ICID 2015: IRRIGATION AND ENERGY

An analysis of energetic cost for an irrigation network in France

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PLAN

1. Presentation of Carpentras Canal
2. Problem Definition and Objective
3. State of the Art
4. Adopted Methodology
   - Data Collection
   - Data Analysis
     - ✓ Demand Evolution
     - ✓ Network Performance
     - ✓ Contracts with the Electricity Supplier
5. Conclusion

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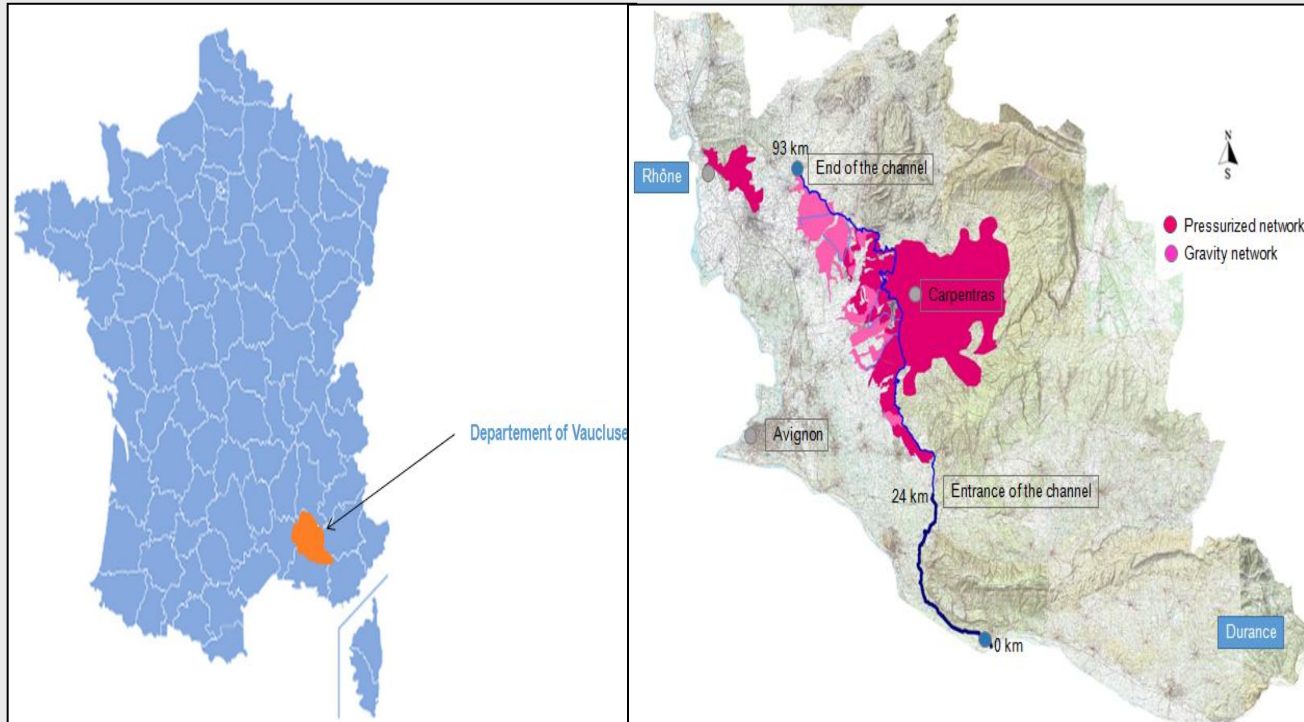
Presentation of Carpentras Canal



a: France Map

b: Vaucluse Department

Figure 1. The considered area

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Presentation of Carpentras Canal

- Mediterranean climate : hot, dry summers and mild, wet winters
- Source of water : the Durance dam and the Rhone river
- Length of main canal : 69 km
- Installation of the **ASA** of Carpentras canal and implementation of an irrigation gravity system: 1853
- Implementation of a pressurized irrigation network : 1975
- Irrigable area: 12000 hectares
- Number of members: 14000
- Irrigation practices: vineyards, olive trees , fruit trees, etc.
- Number of pumping stations : 34
- Number of storage tanks : 24
- Length of the underground piping: 1000 Km

