SmartPV for PV integration and Demand Side Management: First results from Cyprus

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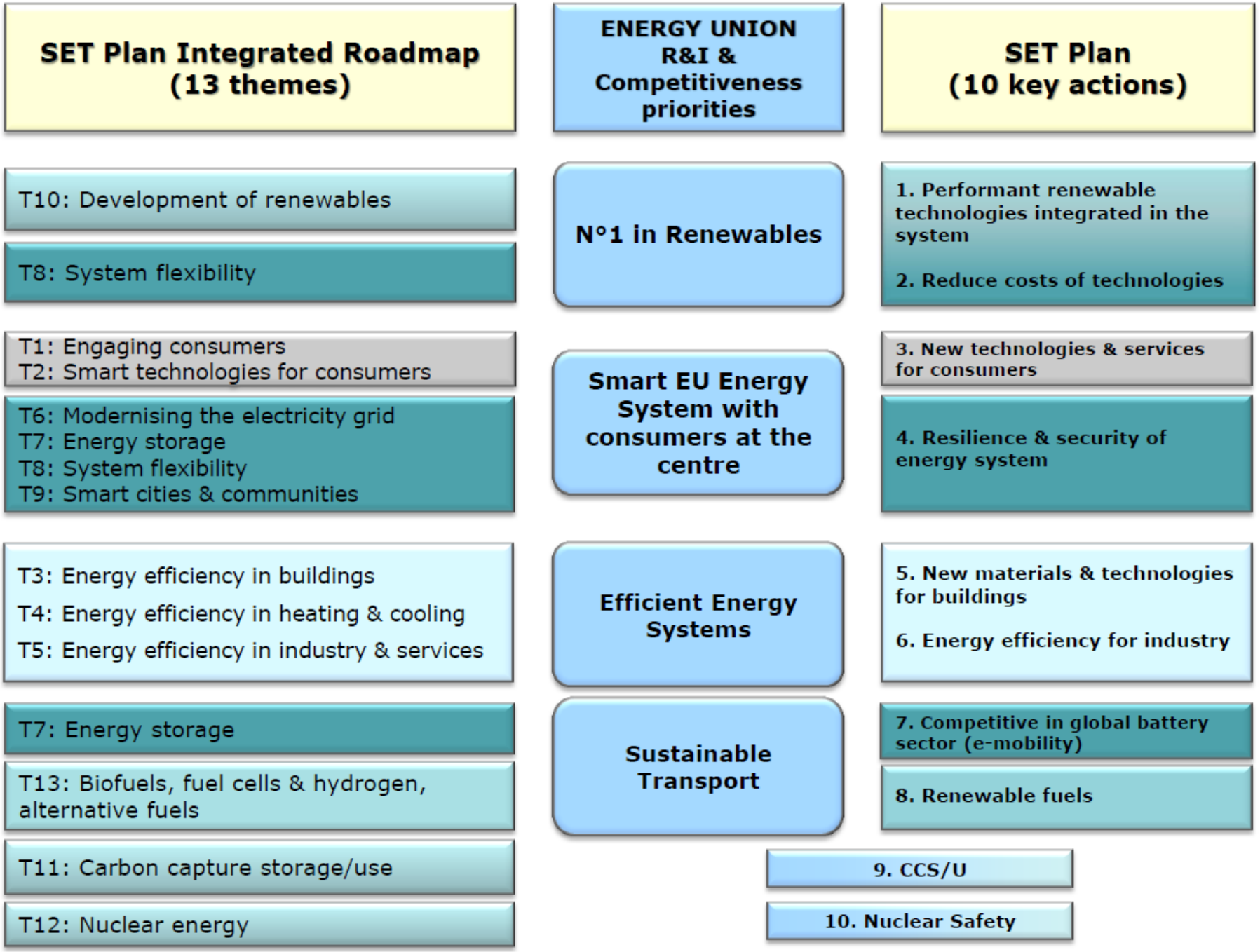
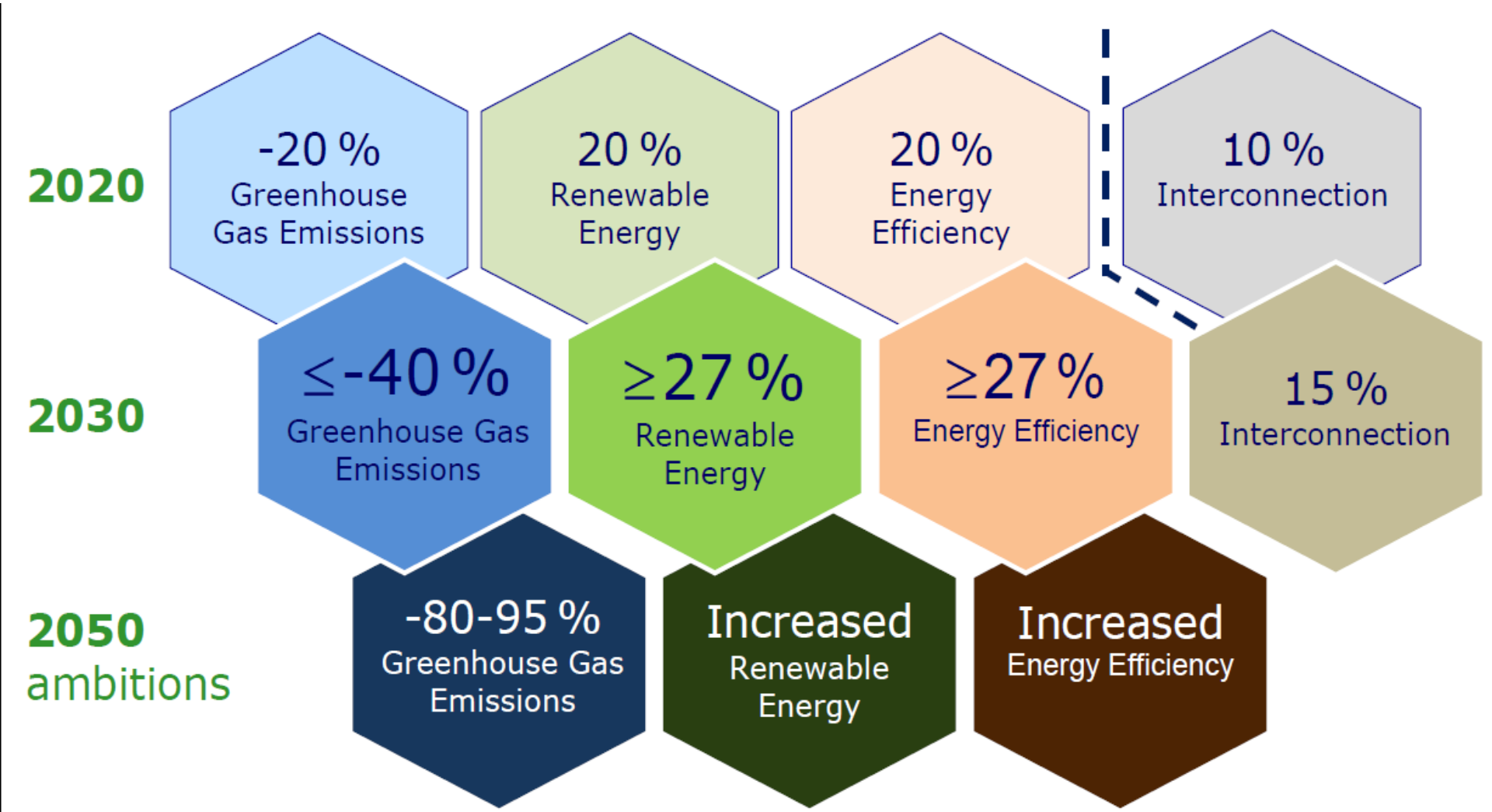

