ENI CBCMED Cooperating across borders in the Mediterranean

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REGIONE AUTÒNOMA DE SARDIGNA
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BERLIN

Cost-effective rehabilitation of public buildings into smart and resilient nano-grids using storage

Thematic Objectives: B.4 - Environmental protection, climate change adaptation and mitigation (Address common challenges in environment)
Priority: B.4.3 - Support cost-effective and innovative energy rehabilitations relevant to building types and climatic zones, with a focus on public buildings
Countries: Cyprus, Greece, Israel, Italy

Output nº: 4.3
Output Title: Stimulating the uptake of PV+ESS+DSM hybrid technology through country specific recommendations
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4 Contents

1 Project summary

In an effort to address high energy consumption in the building sector that is mainly fossil – fuelled, support rural areas and areas powered by weak grids, which are common in the MENA region, and achieve higher grid penetration of renewable energy sources (RES) while maintaining grid stability and power quality, this project aims at the implementation of cross border pilots that will support innovative and cost – effective energy rehabilitation in public buildings based on the nanogrid concept. Thus, BERLIN project focuses on the increase of photovoltaics (PV) penetration, which coupled with energy storage and demand – side management (DSM) will increase the energy efficiency (EE) of the buildings. The implementation of these technologies in a cost – effective way will result in high level of self – resilient public buildings that are green, smart, innovative, and sustainable. A total of 6 pilot buildings will be implemented: 1 in Cyprus, 2 in Greece, 2 in Israel and 1 in Italy.

The project started in September 2019 and will be completed in September 2023.

2 Introduction

Static tariffs do not encourage the widespread of RES without large incentives, which however transfer the RES costs to non-RES owners. One important goal of the BERLIN project is to propose new dynamic tariffs that better reflect the actual dynamic cost of electricity generation in each participating country with a pilot. It noted that such provisions are recommended in the EU's winter package[1]. The current report begins with an overview of the existing tariffs in the four participating countries of the BERLIN project (Cyprus, Greece, Israel, and Italy). Subsequently, information is provided on the proposed dynamic tariffs that can be developed and implemented in each pilot based on electricity market prices. At a later stage, the developed dynamic tariffs will be virtually tested at each pilot site (see deliverable A3.2.4).

[1]https://www.epr.eu/european-commission-publishes-winter-package/

3 Existing tariffs in the Mediterranean region

In this section a summary of the existing tariffs in four partner countries (Cyprus, Greece, Israel, and Italy) is provided.

3.1 Cyprus

Currently, the tariffs in Cyprus are categorized in regard to the type of use, specifically:

- Commercial and industrial use
- Domestic use

3.1.1 Tariffs for commercial and industrial use[2]

In tariffs for commercial use, electricity is solely used for commercial purposes, or for any other purpose related to commerce or profession. This also includes electricity supply to churches, monasteries, hospitals, schools, boarding houses, hotels, hostels, clubs, public buildings, and private buildings. In industrial use tariffs, electricity is used for the purpose of generating electromotive power, or electrochemical/electrothermal processes in factories, workshops, foundries, mills, pumping stations, or other industrial installations[3]. Four different electricity supply schemes are currently available from the Electricity Authority of Cyprus. The details are given below.

1. **Bimonthly[4] low voltage commercial and industrial use tariffs**

These tariffs are applicable to Low Voltage (LV) electricity supply, where the approved Load Entitlement of the customer's premises does not exceed 70 kVA (100A 3-ph). The bimonthly charges for the supply of electricity based on this tariff for the basic price of €300/M.T. of fuel cost are as follows:

Commercial Use

- Energy Charge per unit (kWh) €0.1066
- Network Charge per unit (kWh) €0.0302
- Ancillary Services Charge per unit (kWh) €0.0065
- Meter Reading Charge €0.9800
- Supply Charge €6.0800

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[2] Values valid as of 22 June 2022.
[3] https://www.eac.com.cy/EN/RegulatedActivities/Supply/tariffs/Pages/supply-tariffs.aspx
[4] The period where the meter readings are taken bimonthly, meaning the period from the commencement of the supply to the first routine meter reading or the period from one such reading to the next or the period from one such reading to the termination of the supply on any particular tariff, as the case may be.

