Water Energy
Enerwat
Nexus

From water to energy

Characterization, modelling and measures for the reduction of urban and rural household consumption





WATERS: A system architecture for acquire dwellings water & energy consumptions

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Summary

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   - State-of-the-art
   - Objective
2. The WATERS system
   - System architecture
   - Implementation
   - Cost
3. Results
4. Conclusion

1 Motivation

- The problem
  - It is well known that water consumption is correlated with energy consumption and therefore contributes to emissions of GHG and CO_2 emissions.
  - It is crucial to optimize the inter-relationship between energy and water to minimize consumptions.

- Contribution
  - A low cost system architecture and implementation solution to acquire water and related energy data with high detail and for long periods.

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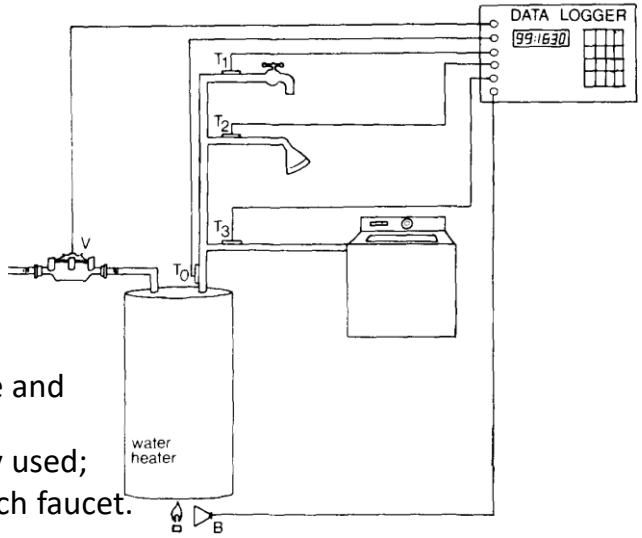
1 State-of-the-art approaches

Initially

- Studies on water and associated energy consumption
  - obtained separately, using surveys, manual readouts and extrapolation from water and energy bills.

Recently

- Automatic systems emerge
  - Willet Kempton [1985,1988]:
    - Period: 7 to 18 months
    - Cases Studied: 7 dwellings
    - Measure:
      - Volume of water and temperature at entrance and exit of the water heater;
      - water heater quantity of gas and/or electricity used;
      - the hot water temperature at the outlet of each faucet.
    - Method:
      - programmable microprocessor-controlled field instrument (**Flow: at least 0.1 liter per minute; Period: 1 minute**);
      - also surveys;
      - Water event.
    - Difficulties:
      - **Costs** and the intrusion levels of the instrumentation;
      - Obtaining the volume of water in each faucet (cost of volume meters).



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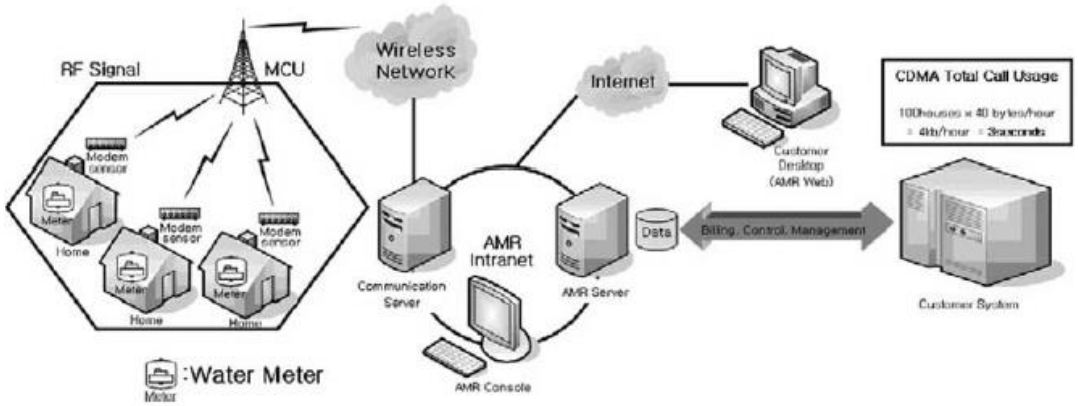
1 State-of-the-art approaches: Automatic systems

- **Sanghyun Kim et al.**[2006] :
  - Period: December 2002 and February 2006
  - Cases Studied: 145 houses
  - Measure:
    - Data from a **public water management company**;
    - Volume of water and temperature at entrance and exit of the water heater;
    - water heater quantity of gas and/or electricity used;
    - the hot water temperature at the outlet of each faucet.
  - Method:
    - Statistical methods of trend analysis (Mann-Kendall test and Spearman's Rho test) and through surveys;
    - The water consumption was monitored by electric flow meters installed at the end of all the household water taps, using the principle of the fluid oscillator. The acquisition of data was done using a wireless network with a server attached to it.
  - Difficulties:
    - Errors associated with equipment failures, system communication errors and unexpected noise.



1 State-of-the-art approaches: Automatic systems

- **Amanda N. Binks et al** [2016]:
  - Period: April 2012 until March 2013
  - Cases Studied: 7 dwellings
    (5 in Melbourne and 2 in Brisbane)
  - Measure:
    - Volume of water and temperature at entrance and exit of the water heater;
    - water heater quantity of gas and/or electricity used;
    - the hot water temperature at the outlet of each faucet.
  - Method:
    - Data was acquired through home audits, interviews, high-resolution water flow meters that recorded frequency, duration and volume of individual water end uses, with detailed flow data (15 second interval, 0.01l resolution), and detailed shower use data monitoring.
  - Difficulties:
    - Errors associated with equipment failures, system communication errors and unexpected noise.

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1 Objective

To measure the water and related energy consumption

- Main requisites
  - Consumptions reads of water and related energy should be done with high-resolution
    - water/ gas: 0.5 liter, electricity 0.5 Watt, at least at 1Hz) and
    - By each use
  - System should be robust,
    - easy to maintain, have a simple solution for installation and posterior removal, involve as small as possible changes in the infrastructure of the dwelling and minimal impact in households daily life;
  - Use low cost devices;
  - Scalable solution (up to 20 installations);
  - Permits long periods of acquisition (at least 6 month);
  - All acquired data should be centralized in a main system
    - for later validation and usage in a consumption simulator.

2 The WATERS system

- How to do it?