SET Plan Integrated Roadmap (13 themes)
ENERGY UNION R&I & Competitiveness priorities
SET Plan (10 key actions)
T10: Development of renewables
T8: System flexibility
N°1 in Renewables
1. Performant renewable technologies integrated in the system
2. Reduce costs of technologies
T1: Engaging consumers
T2: Smart technologies for consumers
T6: Modernising the electricity grid
T7: Energy storage
T8: System flexibility
T9: Smart cities & communities
Smart EU Energy System with consumers at the centre
3. New technologies & services for consumers
4. Resilience & security of energy system
T3: Energy efficiency in buildings
T4: Energy efficiency in heating & cooling
T5: Energy efficiency in industry & services
Efficient Energy Systems
5. New materials & technologies for buildings
6. Energy efficiency for industry
T7: Energy storage
T13: Biofuels, fuel cells & hydrogen, alternative fuels
Sustainable Transport
7. Competitive in global battery sector (e-mobility)
8. Renewable fuels
T11: Carbon capture storage/use
9. CCS/U
T12: Nuclear energy
10. Nuclear Safety

EU Strategy for 2020 to 2030 +



27% renewable energy in 2030: up to 45% renewable electricity

SmartPV

Smart net metering for promotion and cost-efficient grid-integration of PV technology in Cyprus

- LIFE+ Environmental Policy and Governance
- Implementation: Cyprus
- Duration: 1/7/2013 – 31/12/2017
- Budget: 1,219,838 Euro (% EE: 50%)
- Coordinator: Photovoltaic Technology laboratory, University of Cyprus

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Partners

Αρχή Ηλεκτρισμού Κύπρου
Electricity Authority of Cyprus

Deloitte.

