inspected during the assessment period x 365) / assessment period)] / total nominal power of the emergency power systems	Op12=[(D16*365)/H1]/C18	/ year
Op13		Signal transmission equipment inspection	[(Number of the signal transmission units inspected during the assessment period x 365) / assessment period)] / total number of signal transmission units	Op13=[(D17*365)/H1]/C19	/ year
Op14		Electrical switchgear equipment inspection	[(Number of electrical switchgear units inspected during the assessment period x 365) / assessment period)] / total number of electrical switchgear units	Op14=[(D18*365)/H1]/C20	/ year
Op21	Pumps rehabilitation	Pump refurbishment	[(Total nominal power of pumps subject to overhaul during the assessment period x 365) / assessment period)] / total nominal power of pumps] x 100	Op21=[(D25*365)/H1/C6]*100	% / year
Op22		Pump replacement	[(Total nominal power of pumps replaced during the assessment period x 365) / assessment period)] / total nominal power of pumps] x 100	Op22=[(D26*365)/H1/C6]*100	% / year
Op30	Failure	Pump failures	[(Sum, for all pumps, of the number of days during the assessment period when the pump is out of order x 365) / assessment period] / total number of pumps	Op30=[(D27*365)/H1]/C4	days / pump / year
Op34		Power failures	[(Sum, for all pumps, of the number of hours each pumping station is out of service due to power supply interruption during the assessment period x 365) / assessment period] / total number of pumping stations	Op34=[(D31*365)/H1]/C5	hours / pumping station / year
Fi10		Electrical energy costs	(Electrical energy costs / running costs) x 100, during the assessment period	Fi10=(G11/G5)*100	%

Initial status – pilot areas description

- ✓ DEYA Larisas (PP1) replaces 3 classic water pumps of networks supply system, with 3 inverter pumps and it is expected to reduce the electrical energy consumption of the pressure system of DEYAL and by extension the electrical energy cost. This action has to do with energy efficiency.
- ✓ DEYA Kozanis (PP3) pilot action regarding energy recovery will be the placement of 5 hydro-turbines at the entrance and the exit of tanks, that will work as a substitute of power supply of the metering equipment, in case of a power failure. This action has to do with energy recovery.
- ✓ Water Board of Nicosia (PP6) pilot action regarding energy recovery will be the installation of 5 hydro-turbines at inline sites next to water meters. A reduced cost of maintenance and travel for the replacement of the batteries as well as the time needed for the employee to go to that specific area, is expected. This action has to do with energy recovery.

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Ex-ante – PIs (2017 base year)

PI name	DEYAL	DEYAK*	WBN**
Energy recovery (%) (Ph7)	0,00%	0,00%	0,00%
Electrical energy costs (%) (Fi10)	15.34%	25,89%	-
Total energy consumption (kWh) (Ph25)	11.441.234	11.487.545	628.770
Standardized energy consumption (per 100 m geodetical height not pump head) (kWh/m3/100m) (Ph5_1)	-	-	-
Energy consumption for water pumping (kWh/m3) (Ph17_1)	0.68	0,73	0.20
Energy consumption from renewable resources (incl. own recovery) (%) (Ph23)	0,00%	0,00%	0,00%

