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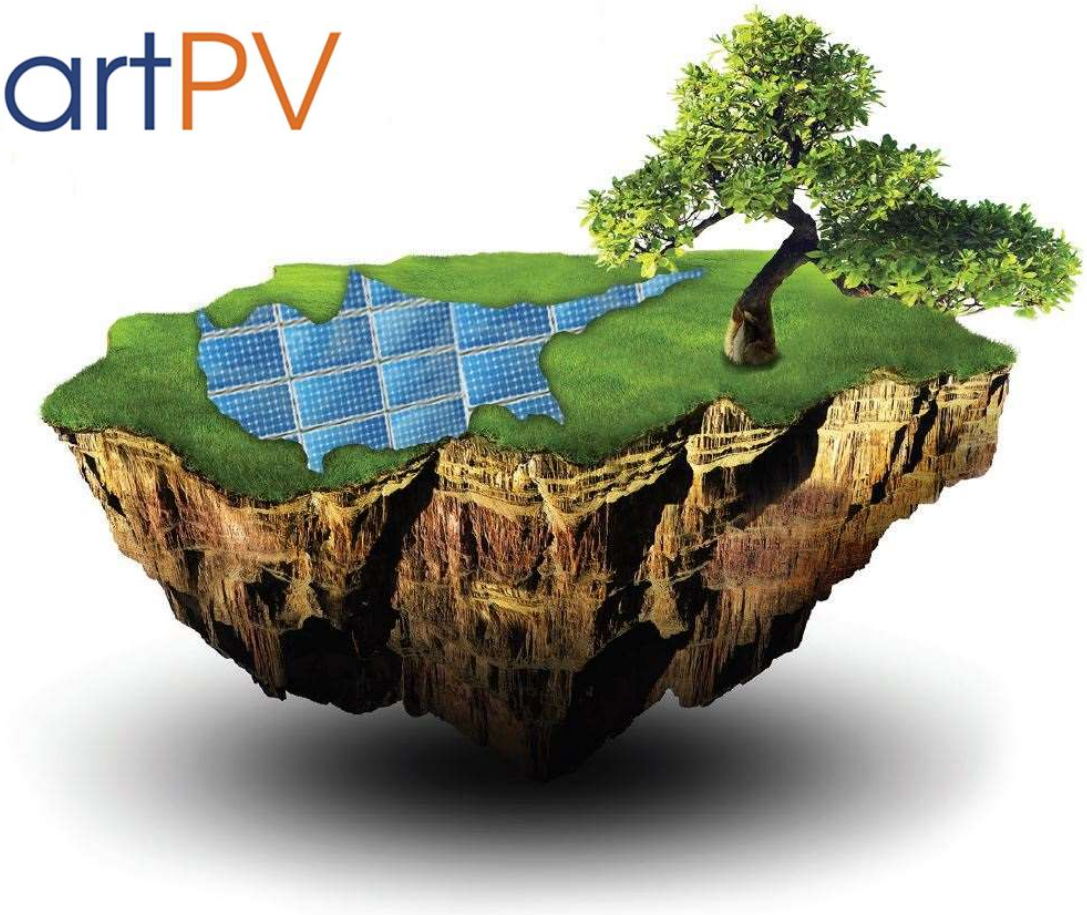

Smart net metering for promotion and cost-efficient grid-integration of PV technology in Cyprus

University of Cyprus
PV Technology

Αρχή Ηλεκτρισμού Κύπρου
Electricity Authority of Cyprus

ρυθμιστική αρχή ενέργειας κύπρου
cyprus energy regulatory authority

DEPARTMENT OF ENVIRONMENT

Deloitte.

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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

University of Cyprus
PV Technology

Deloitte.

Electricity Authority of Cyprus

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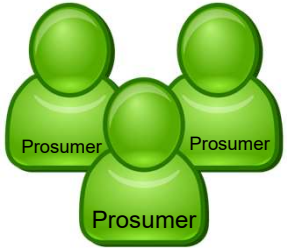

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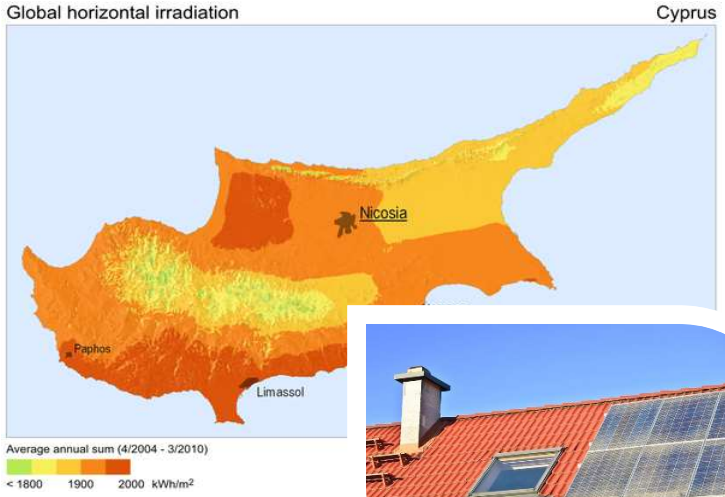
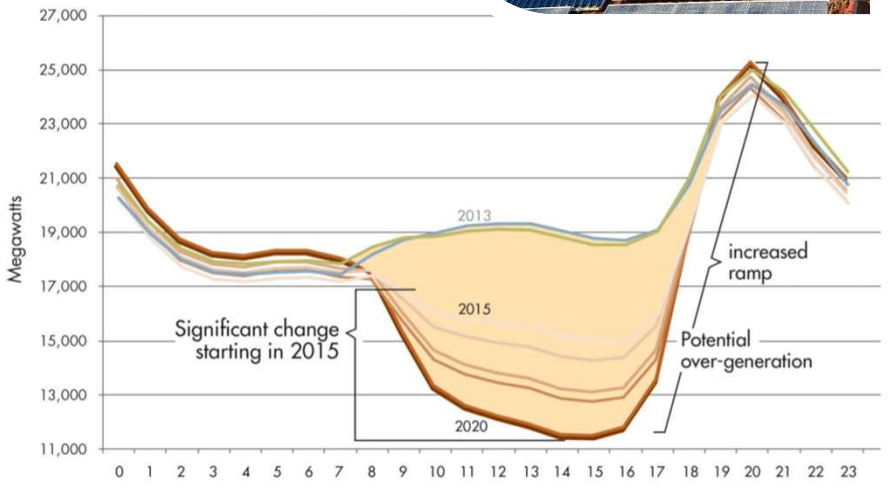
Increased PV penetration levels in Cyprus

- Solar irradiance is one of the highest in Europe (300 days annually considered sunny)
- Utilization of solar energy through solar thermal collectors and PV systems → High PV capacity levels
- Afternoon peak is being replaced by an afternoon valley, when solar generation is at its highest
- The valley period is followed by a steep and problematic peak as power from solar generation decreases → duck curve