University of Cyprus
PV Technology

ρυθμιστική αρχή ενέργειας κύπρου
cyprus energy regulatory authority

DEPARTMENT OF ENVIRONMENT

SmartPV

Coordinator: UCY - Photovoltaic Technology Laboratory

- Part of the FOSS Research Centre for Sustainable Energy
- Indoor and outdoor facilities for characterization, analysis and testing different PV technologies
- Grid integration/smart grids
- Market integration/policies

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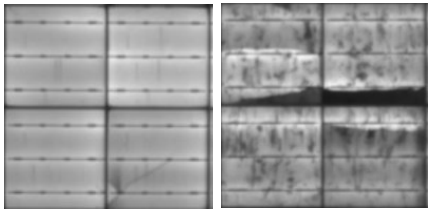
Indoor testing

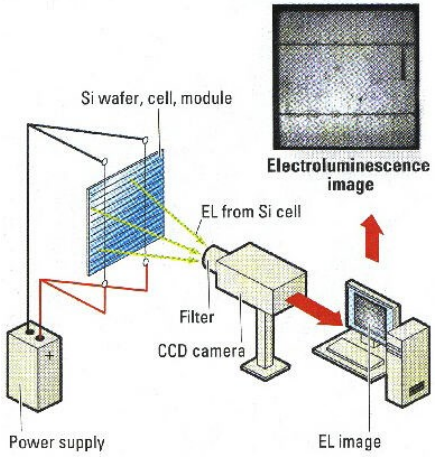
UV Simulator

Climatic Chamber

Solar Simulator



Electroluminescence Apparatus

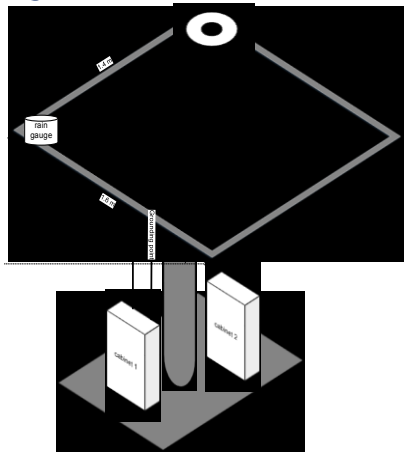


Outdoor testing

PV performance and yield

NOCT measurements (IEC 61215 Clause 10.5)

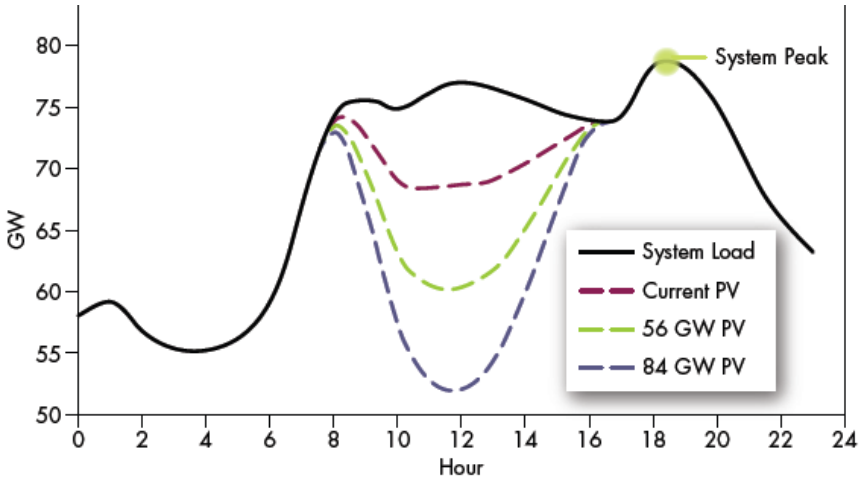
Model PID progression and occurrence



Two axis tracker / solar irradiance assessment

Motivation

- High PV penetration may lead to stability and reliability problems
- Demand Side Management (DSM) can reduce energy consumption and can help convert unsustainable energy practices into cost effective and sustainable energy use
- DSM can mitigate RES operational issues and contribute to effective management of congestion problems



SmartPV objectives

- Develop a cost-optimum dynamic tariff tool for optimal PV grid integration
- Fairer billing → **WIN-WIN** scenario for all the stakeholders
- Cost reflective tariffs that enable demand side management (DSM)
- Information and Education of customers → transition from passive to **active consumers**
- Derive new policies that will increase PV penetration and induce smart grids

Data collection configuration

Prosumer (Producer + consumer)

Datasets:

- PV production
- Import/export

Datasets from PV and import/export energy from grid

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Datasets from smart meters

Datasets synchronization

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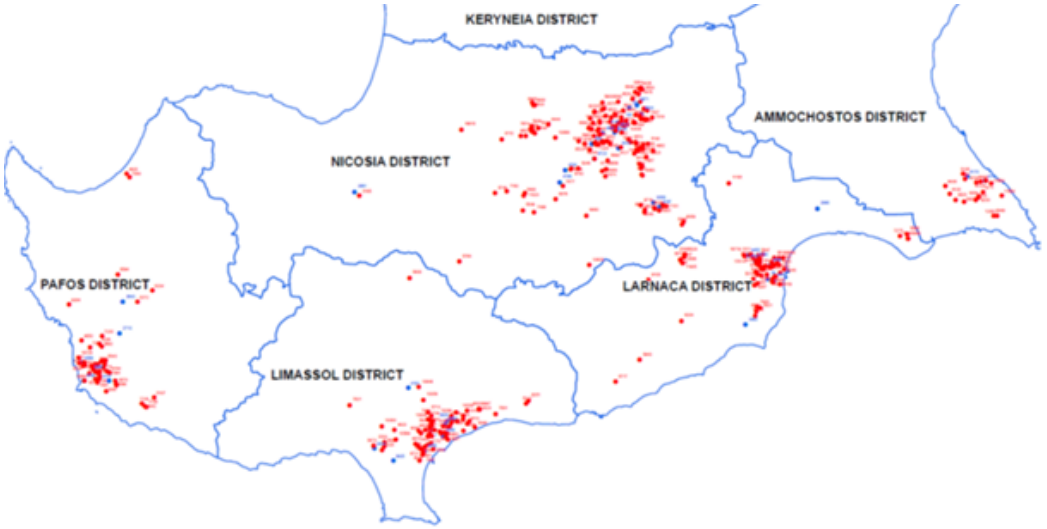
Participants distribution per Area

Area	Participants (targeted	Participants (installation completed)	Participants (1st contact completed)
Lefkosia-Kyrenia-Morphou	124	116	101
Larnaca-Ammochostos	74	71	67
Lemesos	54	51	43
Paphos	48	46	46
TOTAL	***300***	***284***	***257***

Prosumers Supporting

- All participating household prosumers are geographically spread in Cyprus, in order to have a country wide representative sample.

- Examination of energy behaviour change using:
  - IHDs
  - Web-app
  - Bi-monthly mail bill



- For the first time in Cyprus a pilot run of 300 households (prosumers) with Smart meters and grid-connected PV systems installed at their rooftops - consumption and PV production measurements are acquired

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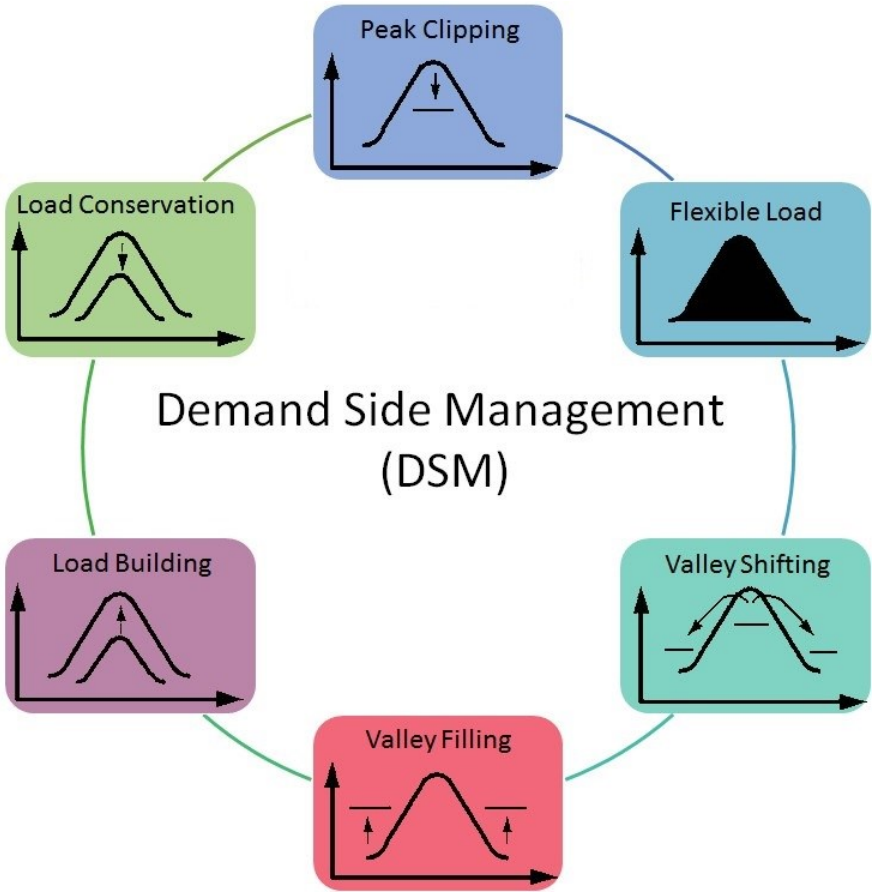
Demand Side Management (DSM)