In

Out

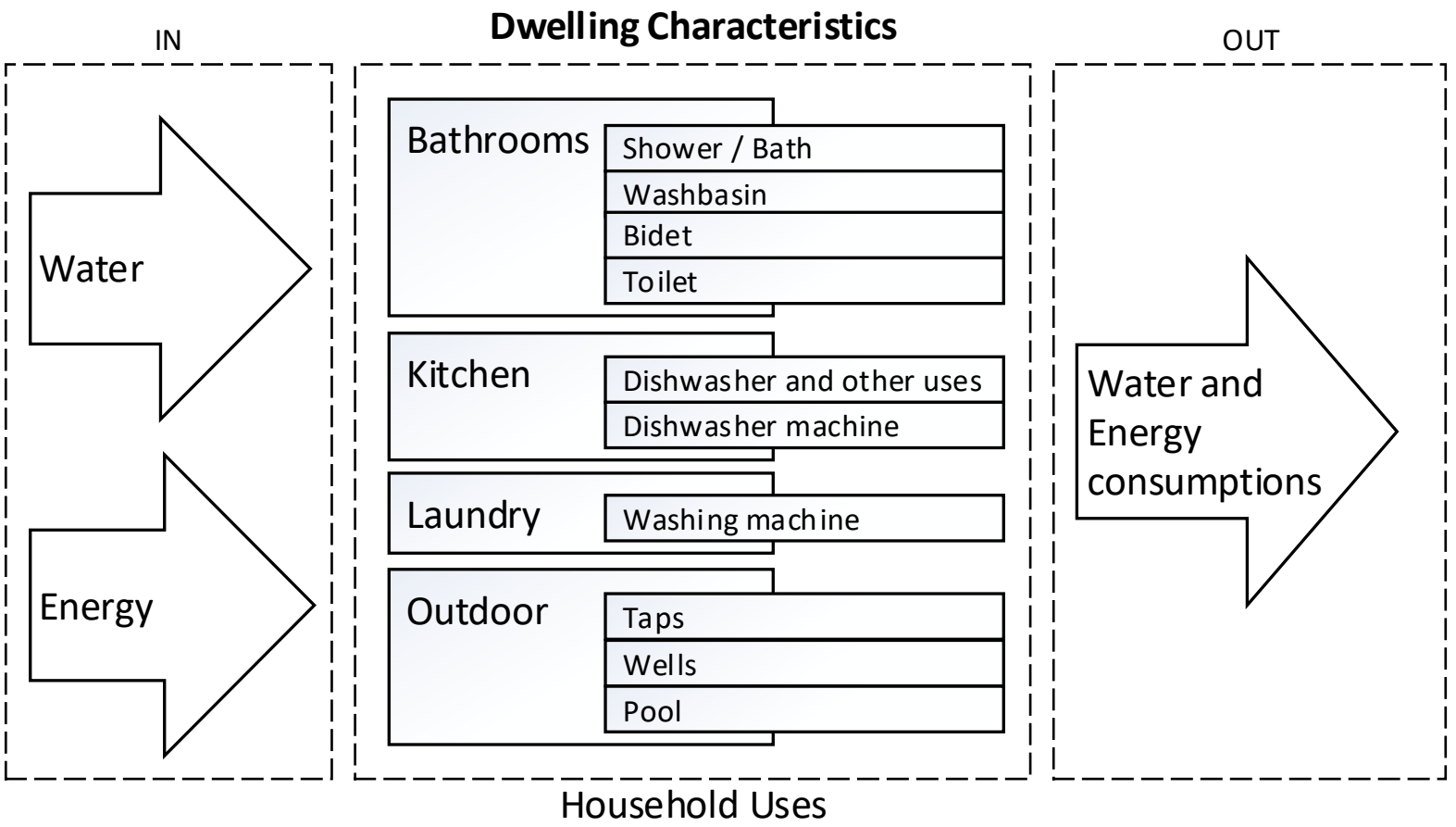
Water

Gas
Electricity
Diesel fuel
Firewood
…

?

2 The WATERS system

- Model of water and energy uses in a dwelling



Where to intervene?

- Simple water consumption points
  - Faucets

- Points of consumption of water and energy
  - Machines: Dishwasher, Clothes washer
  - Heaters, boilers, cylinders, ...

- Domestic water and energy sources
  - Counters: Water, electricity, gas, etc..
  - Water bombs

What to measure?

- Simple water consumption points
  - Register: Faucets On/Off time stamp
  - Learn: Average flows





What to measure?

- Points of consumption of water and energy
  - Register: device On/Off time stamp
  - Learn: consumption signatures
  - Use: manufacturer datasheet

What to measure?