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New Energy Policies

- Match consumption with production
- Mitigate PV operational issues
- Fully utilize solar energy by increasing PV integration while maintaining grid stability

Demand Side Management (DSM) + Storage Solutions

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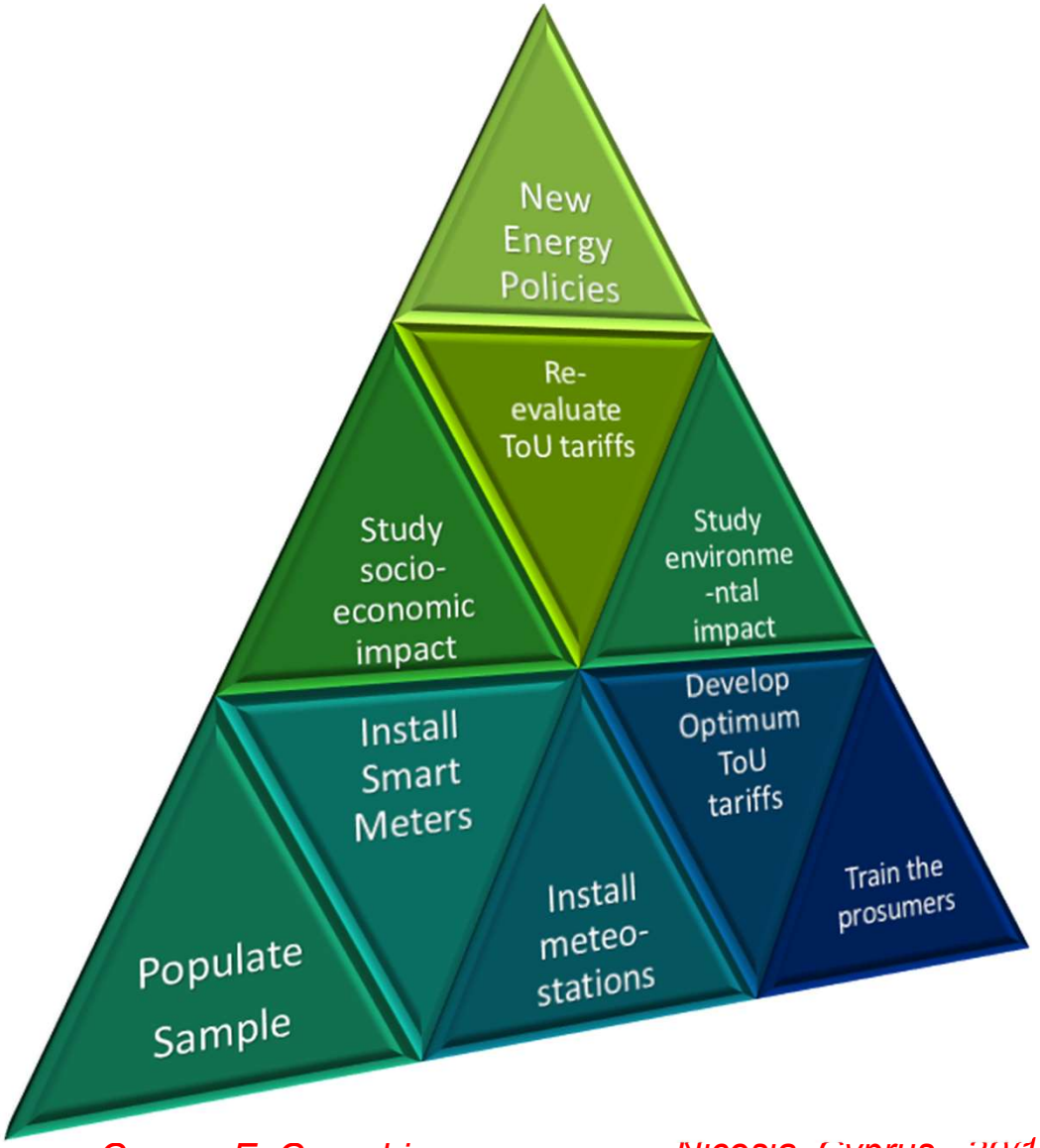
How to enable optimal DSM and Storage?

- Time-of-Use pricing (ToU)
  - Reflect the higher cost of supply during peak periods and the lower cost during off-peak periods
  - Prosumers and utilities get the advantage of risk-averse attitude to price uncertainties due to fuel price adjustments
  - Must be adjusted based on the specific energy profiles of the area of application
    - **Need to put to the test**

SmartPV Three stages for creating effective ToU tariffs



Evaluation Stage - New energy policies

- Promotion of PV integration
- Advantages for both utilities and prosumers

Implementation Stage - One year of ToU application

- Data collection for validation
- Feedback provided to the prosumers through web and tablet applications
- ToU tariff re-evaluation

Planning Stage - One year of data collection

- Define initial and baseline scenarios
- Approval of developed ToU tariffs
- Training the prosumers

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Planning Stage – Data collection

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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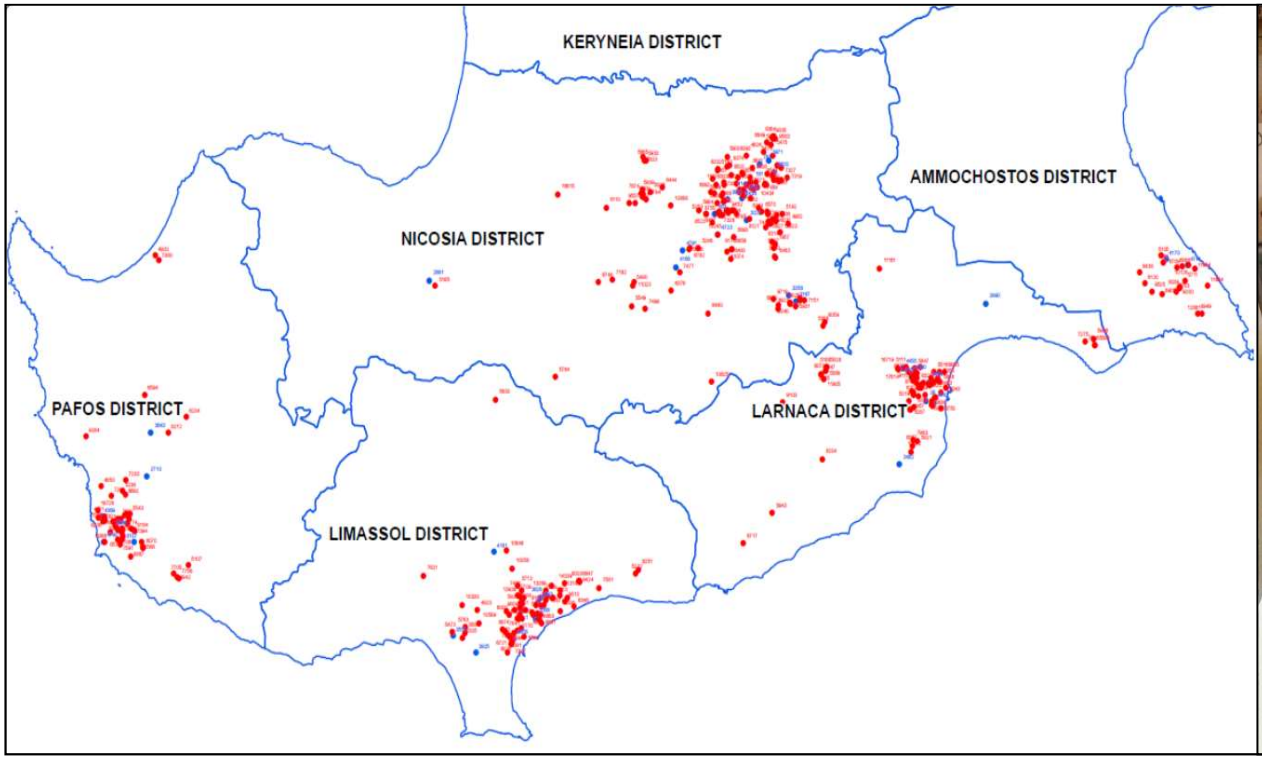
Planning Stage – Smart Meters (SMs)