ASA: **A**ssociation **S**yndical **A**uthorized

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Problem Definition and Objective

Problem Definition

- Increased energy costs of pumping from 2008
- Network performance decrease

Objective

- Decrease of the energy bill (pumping cost)

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State of the art

The subject of the minimization of the cost of pumping has attracted the interest of several authors:

- Definition of number of pumps according the global operating time [1]
- Choice of pumps according the speed (fixed, variable) [2]
- Fault diagnosis (detection and location of water leaks) [3]
- Indicators that evaluate the energy consumption of a water supply system [4]

[1] Moreno et al. « Development of a new methodology to obtain the characteristic pump curves that minimize the total cost at pumping stations », Journal of Biosystems Engineering vol 102(1): 95-105, 2009.

[2] Lamaddalena et al. «Energy saving for a pumping station serving an on-demand irrigation system: a study case», Journal of Water saving in Mediterranean agriculture and future research needs, vol 1 (56): p. 367-379, 2007.

[3] M.A. Jiménez-Belloa, et al. « Methodology to improve water and energy use by proper irrigation scheduling in pressurized networks », Journal of Agricultural Water Management, vol 149 (0): 91-101, 2015.

[4] Hitz HU, Pelli T. « Energy indicators and savings in water supply », Journal of the American Water Works Association, vol 92(6): 55–62, 2000.

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Methodology: Data Analysis

- Available Data
  - ✓ Demand
  - ✓ Electricity consumption
  - ✓ The farm units
  - ✓ The network structure

- Analysis
  - ✓ Demand Evolution
  - ✓ Water volume
  - ✓ Electricity suppliers' billing

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Available Data

- Demand (Number of members, Terminals watering, Irrigable area, Water volume pumped and billed)

- Energy consumption (detailed electricity consumption , detailed bills , contracts options of electricity suppliers, etc.)

- Units (pumps, piping, storage tanks, etc.)
  - ✓ Pumps (power, flow, HMT)
  - ✓ Pipe (diameter, length, type of material)
  - ✓ Storage tanks (capacity, height, form)