Domestic water and energy sources

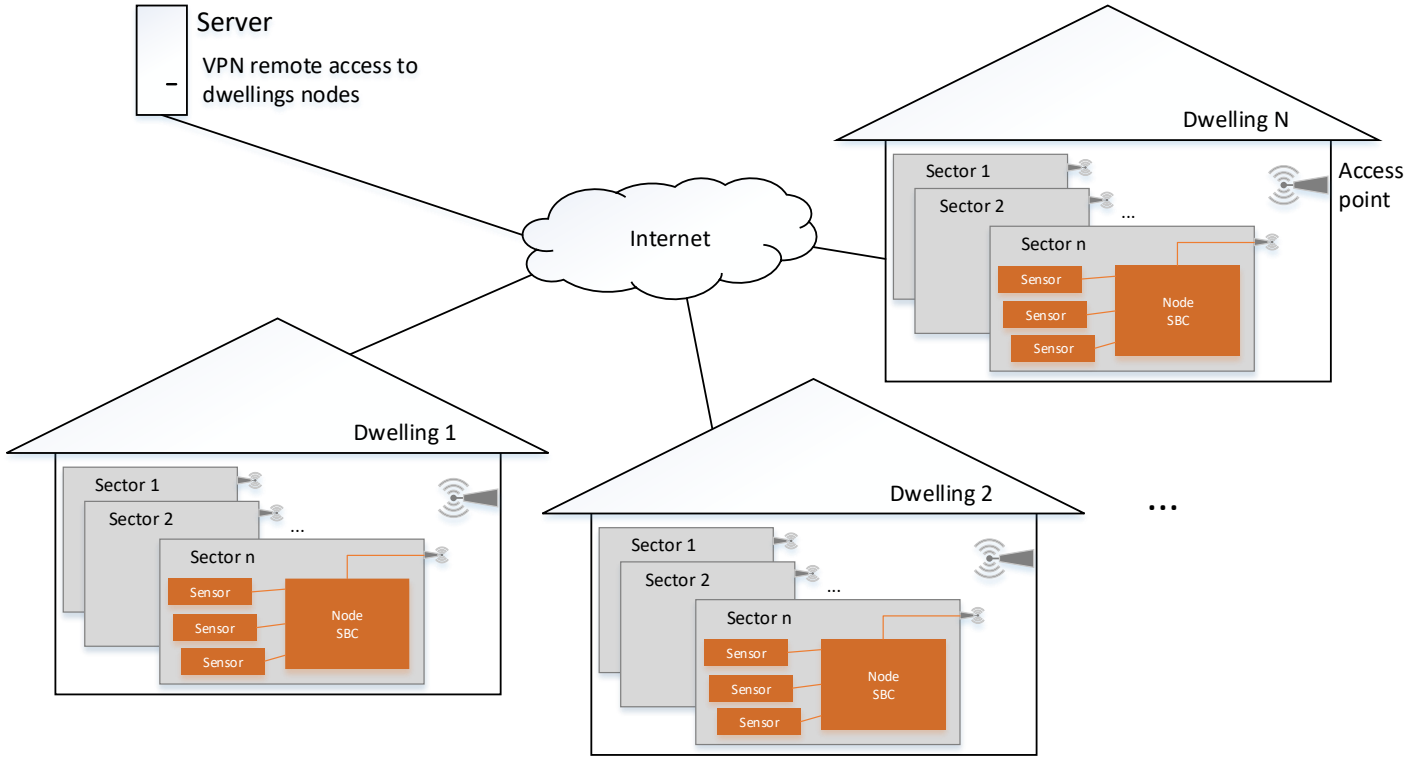
Counters

– Register: timestamp reads

Water pumps

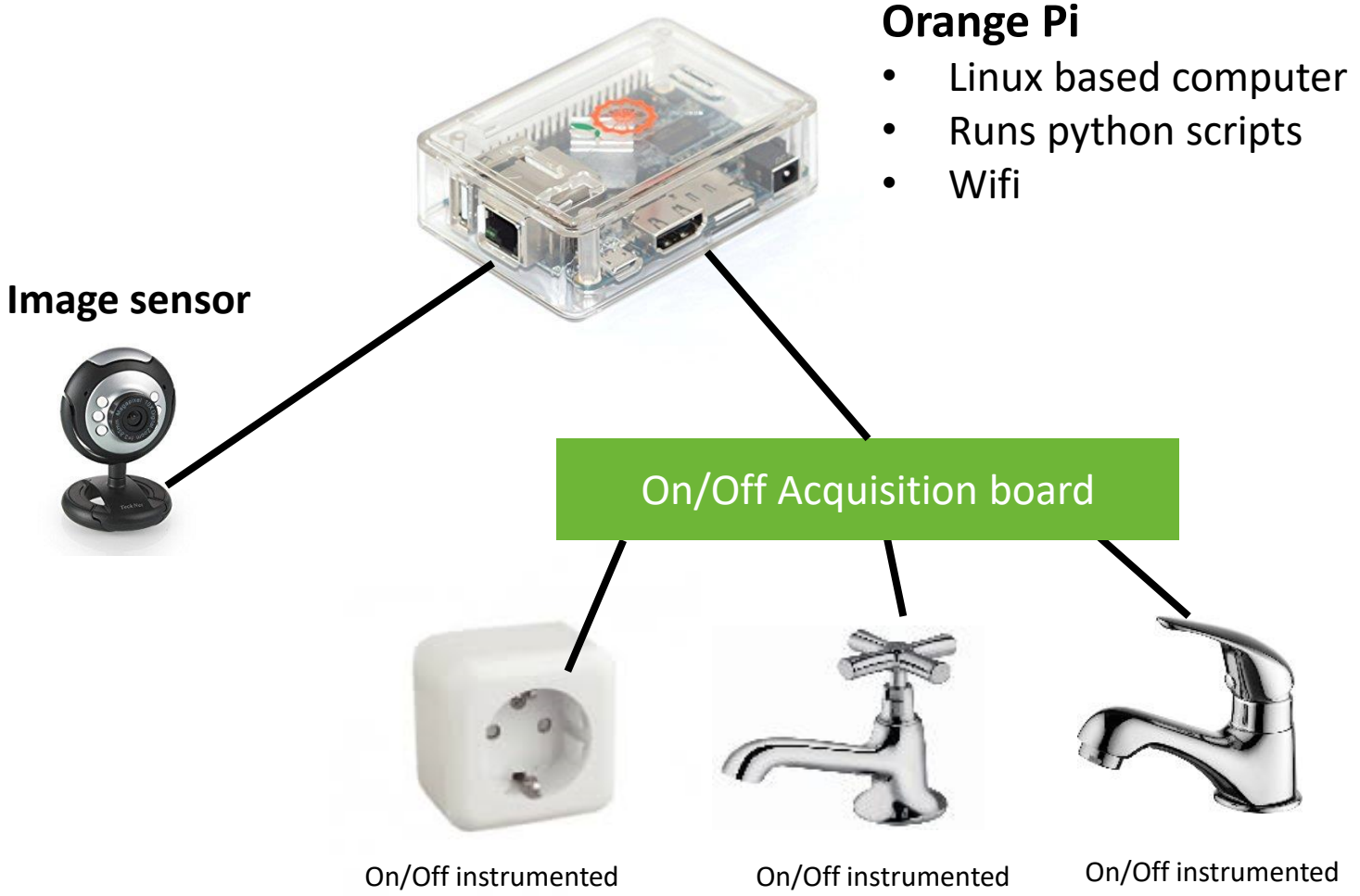
– Register: device On/Off
time stamp

- System architecture



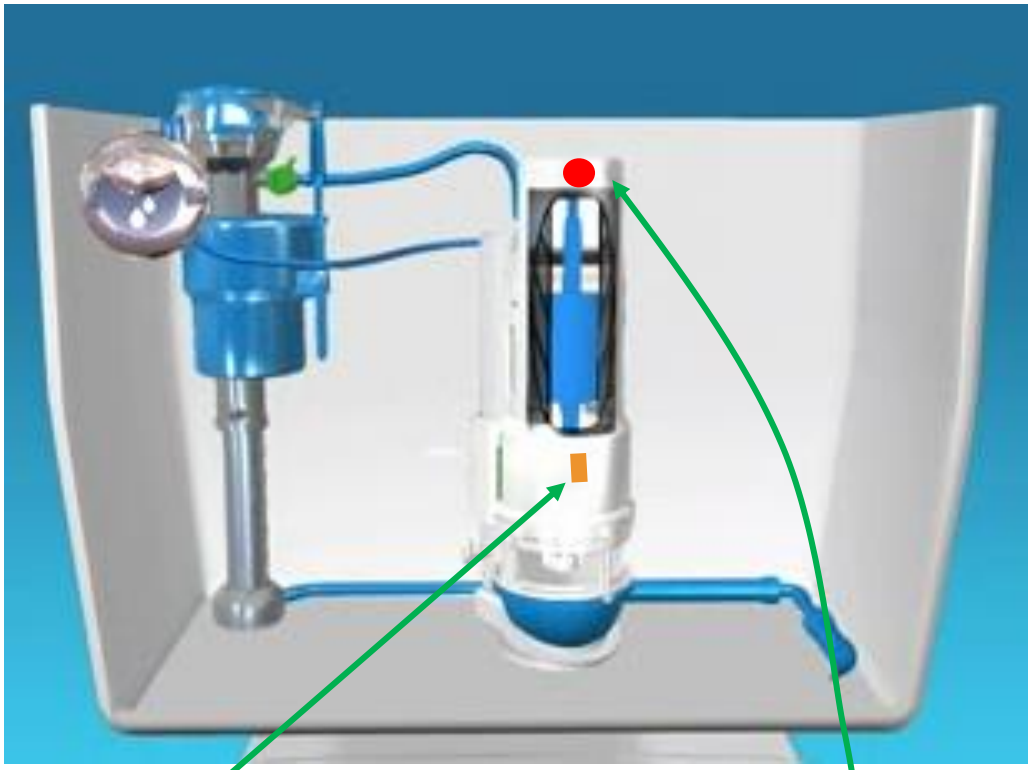
2 The WATERS system

- **Nodes:** Single board computer acquisition system

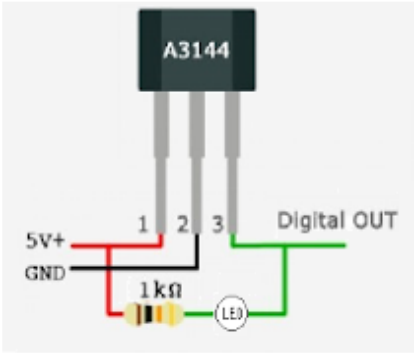


2 Implementation

- **Toilet flushing** On/Off sensor



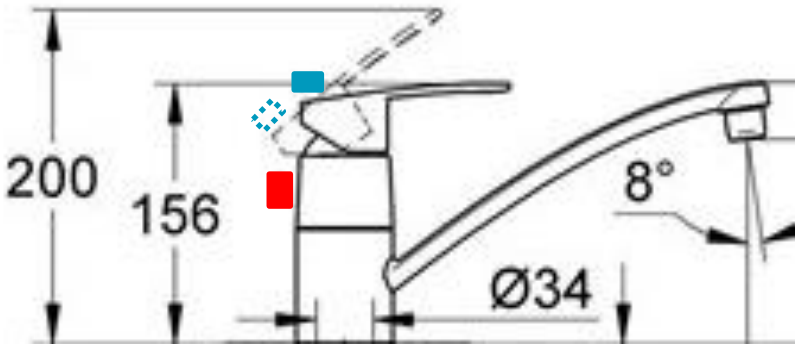