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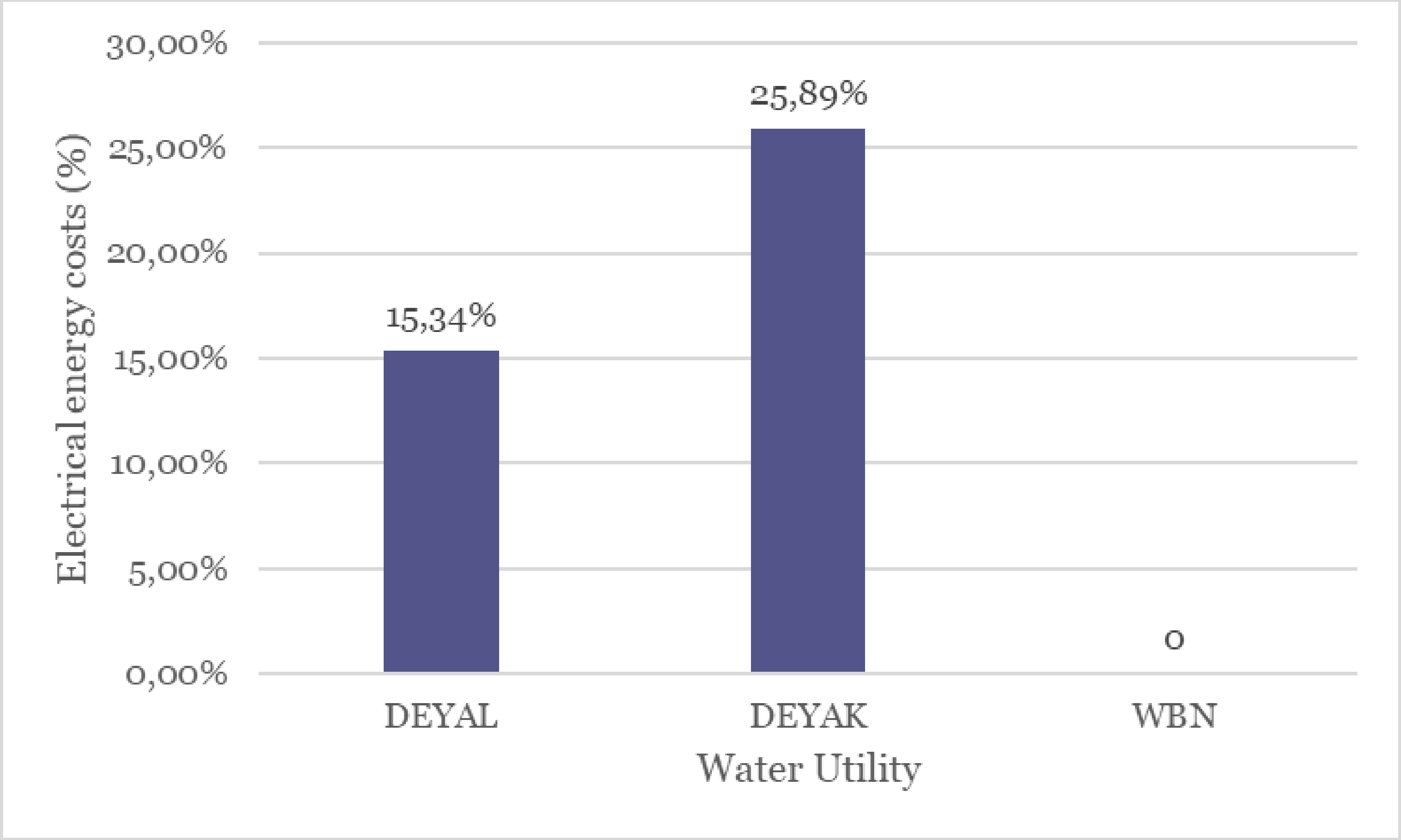
Ex-ante – PIs (2017 base year)

Electrical energy costs



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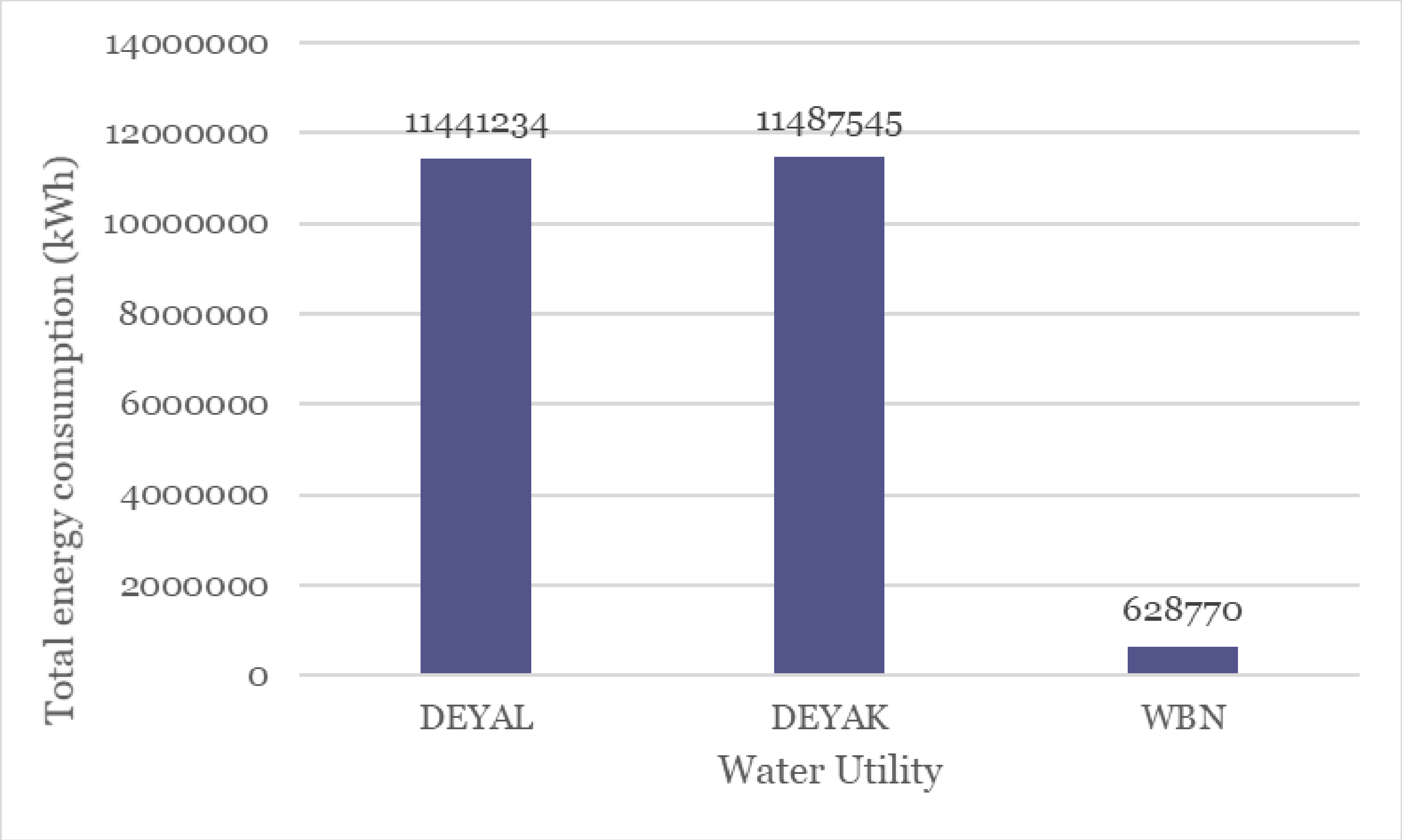
Ex-ante – PIs (2017 base year)
Total Energy consumption