- Demand response programs/load shifting
- Objective:
  - Flatten the electricity profile demand
- Outcomes:
  - Reduction on the customers' electricity bill
  - Decrease the operation and maintenance costs (both sides – utilities and consumers)
  - Decrease carbon footprint and making the whole network more reliable and secure
- Match demand with local production



Time of Use Tariff

- A price-based tool has been developed in order to arrive at an effective Time of Use (ToU) tariff
- Investigate how consumption monitoring methods alter customers energy habits
- Quantify energy behaviour before and after the application of ToU tariff
- The aim is to motivate residential customers to shift load from peak to valley periods resulting to lower electricity bills and smoother load profile

Methodology

- The acquired data from 300 prosumers is used to derive the dynamic ToU tariff in a two step method described below:
  - Statistical Step: Based on the inflection points of the load duration curve and on the probability density function of each load segment, the ToU block periods are derived.
  - Optimization Step: By using the statistical results for ToU as initial conditions, the ToU blocks are varied and subtracted from the load curve (P_k) until the root mean square error (RMSE) is minimized:

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{k=1}^{n}(ToUb_k - P_k)^2}$$

Method	RMSE (%)
Statistical step	19.95 %
Optimization step	12.32 %

Evaluation of ToU Tariffs

- Based on the ToU blocks, the tariffs were derived using optimization in order to maintain neutral cost effect in the case where the prosumers' energy behaviour remains unchanged

Block	Price (€cents/kWh)	Period		
		Winter (Dec - Mar)	Summer (Jun - Sep)	Middle (Apr, May, Oct, Nov)
Peak	18,85	16:00 – 21:59	09:00 – 18:59	08:00 – 20:59
Shoulder	14,85	06:00 – 15:59 22:00 – 23:59	07:00 – 08:59 19:00 – 00:59	06:00 – 07:59 21:00 – 23:59
Off-peak	10,85	00:00 – 05:59	01:00 – 06:59	00:00 – 05:59

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ToU tariff cost vs flat tariff

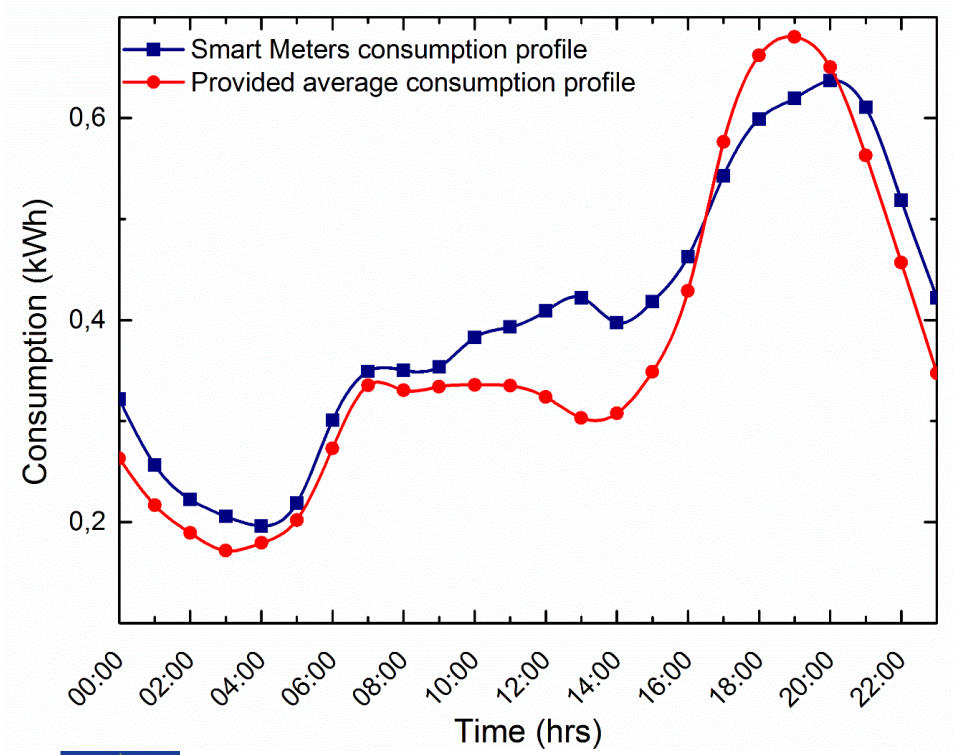
- Peak – shoulder: 27 % difference
- Shoulder – off-peak: 27 % difference

Block	Off-peak	Shoulder	Peak
Balance Charges	0,1085 €/kWh	0,1485 €/kWh	0,1885 €/kWh

Total	Flat tariff	DSM charge	Difference
	Electricity bill as **prosumer**	Electricity bill as **prosumer**	
Over 288	€ 115,774.90	€ 115,699.40	€ -75.45

Results – Correlation indices

- The participants load profile were correlated with the average Island consumption profile as provided by EAC.