Hall sensor



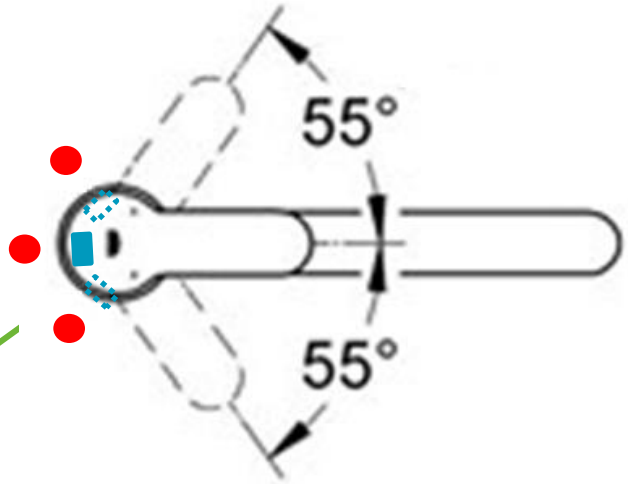
Sensor

2 Implementation

- Faucets mix
  - **On / Off**



  - **Position**
    - Left
    - Center
    - Right



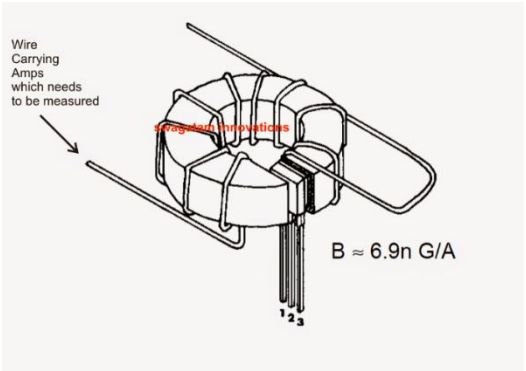
3x magnetic sensors

Magnet

Sensor

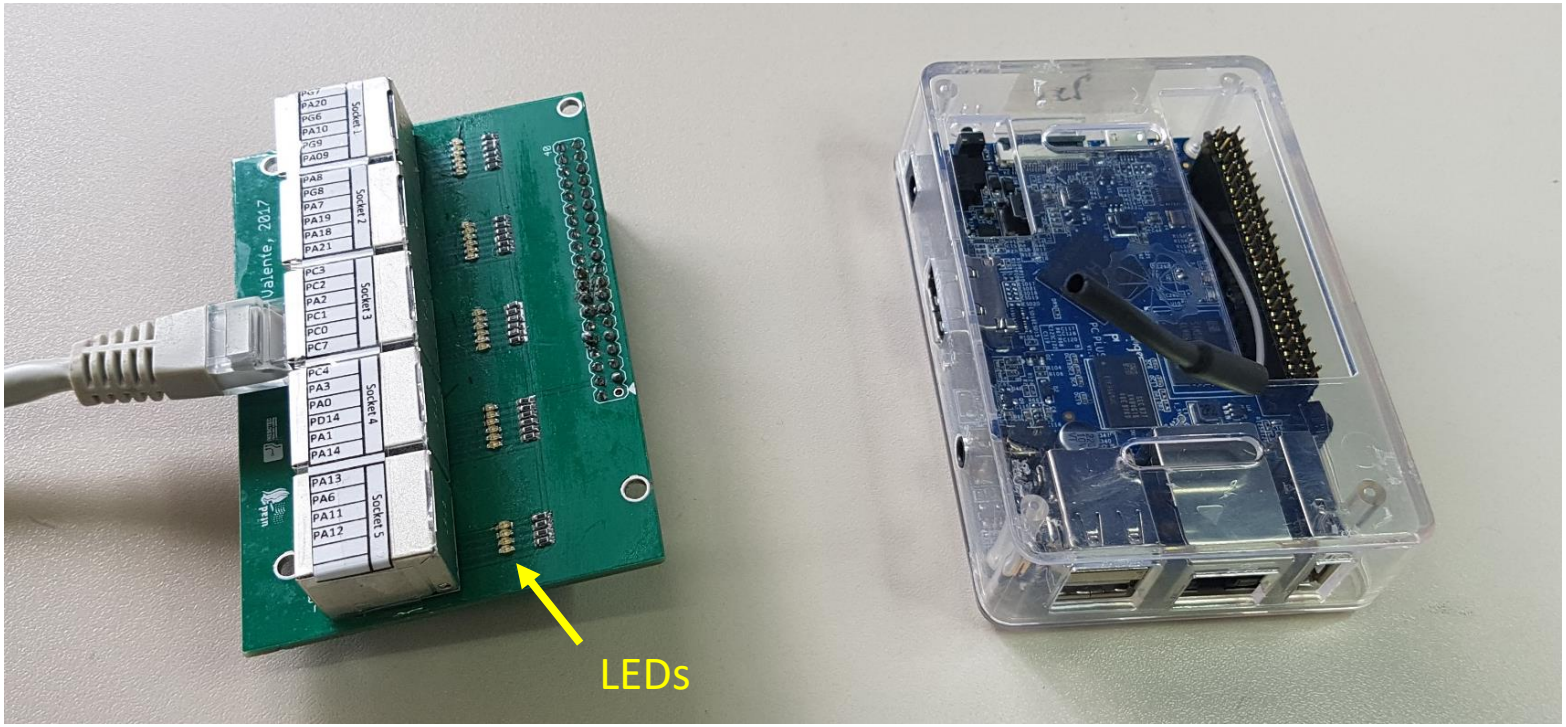
2 Implementation

- Clothes Machine / Dishwasher sensor
  - 220V ON/OFF sensor

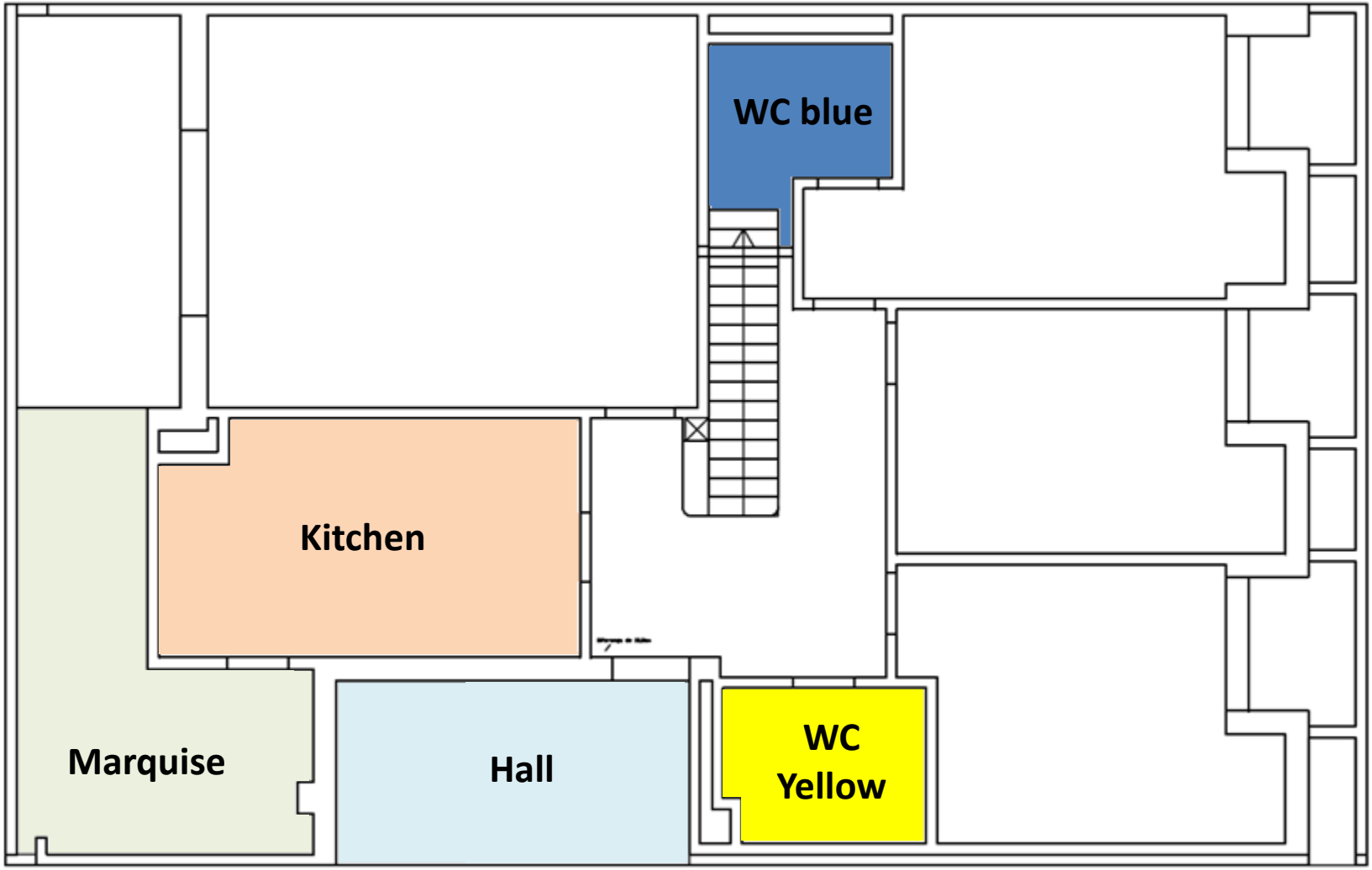


2 Implementation

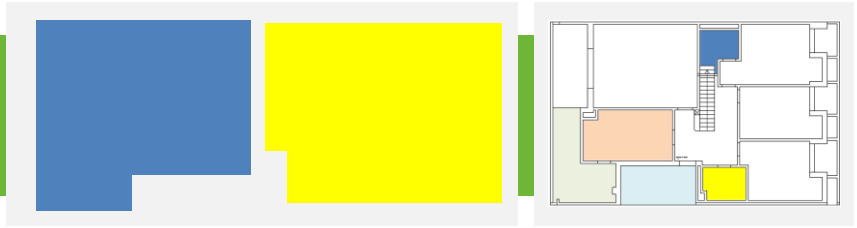