- 300 prosumers selected across the island



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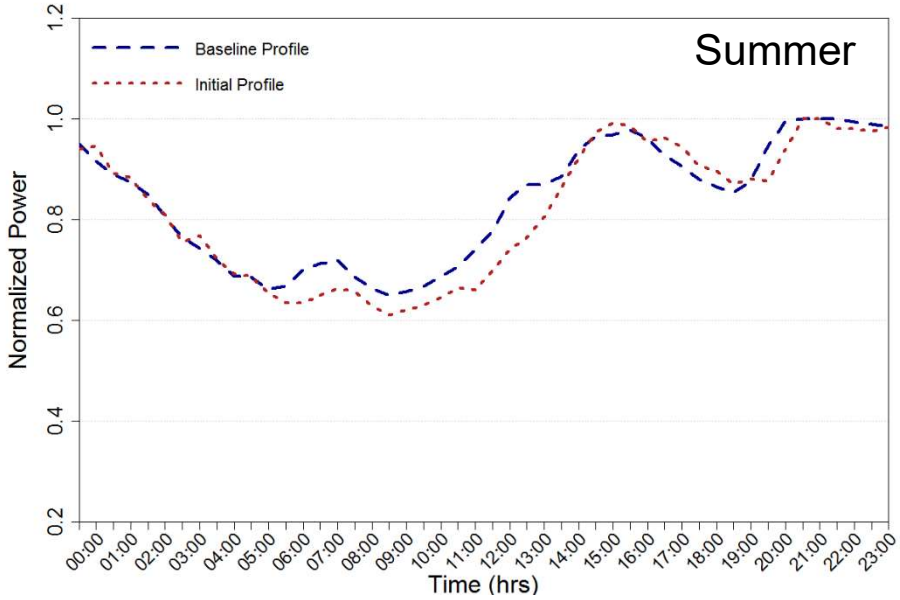
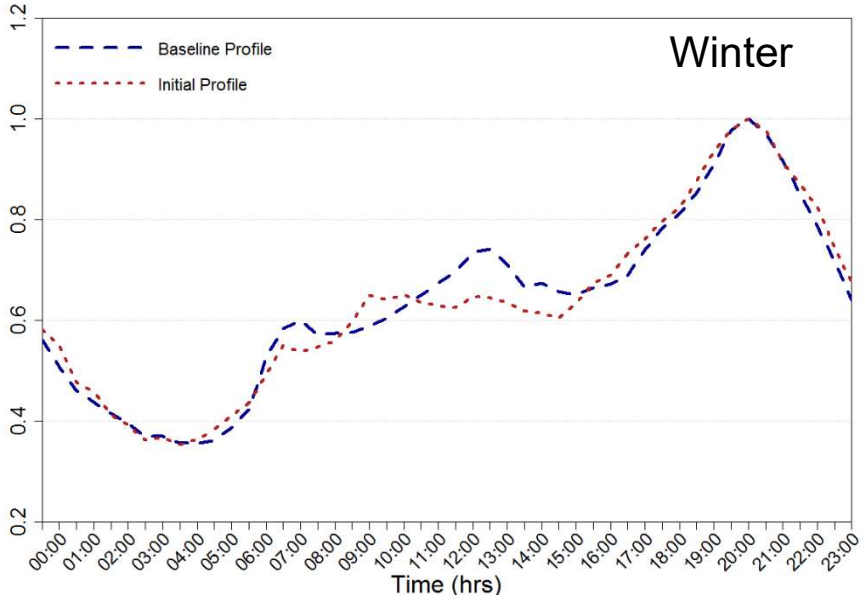
Planning Stage – Meteorological stations

- Weather stations at EAC buildings:
  - Measurements of ambient temperature and solar irradiance in all districts.
- The aim is to collect real consumption, generation and meteorological data for:
  - Optimizing the net-metering and self-consumption policies
  - Examining the environments impacts

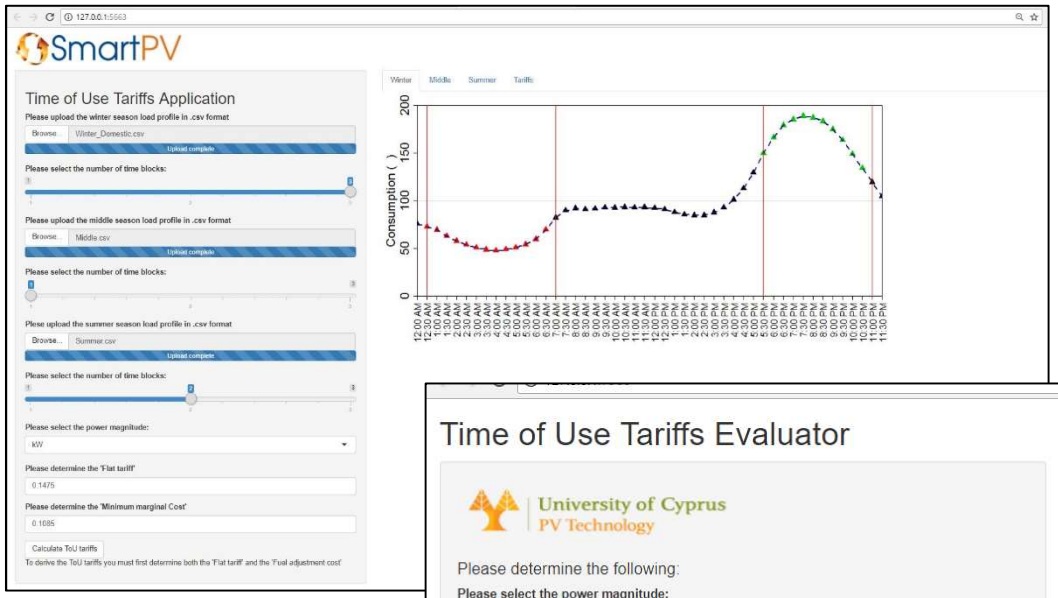
Planning Stage – Initial and baseline

- Each year is divided into three seasons (winter, middle and summer)
- Total Aggregated Consumption → Initial Scenario
- One year of collected data → Baseline Scenario
  - ToU tariffs should be able to reduce the peak demands of the total aggregated consumption
  - Good anchoring point for future evaluations