The Energy Charge per kWh is based on the energy price of the Wholesale Tariff T-W and the basic price of RES purchases for 2022:

- Wholesale Tariff T-W €0.1098
- RES Compulsory purchases €0.0734

Industrial Use

- Energy Charge per unit (kWh) €0.1072
- Network Charge per unit (kWh) €0.0302
- Ancillary Services Charge per unit (kWh) €0.0065
- Meter Reading Charge €0.9800
- Supply Charge €6.0800

The Energy Charge per kWh is based on the energy price of the Wholesale Tariff T-W and the basic price of RES purchases for 2022:

- Wholesale Tariff T-W €0.1106
- RES Compulsory purchases €0.0734

2. Monthly[5] low voltage[6] seasonal commercial and industrial use tariff

This tariff is applicable to LV electricity supply, where the approved Load Entitlement of the customer's premises exceeds 70 kVA (100 A 3-ph). The tariff charges are given in Table 1. The Energy Charge per kWh is based on the energy price of the Wholesale Tariff T-W and the basic price of RES purchases for 2022 (see Table 2).

[5] The period where the meter readings are taken monthly, means the period from the commencement of supply to the first routine meter reading or the period from one such reading to the next or the period from one such reading to the termination of supply on any particular tariff as the case may be.
[6] 'Low Voltage' means supply of electricity metered at 0.5 kV or less.

Table 1: Tariff charges for monthly low voltage seasonal two-rate commercial and industrial use tariff.

Tariff charges	Periods	Charge per Unit (€/kWh) October-May Weekdays	October-May Weekends & holidays	June-September Weekdays	June-September Weekends & holidays	Monthly charge €
Energy charge	Peak	€0.0996	€0.0957	€0.1563	€0.0977	-
	Off-peak	€0.0875	€0.0830	€0.0955	€0.0934	-
Network charge	Peak	€0.0302	€0.0302	€0.0302	€0.0302	-
	Off-peak	€0.0302	€0.0302	€0.0302	€0.0302	-
Ancillary services charge	Peak	€0.0065	€0.0065	€0.0065	€0.0065	-
	Off-peak	€0.0065	€0.0065	€0.0065	€0.0065	-
Meter reading charge		-				€0.49
Supply charge		-				€3.04

Table 2: Wholesale tariff T-W for monthly low voltage seasonal two-rate commercial and industrial use tariff.

	Periods	October-May		June-September	
		Weekdays	Weekends & holidays	Weekdays	Weekends & holidays
Wholesale tariff T-W	Peak	€0.1013	€0.0973	€0.1601	€0.1002
	Off-peak	€0.0909	€0.0863	€0.0972	€0.0949
RES compulsory purchases	All	€0.0734	€0.0734	€0.0734	€0.0734

3. Monthly medium voltage[7] seasonal commercial and industrial use tariff

This tariff is applicable to Medium Voltage electricity supplies. The tariff charges are given in Table 3. The Energy Charge per kWh is based on the energy price of the Wholesale Tariff T-W and the basic price of RES purchases for 2022 (

Table 4).

[7] ‘Medium Voltage’ means supply of electricity metered between 11-66 kV.

Table 3: Tariff charges for monthly medium voltage seasonal two-rate commercial and industrial use tariff.

Tariff charges	Periods	Charge per Unit (€/kWh) October-May Weekdays	Weekends & holidays	June-September Weekdays	Weekends & holidays	Monthly charge €
Energy charge	Peak	€0.0976	€0.0938	€0.1531	€0.0957	-
	Off-peak	€0.0857	€0.0813	€0.0936	€0.0915	-
Network charge	Peak	€0.0183	€0.0183	€0.0183	€0.0183	-
	Off-peak	€0.0183	€0.0183	€0.0183	€0.0183	-
Ancillary services charge	Peak	€0.0064	€0.0064	€0.0064	€0.0064	-
	Off-peak	€0.0064	€0.0064	€0.0064	€0.0064	-
Meter reading charge		-				€0.49
Supply charge		-				€3.04

Table 4: Wholesale tariff T-W for monthly medium voltage seasonal two-rate commercial and industrial use tariff.

	Periods	October-May Weekdays	Weekends & holidays	June-September Weekdays	Weekends & holidays
Wholesale tariff T-W	Peak	€0.0992	€0.0953	€0.1568	€0.0982
	Off-peak	€0.0890	€0.0845	€0.0952	€0.0930
RES compulsory purchases	All	€0.0734	€0.0734	€0.0734	€0.0734

4. Monthly high voltage[8] seasonal commercial and industrial use tariff

This tariff is applicable to High Voltage electricity supplies. The tariff charges are given in Table 5. The Energy Charge per kWh is based on the energy price of the Wholesale Tariff T-W and the basic price of RES purchases for 2022 (see Table 6).

[8] 'High Voltage' means supply of electricity metered at 66 kV or more.

Table 5: Tariff charges for monthly high voltage seasonal two-rate commercial and industrial use tariff.