- **Nodes:** On/off sensor interface



2 Case study dwelling - Urban T3



2 Sectors: Bath rooms



- Instrumentation





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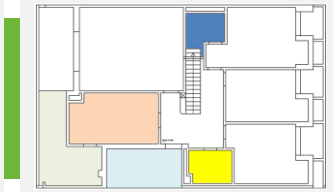
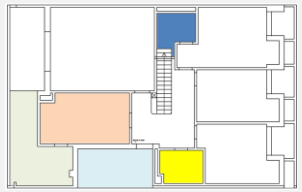
2 Kitchen



- Instrumentation

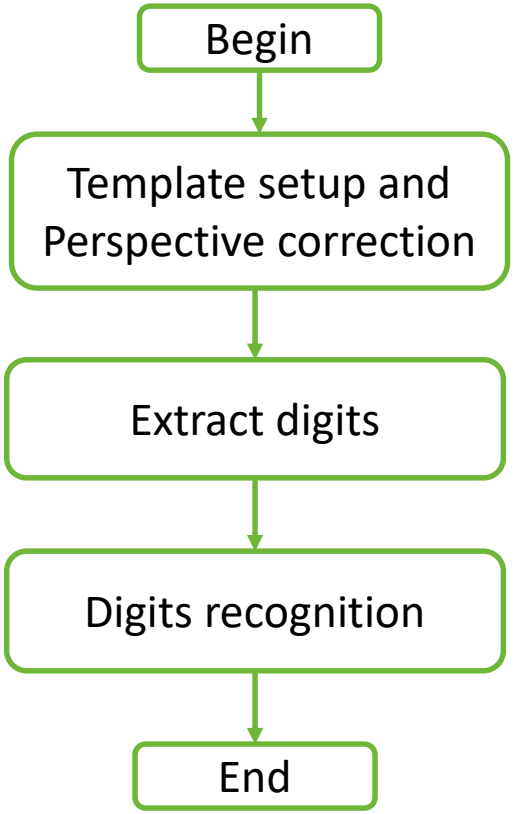
2 Sector: Hall



- Instrumentation

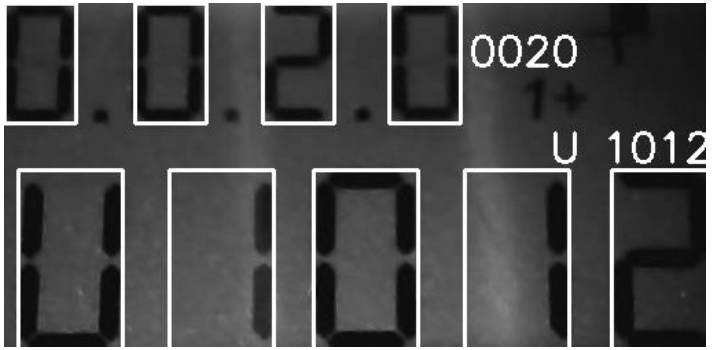
2 Counters Reading - 7 segments digit recognition