- Network structure : mesh, geographical position of members

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Analysis : Demand Evolution

Evolution of irrigable area and terminals watering

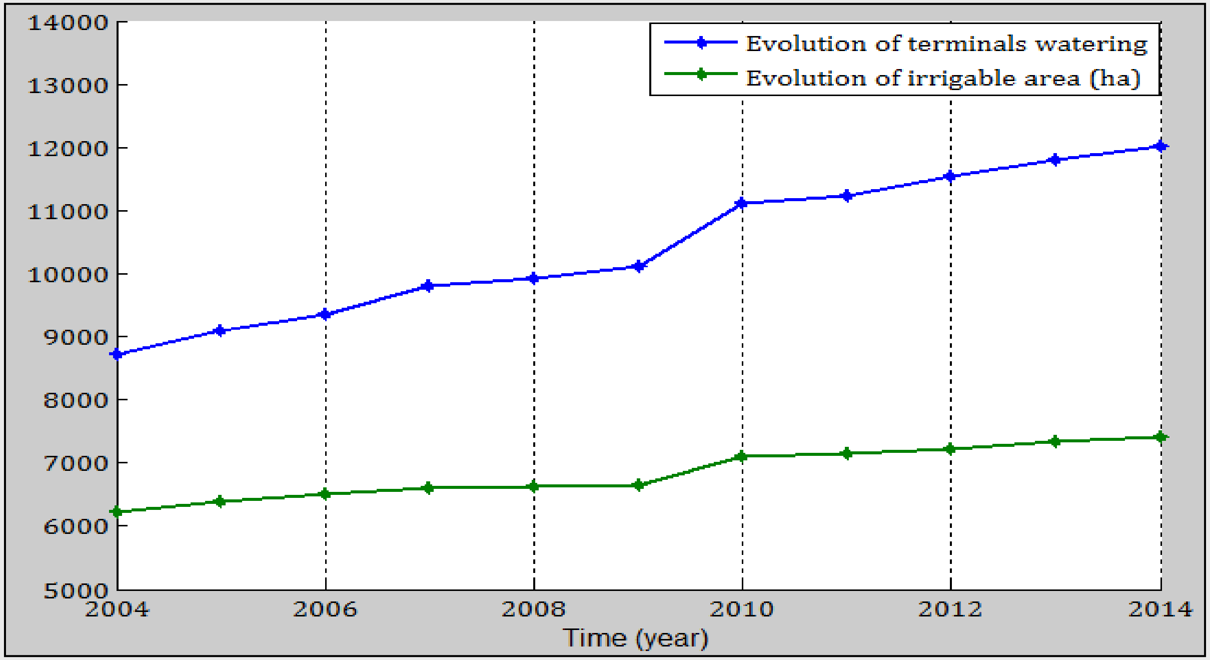

Figure 2. Demand evolution in the pressurized irrigation network of Carpentras

Note: Constant evolution with an annual average of 2% for the irrigable area (120 ha) and 3.3% for terminals (329) .

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Analysis : Demand Evolution

Evolution of volume of water in the total network

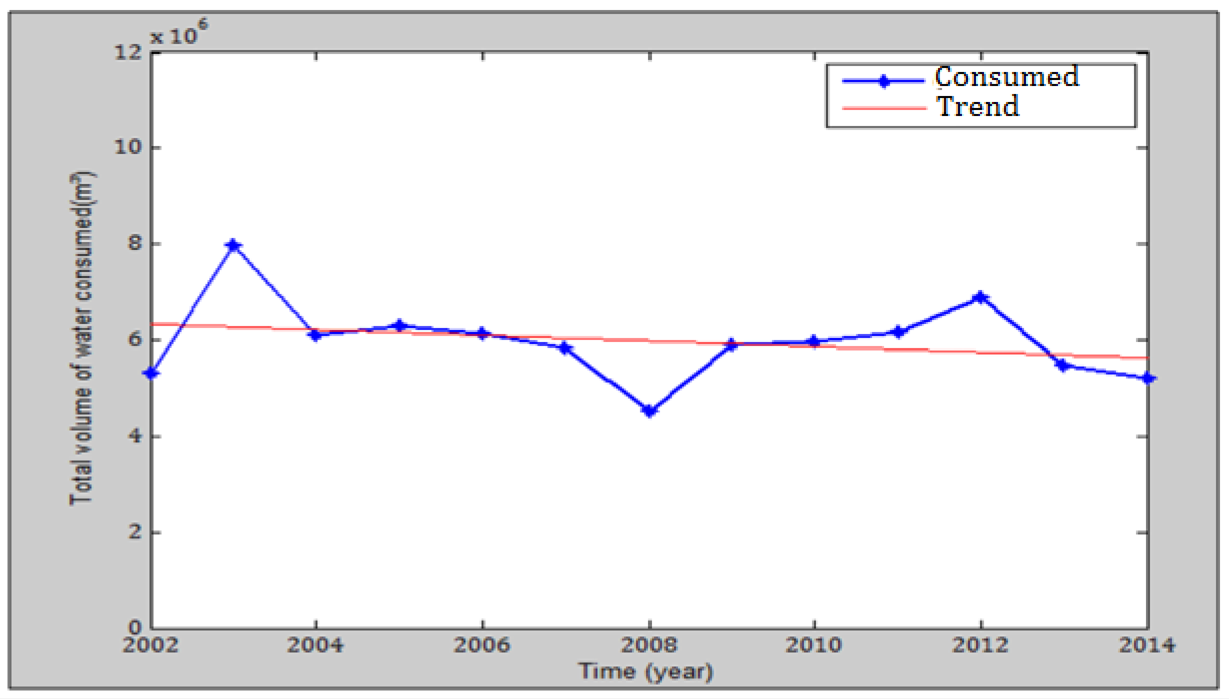

Figure 3. Evolution of volume of water consumed (m^3) in the total network

Notes:

- ✓ Constant evolution with a slight decrease in the last years
- ✓ High consumption in 2003 and 2012 (hot and very dry years)
- ✓ Low consumption in 2008 (very wet year)

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Analysis: Water Volume

Technical for Estimation

The pumped volume of water is based on the constant flow rate (Q) and the operating time of pump (T):

$$V_p = Q * T$$

If T is unknown, it will be estimated by the ratio between the energy consumption (E) and the rated power (P) of pump [5]:

$$V_p = Q * \frac{E}{P}$$

[5] J.-P. Luc et all. « Performance indicators of irrigation pumping stations: application to drill holes of minor irrigated areas in the Kairouan plains (Tunisia) and impact of malfunction on the price of water », Journal of Irrigation and Drainage, vol. 55, no 1, p. 85-98, 2006.