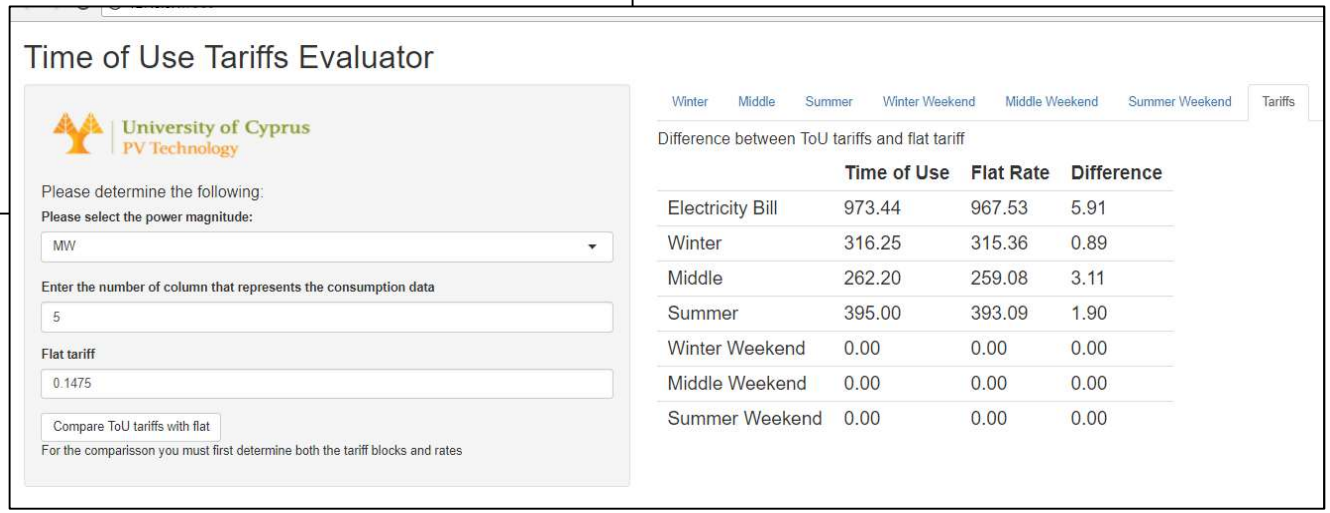


Planning Stage – ToU tariffs Tools



Scientific Approaches

- ❑ Clustering Analysis
- ❑ Optimization Algorithms
- ❑ Changes dynamically



	Time of Use	Flat Rate	Difference
Electricity Bill	973.44	967.53	5.91
Winter	316.25	315.36	0.89
Middle	262.20	259.08	3.11
Summer	395.00	393.09	1.90
Winter Weekend	0.00	0.00	0.00
Middle Weekend	0.00	0.00	0.00
Summer Weekend	0.00	0.00	0.00

- ❑ Both tools can be utilized by CERA and EAC for developing and evaluating ToU tariffs

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Implementation Stage – THINK BIG, start small

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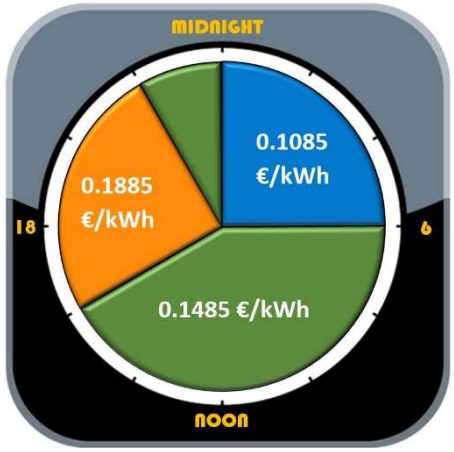
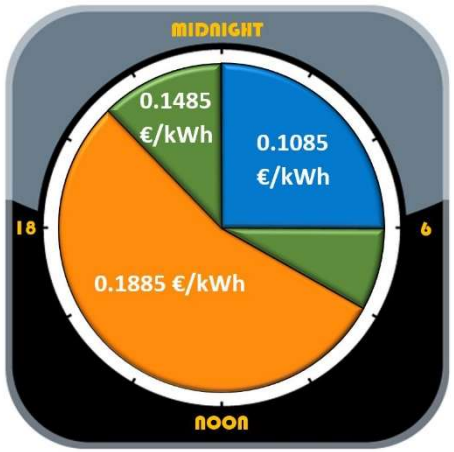
Implementation Stage – ToU tariffs

- Based on participants' consumption
- Approved by CERA
- Real implementation on 01/07/2016

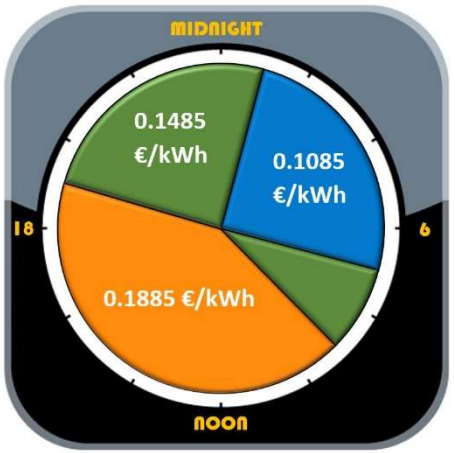
Tariff level	Winter	Summer	Middle	Tariff
Peak	16:00 – 21:59	09:00 – 18:59	08:00 – 20:59	0.1885
Shoulder	06:00 – 15:59 22:00 – 23:59	07:00 – 08:59 19:00 – 00:59	06:00 – 07:59 21:00 – 23:59	0.1485
Off-peak	00:00 – 05:59	01:00 – 06:59	00:00 – 05:59	0.1085