- Digital digits counter

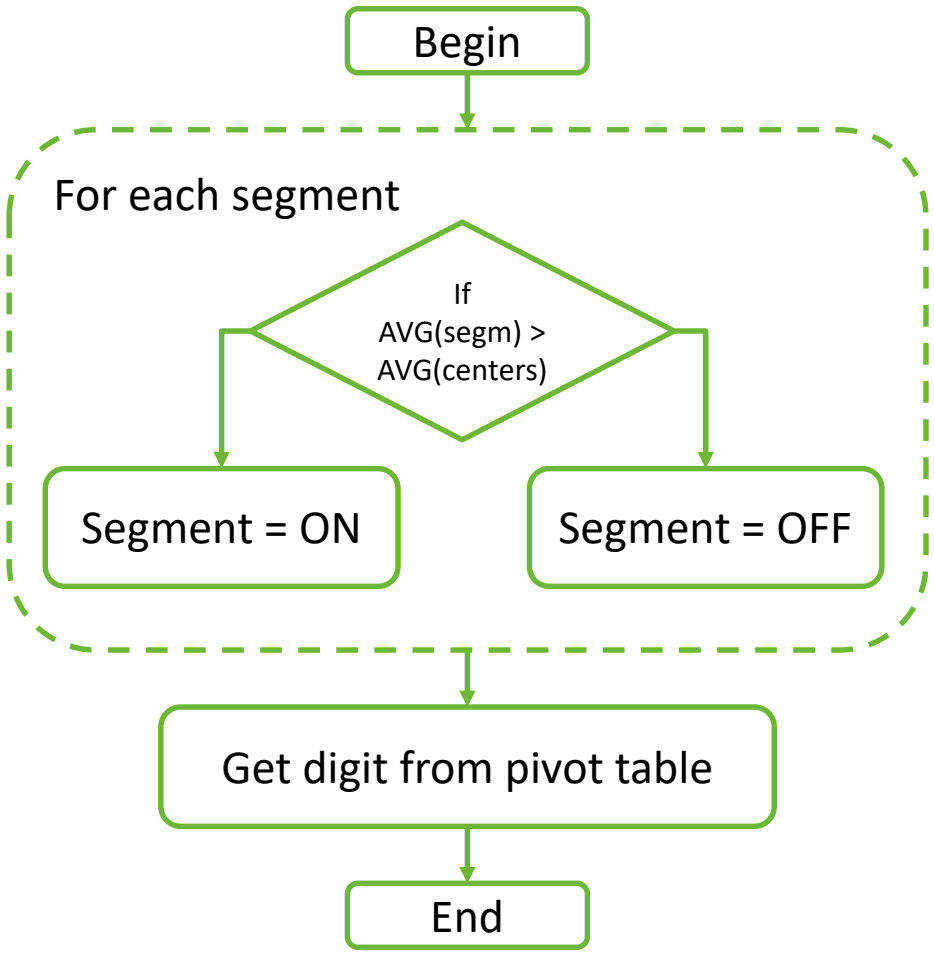


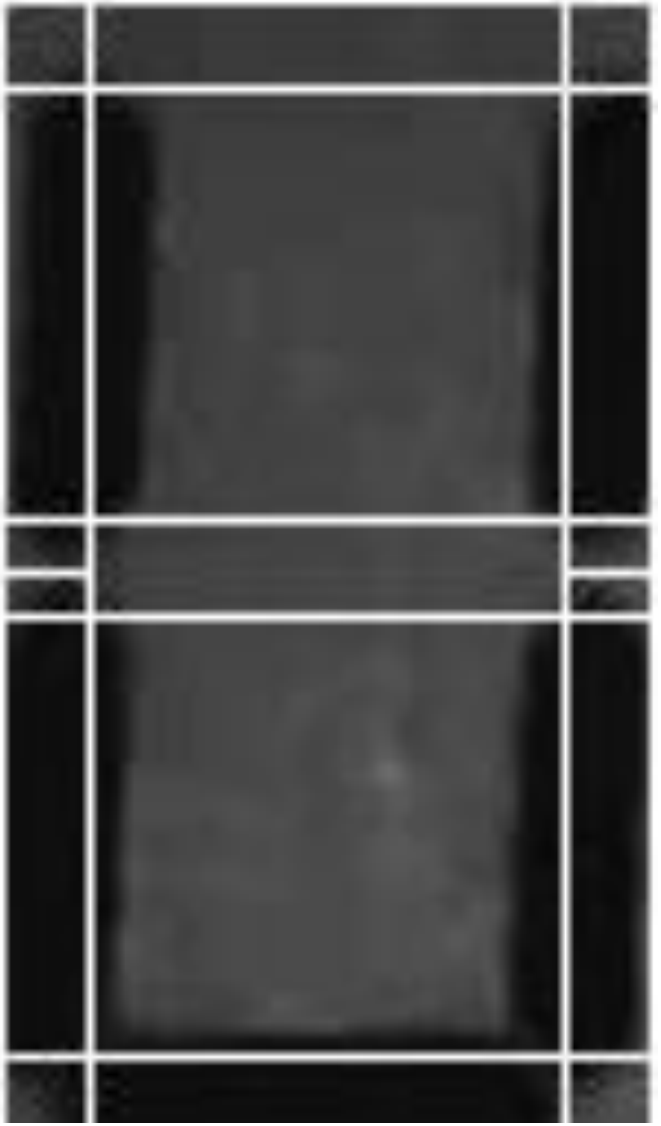
Input

Output



2 Counters Reading - 7 segments digit recognition





Inspired in: Recognizing digits with OpenCV and Python, Adrian Rosebrock, http://www.pyimagesearch.com/2017/02/13/recognizing-digits-with-opencv-and-python/