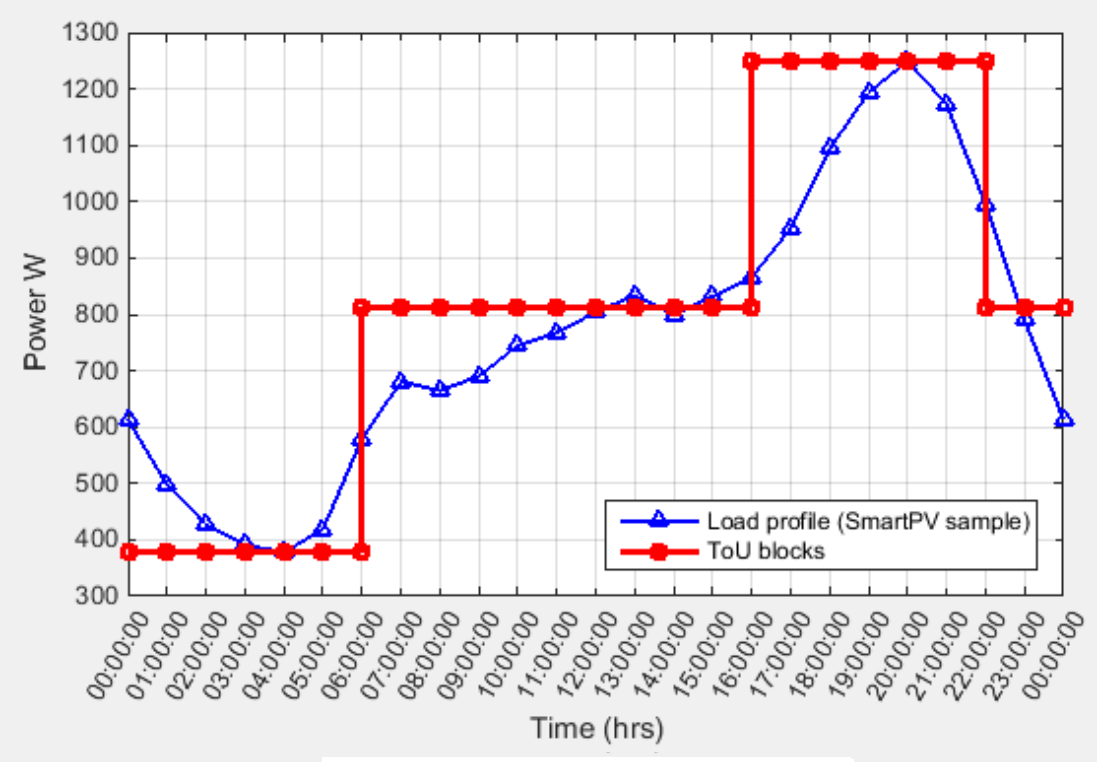


Winter

	Period		
	Winter	Summer	Middle
Correlation	92,56 %	96,41 %	96,28 %

Results – seasonal average profiles

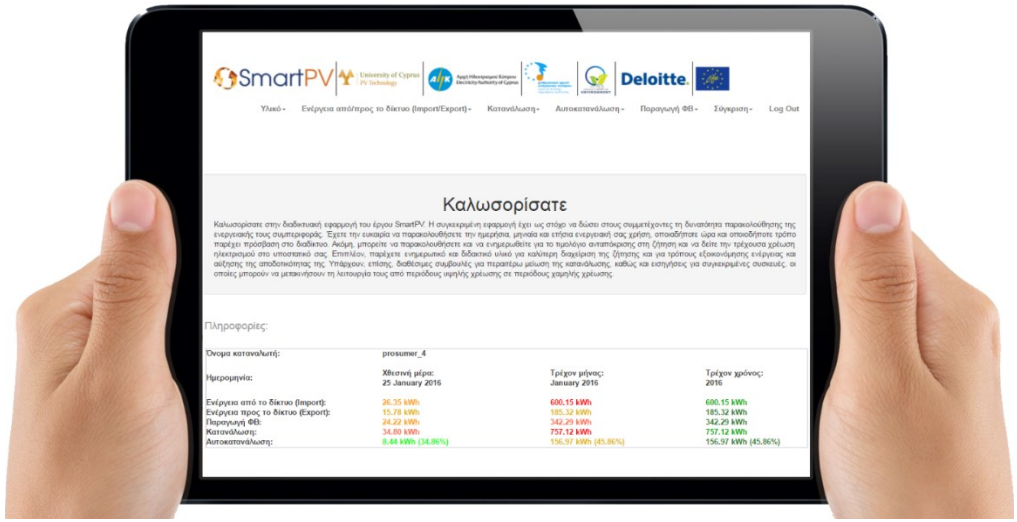
- Seasonal average profiles from the SmartPV sample and the corresponding time and charge blocks of the adapted ToU tariffs