Winter



Middle

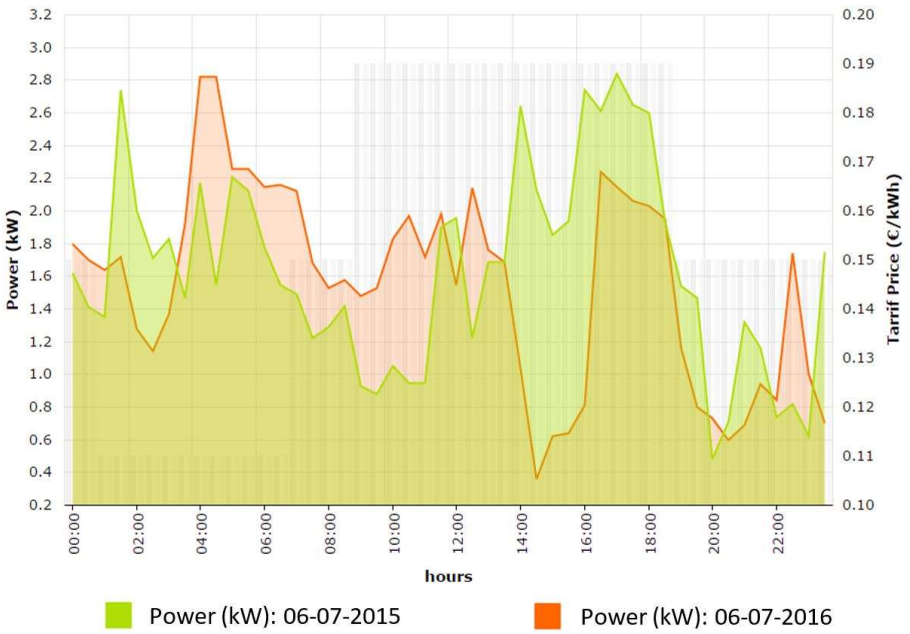


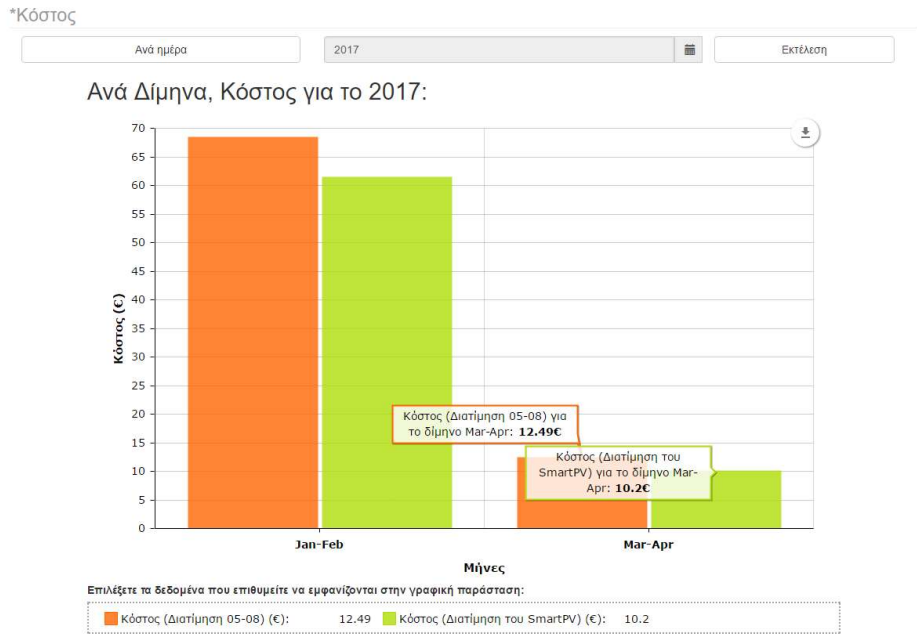
Summer

Implementation Stage – Training the Participants

- Development of material for training
- Individual training at their premises
- Workshops at UCY and EAC
- Monitoring of their real data for effective feedback → active prosumers
  - Web application
  - Tablet application

Implementation Stage – Web Application





- ❑ Helping participants to easily understand and adopt DSM techniques
- ❑ Observe how their actions change their electricity bill
- ❑ Adjustable to the ToU tariff changes

  → Ready for domestic rollout

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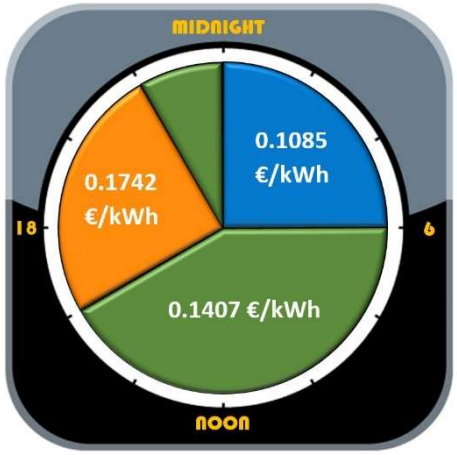
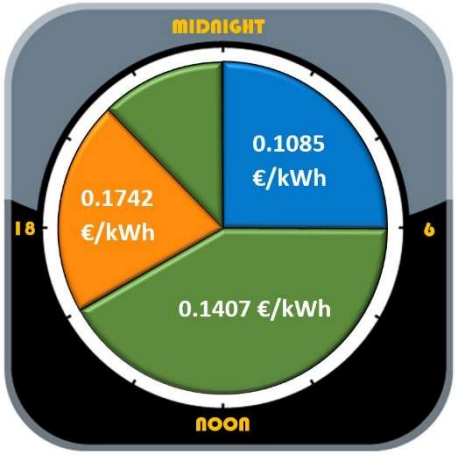
Implementation Stage – ToU tariffs Re-evaluation

- Based on the provided feedback
- ToU tariffs depend on the net-load profiles
- Approved by CERA
- Real implementation on 01/01/2017

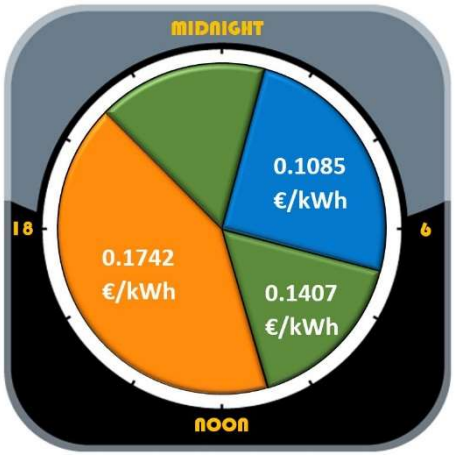
Tariff level	Winter	Summer	Middle	Tariff
Peak	16:00 – 21:59	11:00 – 20:59	16:00 – 20:59	0.1742
Shoulder	06:00 – 15:59 22:00 – 23:59	07:00 – 10:59 21:00 – 00:59	06:00 – 15:59 21:00 – 23:59	0.1407
Off-peak	00:00 – 05:59	01:00 – 06:59	00:00 – 05:59	0.1085