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Analysis: Water Volume

Example for Validation

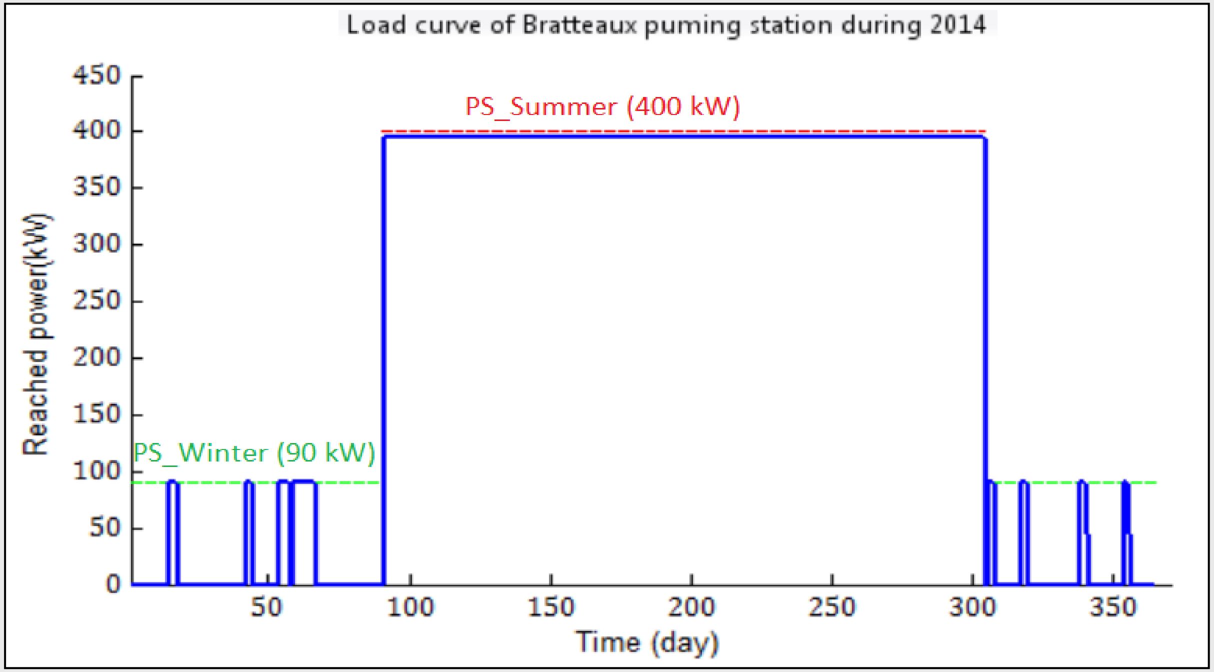

Figure 4. Load curve of « Brotteaux » pumping station during 2014

Analysis: Water Volume

Example for Validation

Seasons 2014	Winter	Summer
Pumps in operation	1 Pump	2 Pumps(mode alternate)
Rated power (P in kW)	90	400
Flow rate (Q in m^3)	360	1000
Energy consumption (E in kWh)	21 220	275 281
Volume estimated (V in m^3)	84 880	688 202

Table1. Data from a station equipped with a flow meter « Brotteaux »

Notes:

✓ The pumped volume of water registered by a flow meter is $\mathbf{75.10^{4}}$ m^3 in 2014.
✓ The estimated volume of water is $\mathbf{77.10^{4}}$ m^3 in 2014.