Winter

Behavioural change

- In House Displays (IHDs) / web access:
  - Import/Export
  - Consumption
  - PV production
  - Comparisons
  - Informative material



http://www.pvtechnology.ucy.ac.cy/smartpv/

In-house display and web application

SmartPV | University of Cyprus PV Technology | Αρχή Ηλεκτρισμού Κύπρου Electricity Authority of Cyprus | Deloitte. | Life

About ▾ Energy from/to Grid ▾ Consumption ▾ Self Consuption ▾ PV Production ▾ Compare ▾ Contact ▾ Log Out

Welcome

Welcome to the SmartPV web application developed to provide monitoring capabilities to the participating prosumers. You can now view your individual energy pattern on a daily, monthly and yearly basis anytime and wherever there is internet access. The energy behaviour and load profile of your household can be viewed remotely. Beyond these, you can also monitor the price-based demand side management (DSM) scheme and the up to date electricity charge. In addition, the application displays useful information and educational material as concerns demand side management measures and energy efficiency and conservation. Tips for consumption reduction as well as suggestions for the available appliances, whose operation can be shifted to a different time period are available.

Information/Details:

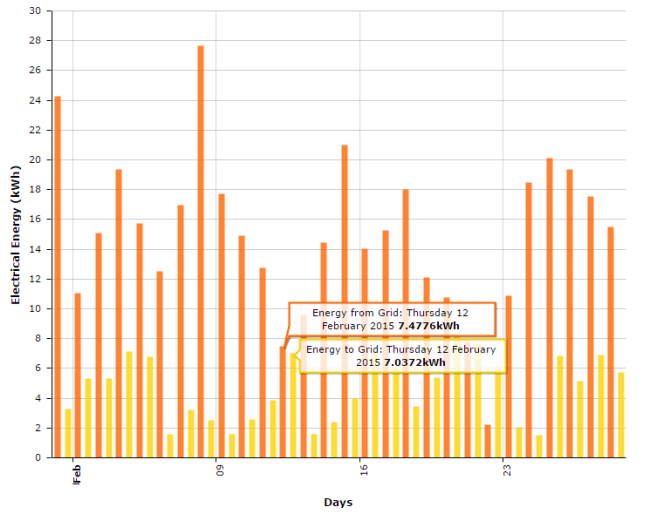
Customer Name:	**prosumer_1**		
Date:	**Yesterday:** **31 January 2016**	**Current Month:** **January 2016**	**Current Year:** **2016**
Electrical Energy from Grid:	**0.07 kWh**	**85.02 kWh**	**85.02 kWh**
Electrical Energy to Grid:	**0.00 kWh**	**6.16 kWh**	**6.16 kWh**
Photovoltaic Production:	**0.00 kWh**	**14.57 kWh**	**14.57 kWh**
Consumption:	**0.07 kWh**	**93.42 kWh**	**93.42 kWh**
Self Consumption:	**0.00 kWh (0.00%)**	**8.46 kWh (58.00%)**	**8.46 kWh (58.00%)**

In-House Display (IHD) – web-application

Energy from & to Grid Daily

Monthly | Daily | Hourly | 2015-02 | Submit

Energy from & to Grid, Daily, February 2015:



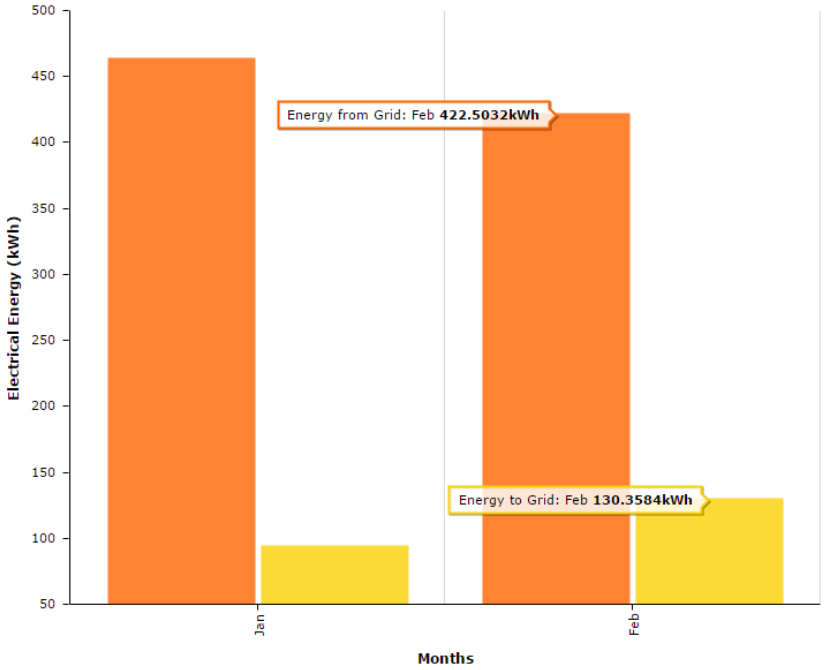
Legend div:

Energy from Grid (kWh): 7.4776 Energy to Grid (kWh): 7.0372

Information/Details:

Customer Name:	christos
Date:	February 2015
Electrical Energy from Grid:	422.50 kWh
Electrical Energy to Grid:	130.36 kWh
Photovoltaic Production:	216.60 kWh
Consumption:	508.75 kWh
Self Consumption:	142.52 kWh

Energy from & to Grid, Monthly, 2015:



Legend div:

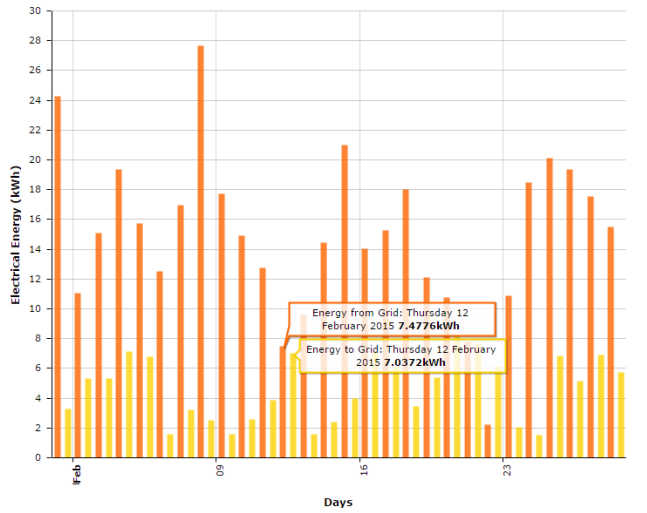
Energy from Grid (kWh): 422.5032 Energy to Grid (kWh): 130.3584

In-House Display (IHD) – web-application

Energy from & to Grid Daily

Monthly | Daily | Hourly | 2015-02 | Submit

Energy from & to Grid,
Daily, February 2015:



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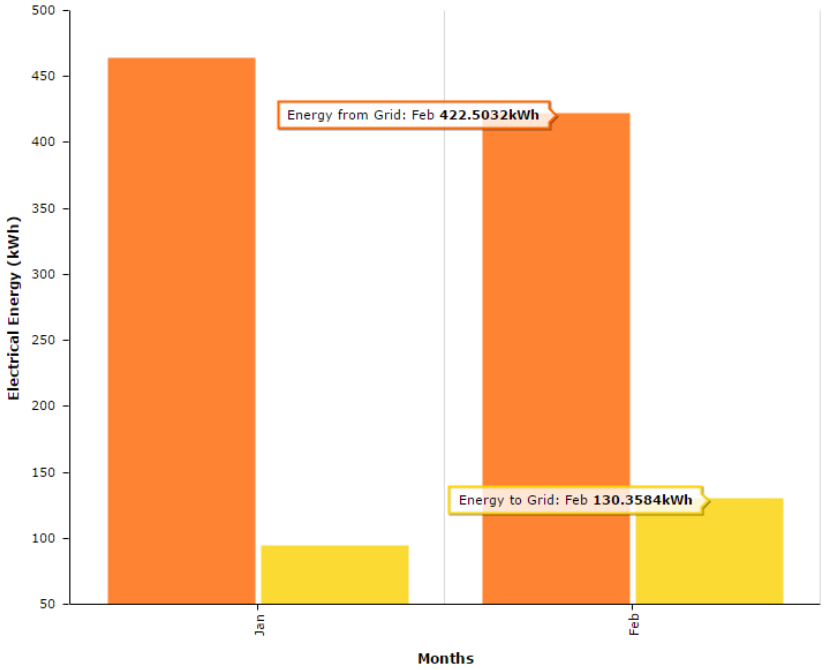

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Thank you !!