Winter



Middle



Summer

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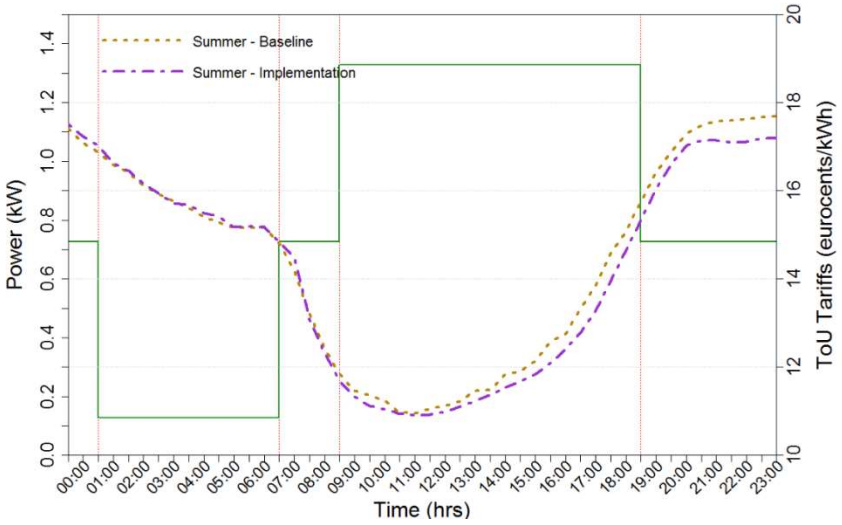
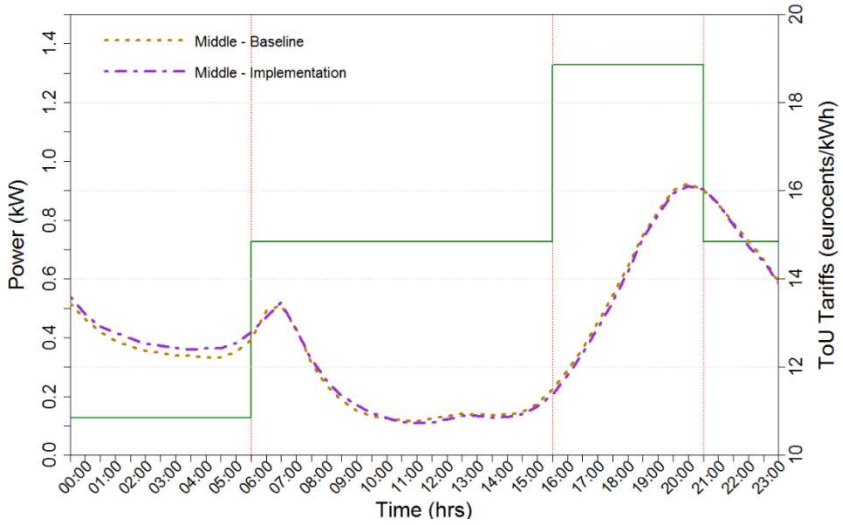
Evaluation Stage – Load Shifting Results

- Evidence that the prosumers shifted their energy demand from the peak to off-peak periods.





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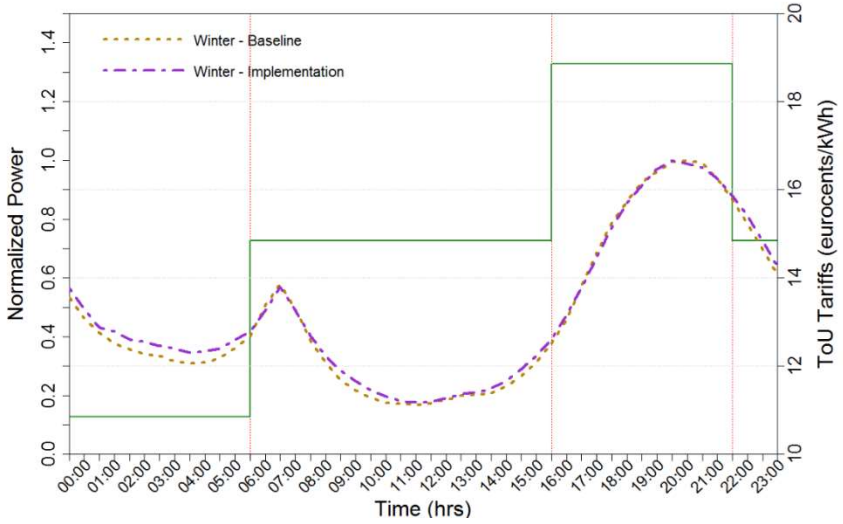
Evaluation Stage – Load Shifting Results



	Summer (%)			Middle (%)			Winter (%)		
Tariff level	2015	2016	Difference	2015	2016	Difference	2015	2016	Difference
Peak	42.70	39.51	- 3.19 ↓	36.11	35.08	- 1.03 ↓	61.02	59.62	- 1.40 ↓
Shoulder	24.01	25.66	1.65 ↑	15.12	16.87	1.75 ↑	22.89	23.33	0.44 ↑
Off - Peak	33.29	34.82	1.53 ↑	48.77	48.05	- 0.72 ↓	16.08	17.05	0.97 ↑

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Evaluation Stage – Impact of ToU tariffs

- After starting the implementation the ToU tariffs, the CO_2 emissions are consistently decreasing (average decrease of 12%).
- An increase of the Load Factor (LF) from 40.65% (baseline year) to 41.43% (implementation year) was observed.
- The energy behaviour change was investigated by comparing the average annual consumption of the smart prosumers with the rest of Cyprus.
  - Rest of Cyprus Sample: Domestic consumers with similar consumption levels with the SmartPV sample

	Average Consumption Baseline Year	Average Consumption Implementation Year	Percentage Increase
SmartPV Sample	6864.11 kWh	7138.98 kWh	4,00
Rest of Cyprus Sample	6785 kWh	7204 kWh	6,18
		SmartPV Savings	-2,18

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Evaluation Stage – Impact of ToU tariffs

- Peak kWh reduction due to possible various ToU price ratios was investigated using a constant elasticity of substitution (CES) expenditure function.
- Coefficient estimates indicate that:
  - Participant responsiveness to the time-varying prices is adequate
  - The developed ToU tariff structure is a major driver in the reduction of the consumption ratio
  - Total consumption has a compelling role in the peak kWh reduction
  - Rising temperatures tend to increase the participants' consumption ratio
  - During the weekends the ratio of peak to off-peak consumption is lower
  - Across the whole sample, the calculated cost index *I (=CES at ToU / CES at flat)* is below one → Based on similar studies the developed ToU tariff is welfare improving

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Evaluation Stage – Participants' Acceptance

Υπάρχει πιθανότητα επέκτασης της διατίμησης για ακόμη ένα χρόνο?