Result : There is a 3 % difference between the volume of water pumped and estimated

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Analysis: Water Volume

Case study: Grande Bastide pumping station

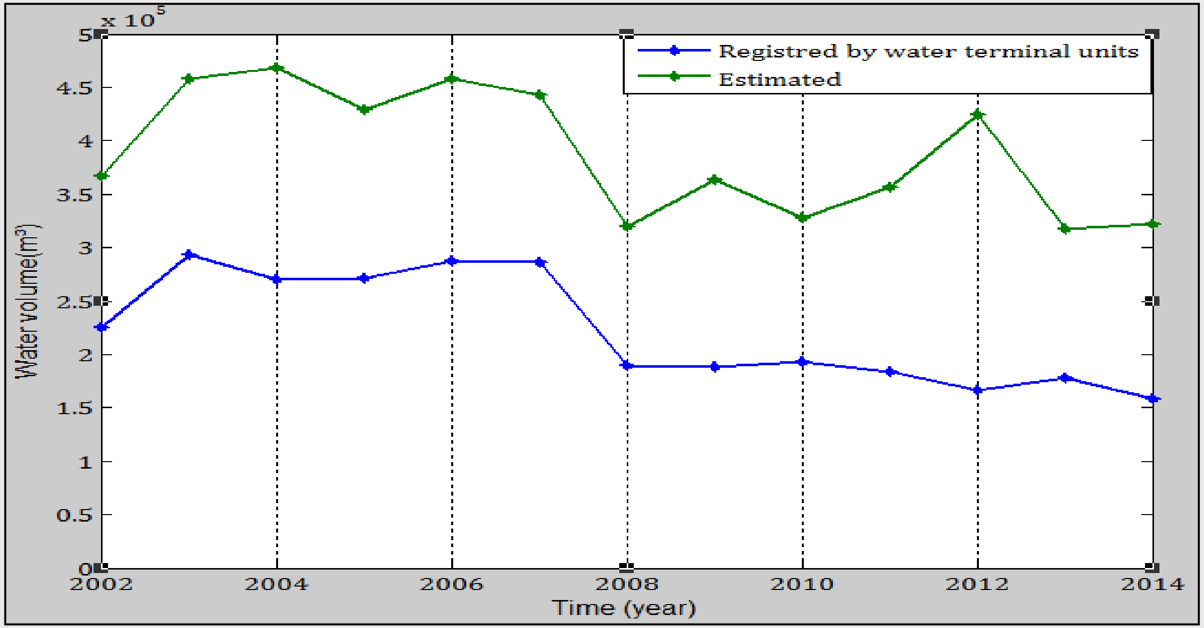

Figure 5. Evolution of the water volume registered an estimated « Grande Bastide »

Result : 57% of the water volume is pumped but not billed
Possible Causes : leaks , lack or dysfunction of water meters

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Analysis : Energy Bill

Evolution of the energy bill

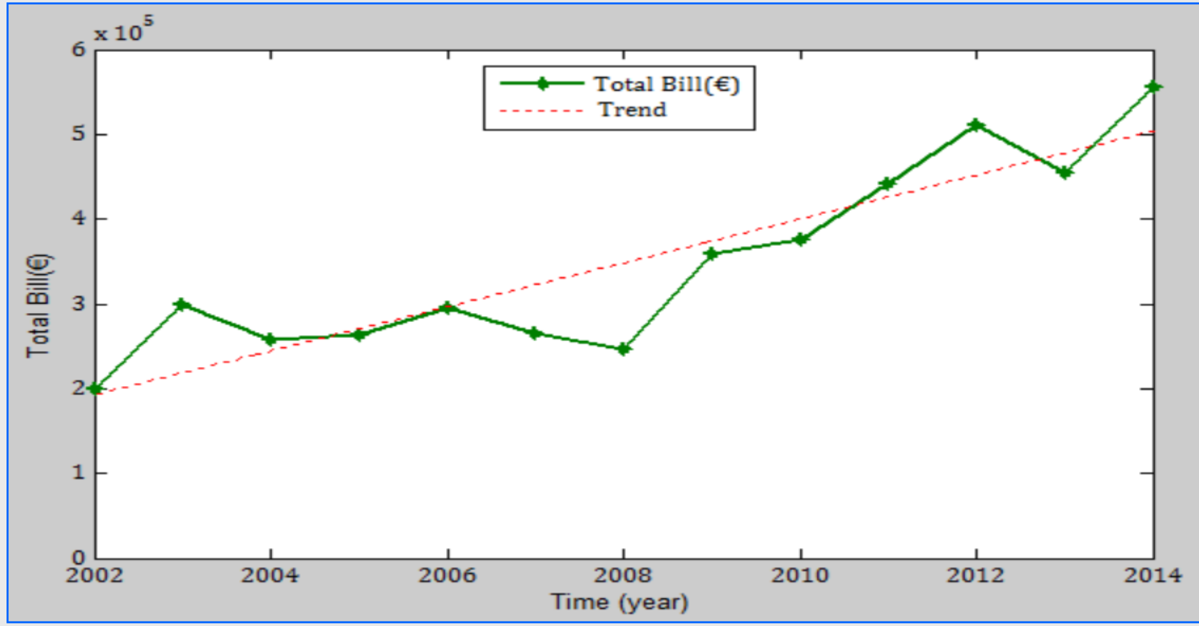

Figure 6. Evolution of the energy bill (€)