2 Analog counters: image aquisition

Gas counter

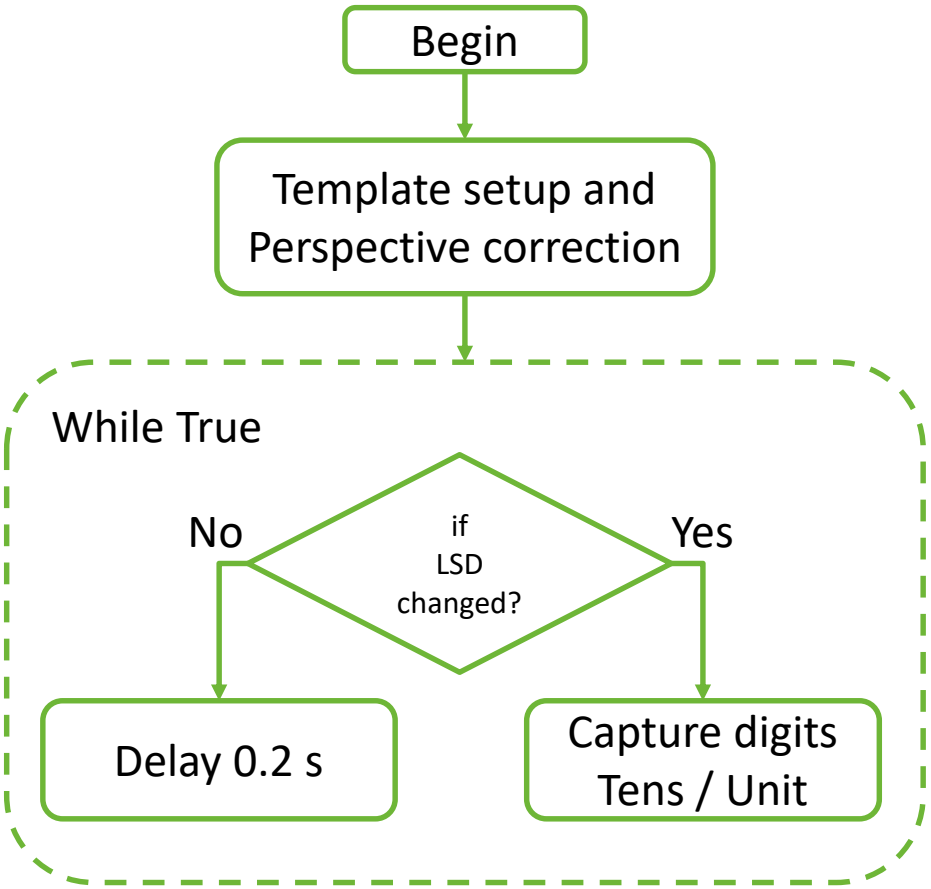
Water counter

Electricity counter

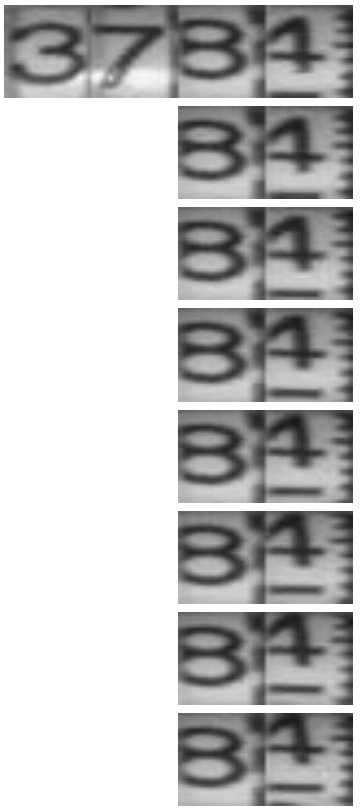
OCR / Machine learning

Reads	9461,5	2077,0	9461,5

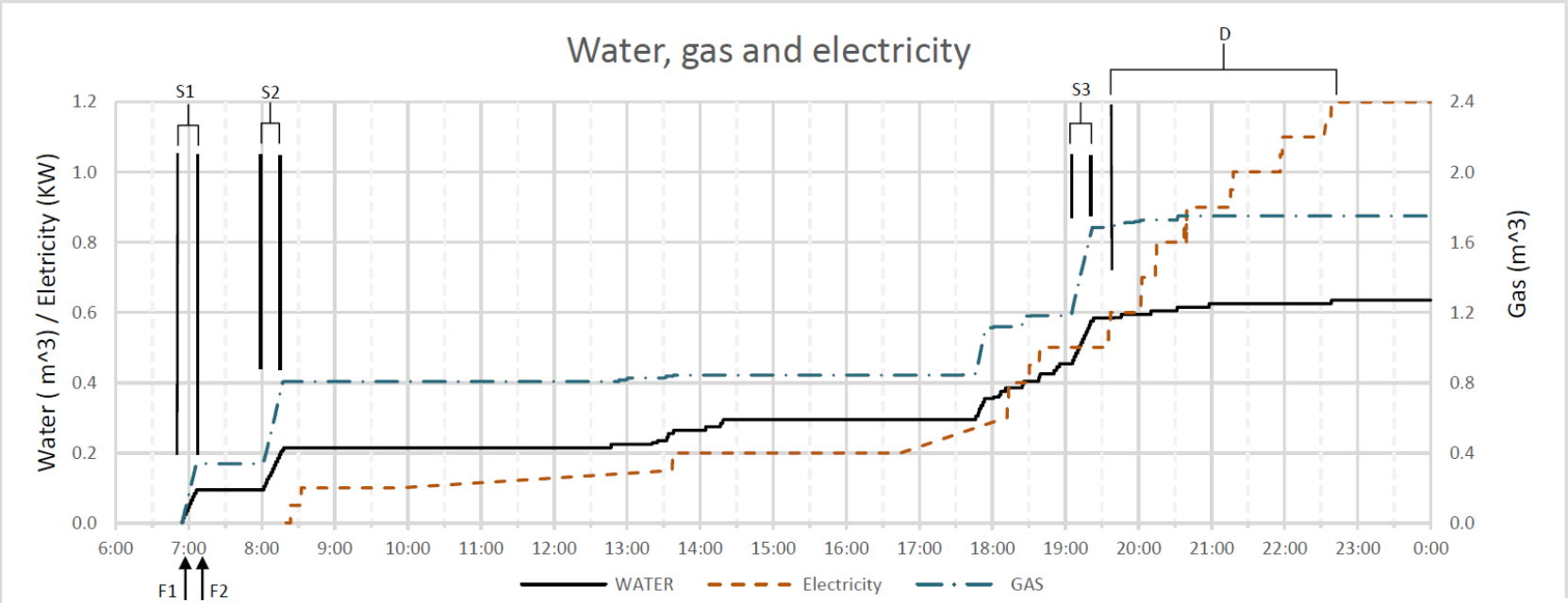
2 Analog counters: Algoritm



Water counter



2 Reads



		Start	Duration	Water (litres) Read	Gas (litres) Read	Electricity (KW) Read
Shower	S1	06:56:22	00:09:53	72.5	281.0	N.A.*
	S2	08:01:13	00:15:57	115.0	468	N.A.*
	S3	19:04:56	00:16:55	128.0	469	N.A.*
Flushing Cistern	F1	06:55:07	00:01:03	9.0	N.A.*	N.A.*
	F2	07:11:39	00:00:33	4.0	N.A.*	N.A.*
Dishwashing Machine	D	19:36:50	03:01:10	44.5	N.A.*	6.0