Είχα οικονομικό όφελος σε όλα τα δίμηνα. Απλά δεν χρησιμοποιούσα συσκευές σε ώρες αιχμής εκτός και αν ήταν ανάγκη.

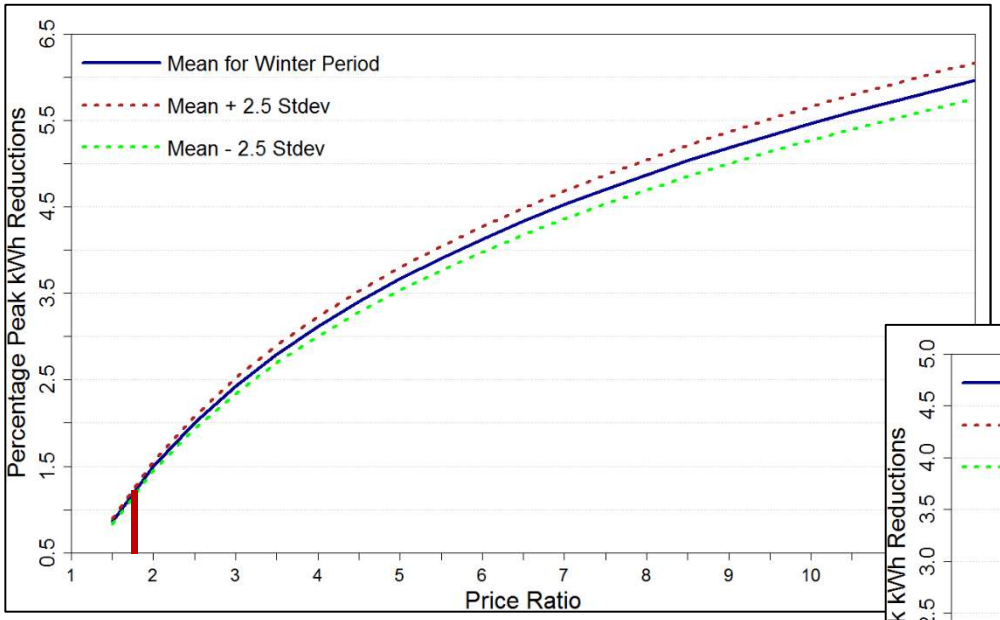
Το πιο σημαντικό ήταν η ιστοσελίδα, πρέπει να συνεχίσει η λειτουργία της!

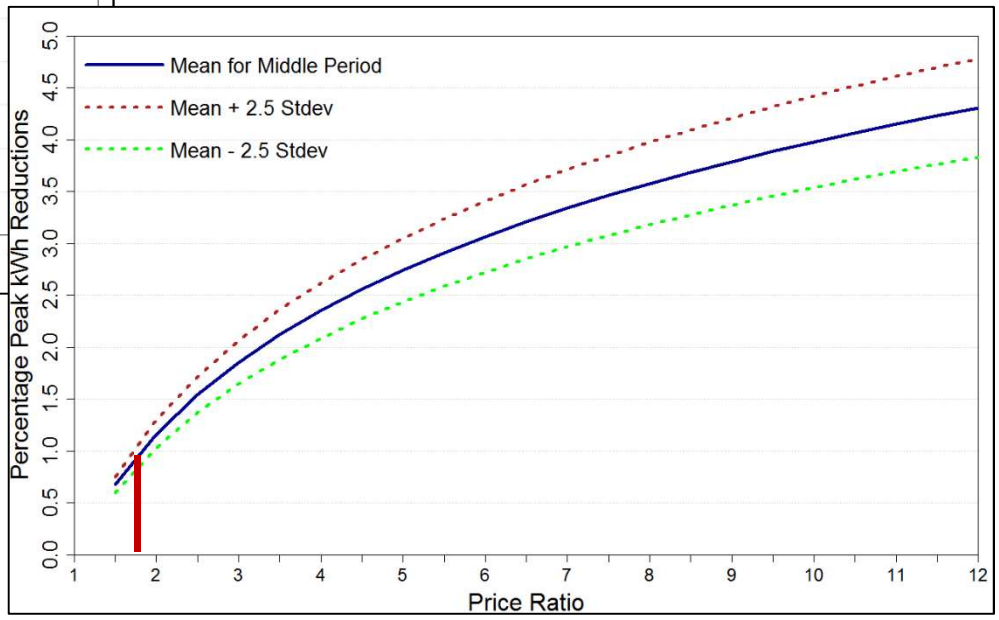
SmartPV

Evaluation Stage – Constant Refinement

- Implementing optimum ToU tariffs requires constant evaluation and refinement.
- Evaluation depends on:
  - Accurate calculation of the load shifting, peak clipping or energy conservation percentages.
  - Investigation of expenditure and consumption functions.
  - Estimation of the parameters that affect the participants' responsiveness.
  - Identification of areas of improvement.
- Refinement depends on:
  - Knowledge of new scientific methodologies for developing optimum ToU block periods and rates.
  - Consideration of new energy sources introduced into the energy mix.
  - Investigation of the potential impact on the participants as well as the power utility.
  - The effect of current energy policies.
- PV Lab can assess all the above through the expertise gained from numerous funded projects and provided services in the energy sector.