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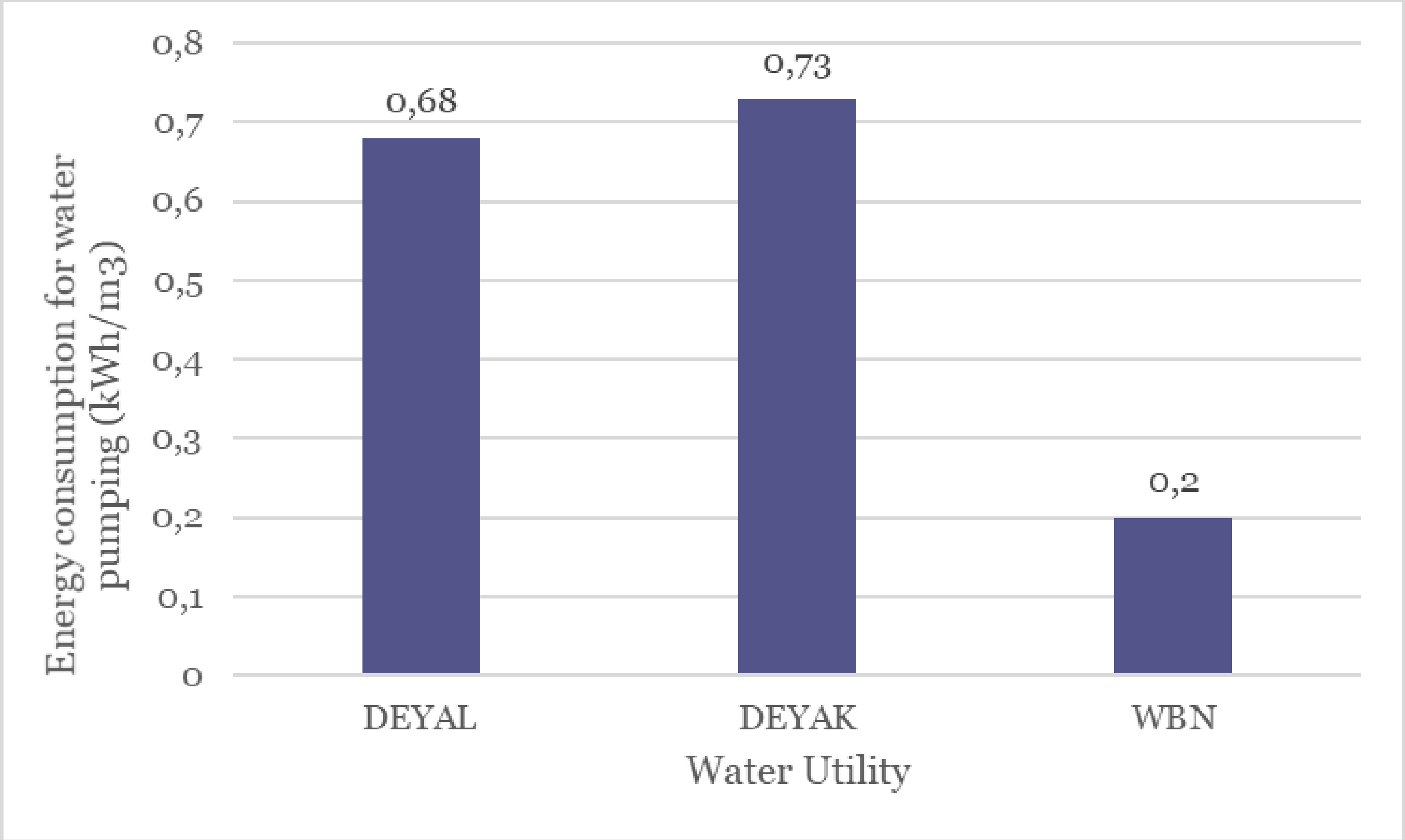
Ex-ante – PIs (2017 base year)

Energy consumption for water pumping



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