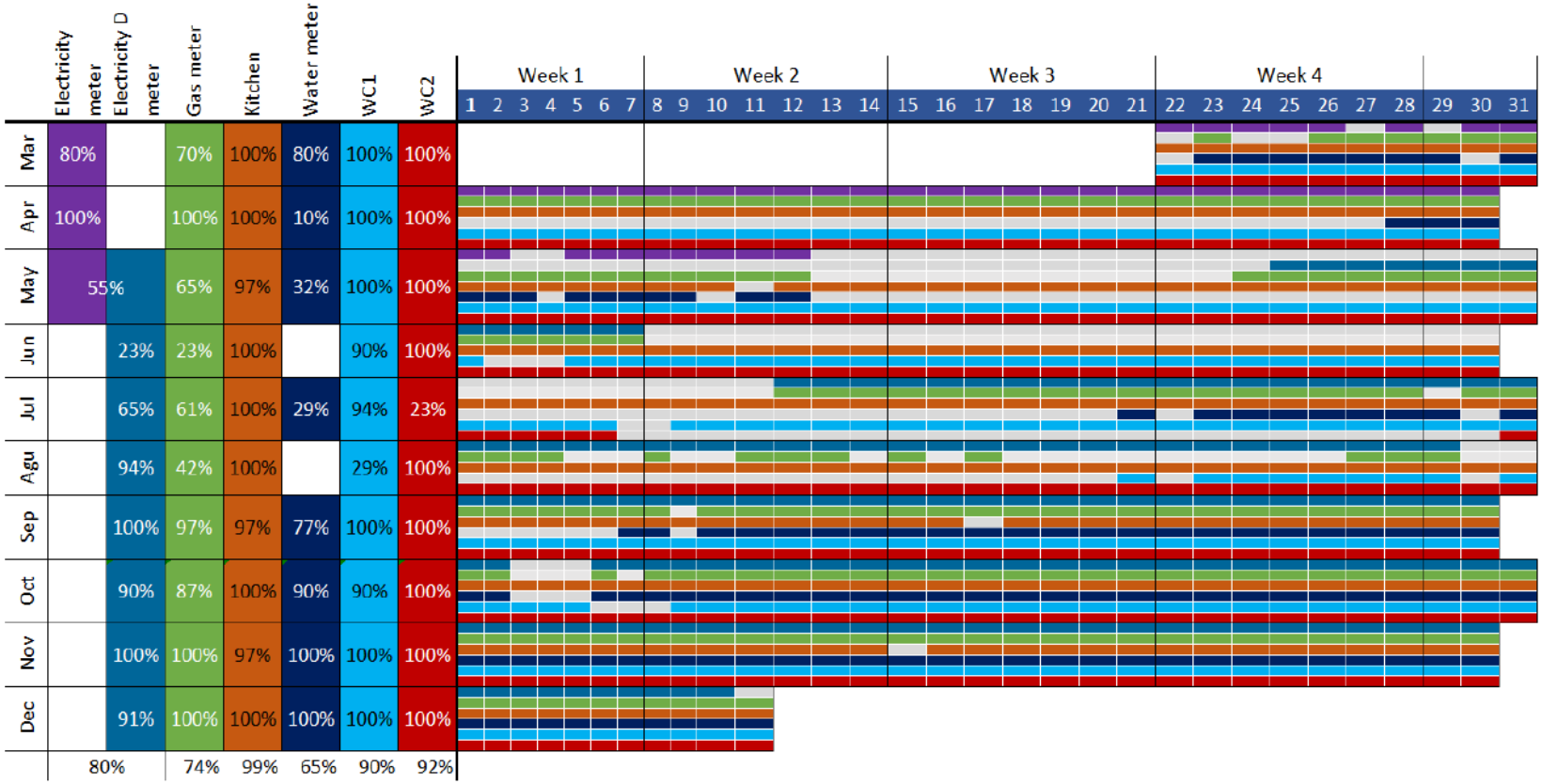
2 Costs

Devices	Cost (€)
4 Orange PI SBC (with case, memory card and sensor interface)	263
Sensors	15
Cables, chargers, sockets, plugs	47
3 Webcams	36
Other material (tape, glue, magnets)	10
Total	**371**

- The hardware cost is very low compared to other systems used in the literature
- Labor costs and travel costs for an operator to configure and maintain the system are not included
  - but are an important parcel of the costs.
  - however we believe that these will be the same or lower than other systems used.

3 Results

- WATERS system acquisition – Case study dwelling



	Electricity meter	Electricity D meter	Gas meter	Kitchen	Water meter	WC1	WC2
Mar	80%		70%	100%	80%	100%	100%
Apr	100%		100%	100%	10%	100%	100%
May	55%		65%	97%	32%	100%	100%
Jun		23%	23%	100%		90%	100%
Jul		65%	61%	100%	29%	94%	23%
Agu		94%	42%	100%		29%	100%
Sep		100%	97%	97%	77%	100%	100%
Oct		90%	87%	100%	90%	90%	100%
Nov		100%	100%	97%	100%	100%	100%
Dec		91%	100%	100%	100%	100%	100%
	80%		74%	99%	65%	90%	92%

Week 1: 1 2 3 4 5 6 7 | Week 2: 8 9 10 11 12 13 14 | Week 3: 15 16 17 18 19 20 21 | Week 4: 22 23 24 25 26 27 28 29 30 31

At the time of this publication the system is installed in 9 dwellings acquiring data.

3 Results

- Reasons that contributed for the missing files
  1. The first installed sensors to register faucets were poorly insulated.
     - After some time, they had water infiltration and stop working.

Solution: new sensors were made and installed with rubber tape;

3 Results

- Reasons that contributed for the missing files
  1. The first installed sensors to register faucets ….
  2. It was verified that SBCs sometimes stop working:
     - Sometimes due the power supply that required replacement,
     - other times the software just crashed requiring reboot, or
     - simple the household unintentionally disconnect the node.

Solution: These situations lead to the development of the monitoring routine, implemented in a server, and to periodically verifications of all the nodes.

3 Results

- Reasons that contributed for the missing files
  1. The first installed sensors to register faucets …
  2. It was verified that SBCs sometimes stop working
  3. In May the electricity company informed the owners that the **analogical meter** “Electric meter” would be replaced by a **digital meter** “Electricity D meter”.
     - It was decided to remove all 3 webcams (water, gas and electricity) in 13 May.
     - Although the new digital routine was implemented and installed at 25 May, several adjusts were necessary to have it works properly.
     - The problem was solved in the begin of September, after the summer vacations

4 Conclusion and Future work

- Conclusion
  - The WATERS system architecture and implementation solutions was presented.
  - The system has been thought to have low cost, acquire water and related energy with high detail and for long periods.
  - The system is presently installed in 9 dwellings
  - For the case presented dwelling, the costs with hardware and other material were approximately 371€, that was consider low in comparison with other systems.

- Future work
  - Finish the data interpretation and validation system.

AcknowledgEments

- This work was partially funded by project POCI-0-0145-FEDER-016730 (PTDC / AAG-REC / 4700/2014) under the name ENERWAT: Water for energy: characterization, modelling and measures for reducing domestic urban and rural consumption, funded by the Foundation for Science and Technology and co-financed by the European Regional Development Fund (ERDF) through COMPETE 2020 - Operational Competitiveness and Internationalization Program (POCI).
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Questions

Thanks!