Evaluation Stage – Potential impact of future refinement





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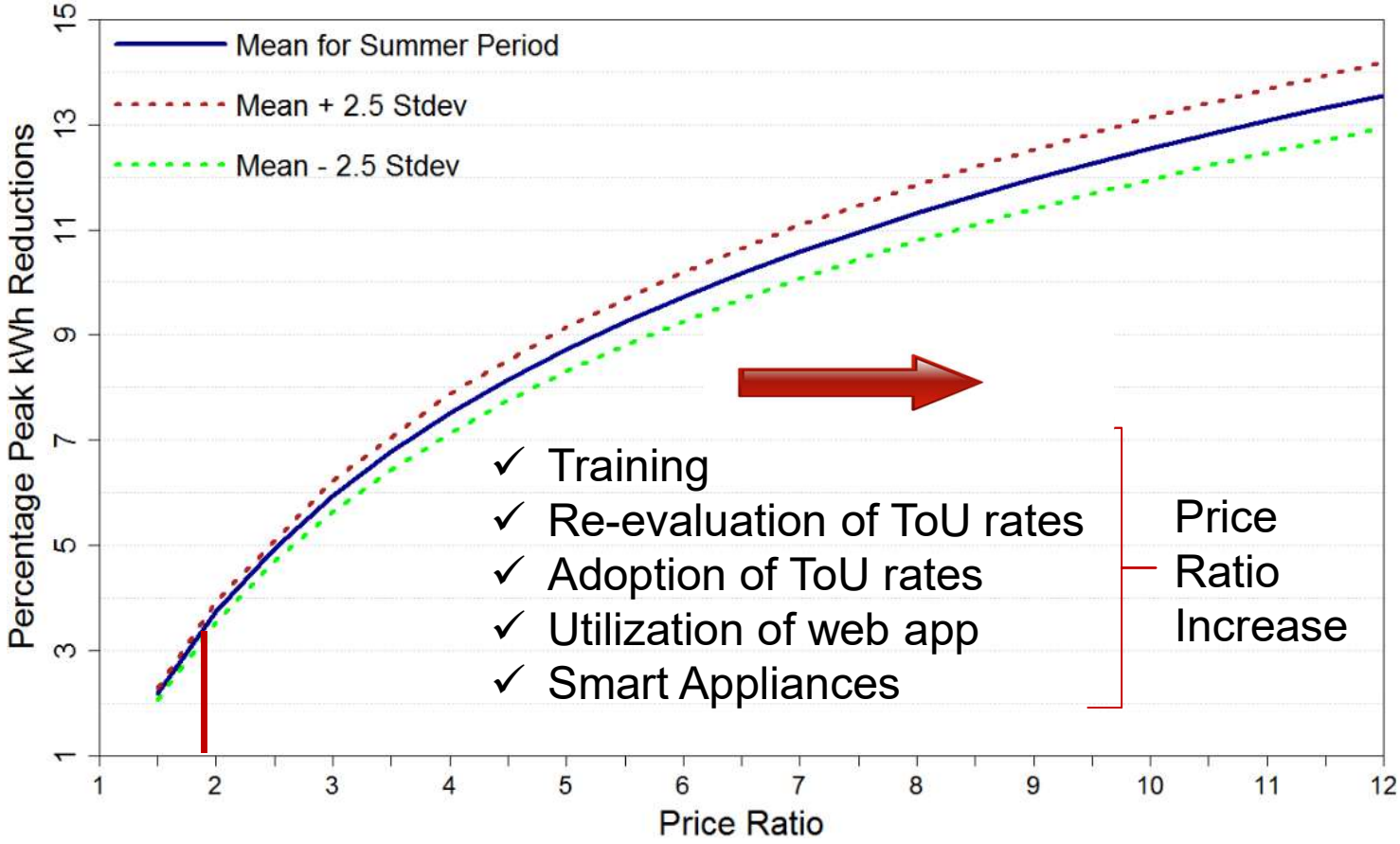
Evaluation Stage – Potential impact of future refinement



- Adopting a higher price ratio (peak/off-peak) for the summer period can potentially lead up to 14% peak kWh reduction.

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Contribution of the DSO

- Population of a base case sample of prosumers that is representative of the whole Cyprus
- Installation of Smart Meters and associated accessories in pilot net metering sites (284/300 prosumers, 377/400 SMs)
- Installation of 17 Weather stations at EAC buildings
- Energy and weather data collection and monitoring for one year (baseline)
- Development of optimum Time of Use tariffs
  - Cost reflective
  - Revenue neutral

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Contribution of the DSO

- Main training campaign by individual visits at the participants' premises.
- Development and maintenance of the web application
- Monitoring the participants' load profiles and comparing between ToU and flat tariff bimonthly electricity bills based on the consumption changes (implementation year)
- Progress evaluation meetings with the participants – feedback and suggestions
- Refinement of the applied ToU tariffs
- Final Results and Cost benefit analysis
- Continuous close collaboration with the UCY throughout the whole progress of the project

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Benefits for the DSO

- The pilot network acts as first class demonstration of the future smart grids.
- Technical know-how on smart meters installation, communication and data acquisition that will enable dynamic tariff structures.
- Experience on developing a time-varying pricing scheme that encourages the end-users to behave in a way that improves the overall efficiency of the energy system while minimizing the total costs → A flexible software tool for developing and evaluating ToU tariffs
- Glimpse on the participants' acceptance and responsiveness to time-varying electricity pricing.
- Cost benefit analysis will indicate the impact of a wide-scale rollout of smart net-metering in Cyprus.
- With the rise in DERs the system cannot be designed to cater for all contingencies without significant investment

  → Price-based DSM is the first step towards optimum flexibility that can reduce or postpone investment needs.
- A well structured ToU tariff scheme is the key to unlocking the potential of battery storage and maximize overall savings.

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Benefits for the Energy Ministry

- The pilot network acts as first class demonstration of the future smart grids
- More than 300 prosumers were educated on RES, smart net-metering and on their actual energy needs → Help in investing in PV systems
- A dynamic tool for developing and evaluating cost reflective ToU tariff structures based on a plethora of parameters.
- Real pilot-network results that can be utilized for successful testing and benchmarking of net-billing schemes.
- Based on the expertise gained through the project, UCY can provide guidelines that will assist authorities to improve energy and environmental policies.

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Benefits for the Industry

- Advanced metering can enable businesses to identify energy, cost and carbon savings by providing detailed information about the way in which industries as well as SMEs use their energy.
- Companies can benefit by altering their business models to realise new opportunities, such as sales of higher-margin metering services or products.
- Strengthen their market position and create new jobs.
- Former consumers may become suppliers and even service-providers (flexibility aggregators, BRPs) which leads to changes in the traditional business models of energy companies.
- Active collaboration will enhance networking and help in developing synergies among the SMEs.

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Conclusions

- As an island, Cyprus faces some electricity constraints that other countries may not have to contend with.
- The rapid growth of PV on the island will eventually render prosumers as the main class of residential electricity customers.
- Promoting higher levels of PV penetration that can be accommodated without grid reinforcement is of utmost importance → price-based DSM can be the solution.
- SmartPV led the way where Cyprus, as well as other solar countries, will be heading soon.
- The introduction of storage, EVs, aggregators, smart appliances and "active" prosumers will drastically change the energy landscape
  → it's time to change too.

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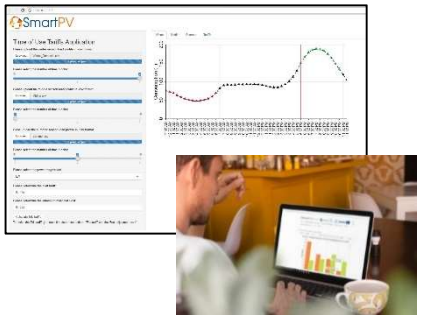
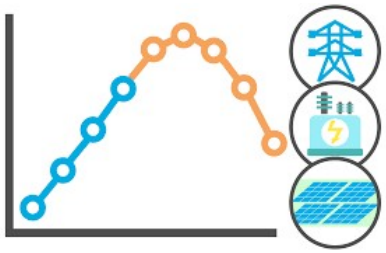


Optimum ToU tariffs & Energy Management (SmartPV, GoFLEX)

Storage Solutions (StoRES, PVESTIA)



Hour-ahead Forecasting (INFORPV)

Scientifically Justified Results

= Innovative Practices for Energy Transition

George E. Georghiou

Nicosia, Cyprus - 20/11/2017

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Thank you for your attention!

George E. Georghiou

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