Notes:

From 2002 to 2008: constant evolution of the bill (the average cost of a kWh with taxes is 0.037 €)

From 2009 to 2014: significant increase in bill (the average cost of a kWh with taxes is 0.067 €)

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Analysis : Energy Bill

Evolution of the consumed energy

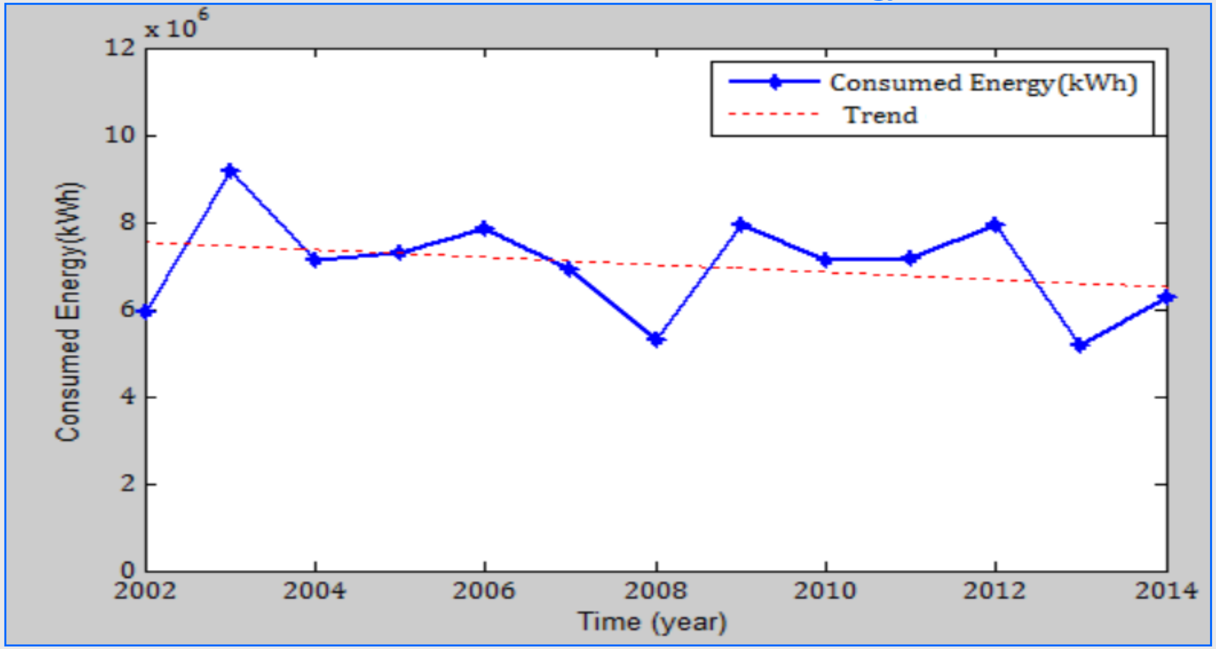

Figure 7. Evolution of the energy consumed (kWh)

Notes:

- ✓ Constant evolution with a slight decrease in the last years
- ✓ High consumption during 2003 and 2012 (hot and very dry years)
- ✓ Low consumption during the wet year 2008 (same trend as the volume of water)
- ✓ The evolution of the bill does not follow the evolution consummation from 2008

Analysis : Energy Bill

Evolution of the cost of kWh in ASA (France)

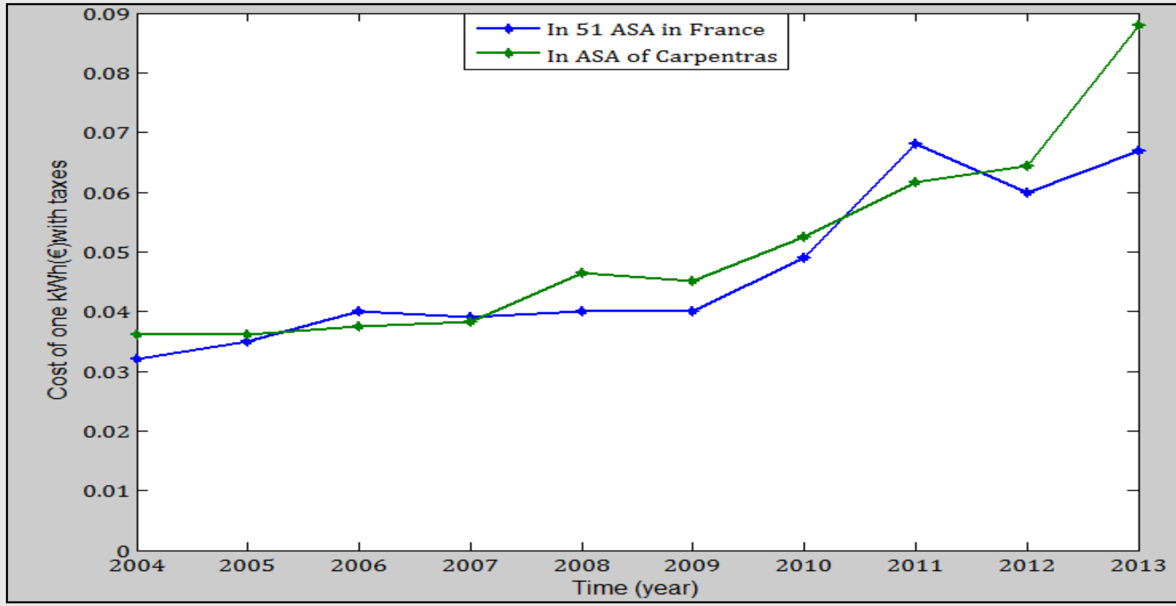

Figure 8. Evolution of the cost per kWh in ASA

Notes:

- ✓ The cost of one kWh increased with a significant way in ASA
- ✓ The cost of one kWh in Carpentras is above the average of others ASA

[6] Source CACG (Development Company for Gascogne): data collected from 51 collective irrigation structures in France

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Analysis : Energy Bill

Electricity billing in France

✓ Many kinds of contracts: $t_c \in T_c = \{Blue, Yellow, Green\}$

✓ Many tariff versions: $v_t \in V_t(t_c) = \{SU, MU, LU, VLT\}$

SU : Short Utilization
MU : Medium Utilization
LU : Long Utilization
VLU : Very Long Utilization

✓ Many tariff periods: $i \in I(t_c) = \{1, 2, 3, 4, 5 \ldots\}$

1 : Rush Hours
2 : Winter Peak Hours
3 : Winter Off-Peak Hours
4 :Summer Peak Hours
5 : Summer Off-Peak Hours
...

Analysis : Energy Bill

Electricity billing in France

✓ Power subscribed by a tariff period: $p_i \in P_i(t_c) = \{p_1, p_2, p_3, p_4, p_5, \ldots\}$

✓ Coefficient of reduced power: $k \in K\,(t_c\,, i\,, v_t)$

✓ The total bill is composed by a fixed prime, cost of consumed energy, cost of exceeded power and taxes:

$$B_t = P_f\,(t_c, p_s, v_t) + C_E\,(t_c, E, v_t) + C_d(t_c, p_s, p_c) + \text{Taxes}$$

In 2014: $B_t = 23\% + 43\% + 10\% + 24\%$

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Analysis : Energy Bill

Hypothesis

- ✓ Fixed kinds of contract (Green for example): $t_c = t_c{}^{\circ}$
- ✓ Subscribed power fixed: $p_i = p_i{}^{\circ} = \{p_1, p_2, p_3, p_4, p_5\}$
- ✓ Fixed prime: $P_f = C^{v_t} . [P_1 + \sum_{i=2}^{I} k_i^{v_t} . (P_i - P_{(i-1)})]$
- ✓ Cost of consumed energy : $C_E = \sum_{i=1}^{I} E_i . C_i^{v_t}$

$$B_t = C^{v_t} . \left[P_1 + \sum_{i=2}^{I} k_i^{v_t} . (P_i - P_{(i-1)}) \right] + \sum_{i=1}^{I} E_i . C_i^{v_t} + C_d(\mathbf{t_c}^{\circ}, \mathbf{p_s}^{\circ}, \mathbf{p_c}) + \text{Taxes}^{\circ}$$

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Analysis : Result

Simulation of the different tariff versions

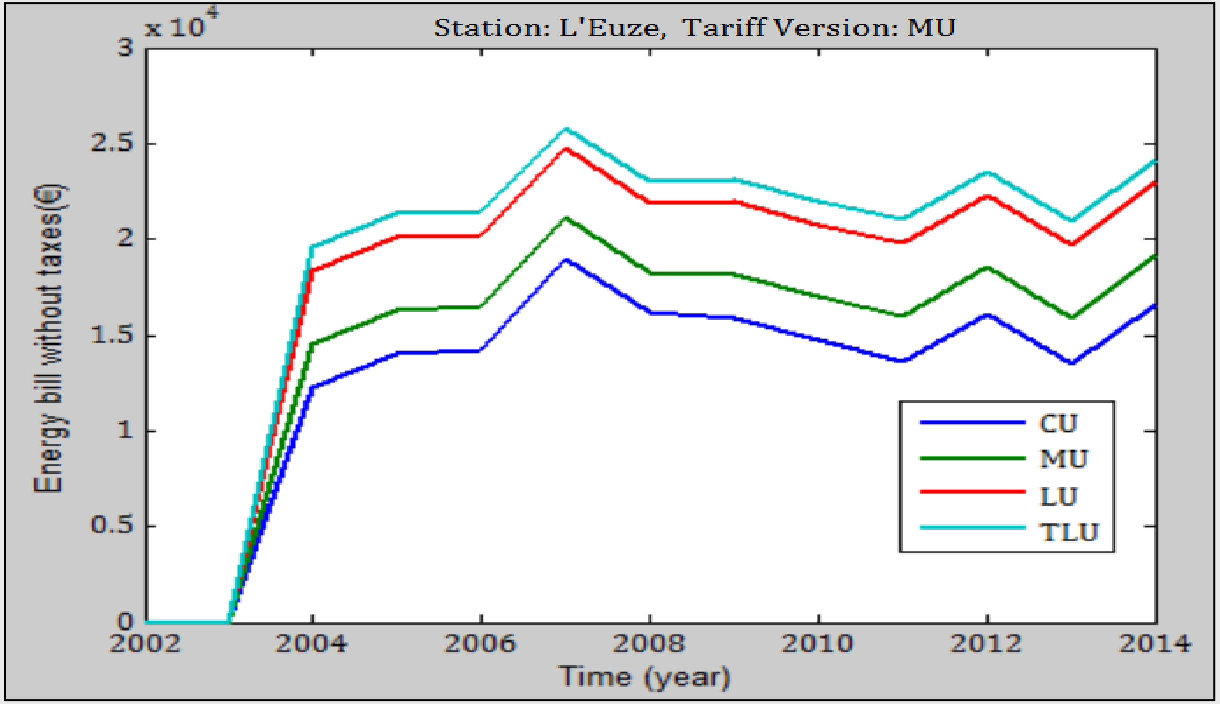

Figure 9. Simulation of tariff versions in « L'EUZE » pumping station

Result: In this station, an optimal choice of the tariff Version (SU) may reduce the total bill about 16% between 2004 and 2014

Conclusion

- Analysis of energy costs and network performance
- Optimization of contracts: tariff versions and subscribed power
- Expand network performance evaluation on all stations
- Control and monitoring of pumping station [7]
- Installation of hybrid systems for the production of renewable energy [8]

[7] Tang, Y et al. "Optimal control approaches of pumping stations to achieve energy efficiency and load shifting ". International Journal of Electrical Power & Energy Systems 55(0): 572-580, 2014

[8] Atul Kumar et al. " Renewable energy technologies for irrigation water pumping in India: A preliminary attempt towards potential estimation". Journal of Energy 32 : 861–870,2007

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