Tariff charges	Periods	Charge per Unit (€/kWh) October-May Weekdays	October-May Weekends & holidays	June-September Weekdays	June-September Weekends & holidays	Monthly charge €
Energy charge	Peak	€0.0956	€0.0919	€0.1500	€0.0937	-
	Off-peak	€0.0840	€0.0797	€0.0917	€0.0896	-
Network charge	Peak	€0.0054	€0.0054	€0.0054	€0.0054	-
	Off-peak	€0.0054	€0.0054	€0.0054	€0.0054	-
Ancillary services charge	Peak	€0.0064	€0.0064	€0.0064	€0.0064	-
	Off-peak	€0.0064	€0.0064	€0.0064	€0.0064	-
Supply charge		-				€3.04

Table 6: Wholesale tariff T-W for monthly high voltage seasonal two-rate commercial and industrial use tariff.

	Periods	October-May		June-September	
		Weekdays	Weekends & holidays	Weekdays	Weekends & holidays
Wholesale tariff T-W	Peak	€0.0972	€0.0934	€0.1536	€0.0962
	Off-peak	€0.0872	€0.0828	€0.0933	€0.0911
RES compulsory purchases	All	€0.0734	€0.0734	€0.0734	€0.0734

Peak and *off-peak* periods have been defined and approved by the Cyprus Energy Regulatory Authority (CERA) according to Decision No. 97/2017. The tariff structure for peak and off-peak periods is given in Table 7.

Table 7: Tariff structure for peak and off-peak periods.

Periods	Tariff structure October-May Weekdays	October-May Weekends & holidays	June-September Weekdays	June-September Weekends & holidays
Peak	16:00-23:00		9:00-23:00	
Off-peak	23:00-16:00		23:00-9:00	

3.1.2 Tariffs for domestic use[9]

Domestic Use tariffs are applicable where the electricity is solely used for domestic purposes to private dwellings.

1. Single Rate Domestic Use Tariff

The bi-monthly charges, at the basic price of €300/M.T. of fuel cost, for the supply of electricity based on this tariff, are given below:

Energy Charge per unit (kWh)	€0.1035
Network Charge per unit (kWh)	€0.0302
Ancillary Services Charge per unit (kWh)	€0.0065
Meter Reading Charge	€0.98
Supply Charge	€6.08

The Energy Charge per kWh is based on the energy price of the Wholesale Tariff T-W and the basic price of RES purchases for 2022.

Wholesale Tariff T-W	€0.1065
RES Compulsory purchases	€0.0734

2. Two Rate Domestic Use Tariff

The bi-monthly charges, at the basic price of €300/M.T. of fuel cost, for the supply of electricity based on this tariff, are given below:

Energy Charge per unit (kWh) during standard periods (09:00-23:00)	€0.1105
Energy Charge per unit (kWh) during economy periods (23:00-09:00)	€0.0901
Network Charge per unit (kWh) during standard periods (09:00-23:00)	€0.0302
Network Charge per unit (kWh) during economy periods (23:00-09:00)	€0.0302
Ancillary Services Charge per unit (kWh) during standard periods (09:00-23:00)	€0.0065
Ancillary Services Charge per unit (kWh) during economy periods (23:00-09:00)	€0.0065
Meter Reading Charge	€0.9800
Supply Charge	€6.0800

[9] Values valid as of 22 June 2022.

The Energy Charge per kWh is based on the energy price of the Wholesale Tariff T-W and the basic price of RES purchases for 2022.

- Wholesale Tariff T-W
  - Standard periods (09:00-23:00) €0.1134
  - Economy Periods (23:00-09:00) €0.0929
- RES Compulsory purchases
  - Standard periods (09:00-23:00) €0.0734
  - Economy Periods (23:00-09:00) €0.0734

3.2 Greece

As multiple electricity providers exist in the energy market of Greece, indicative charges are selected to be analysed below, that refer to the provider with the largest part (64% in August 2022) of consumers market, i.e., the Public Power Corporation S.A. (www.dei.gr). The charges are categorized according to the type of the consumer, in commercial and domestic customers. Moreover, since the charges of electrical energy are highly volatile due to the energy crisis, the analysis refers to the most recent price, that is of September 2022. An analytical list with electrical charges in Greece containing all electricity providers may be found at: https://www.rae.gr/times-kai-xreoseis/.

It is noted that charges for consumed energy deviate among electricity providers. All other costs (network, special, etc.) are regulated by the DSO and TSO and are identically charged to the customers of all providers.

Furthermore, all prices in the following tables are before VAT, that is 6%, and is applied at the final cost of the electricity bill.

3.2.1 Tariffs for commercial use

1. **Single rate low voltage commercial use tariffs**

These tariffs (Product G22) are applicable to Low Voltage electricity customers, with an approved Load Entitlement (ALE) between 25 kVA and 250 kVA. It actually refers to office buildings, large shops, medium industries. The charges for the supply of electricity are applied every 4 months as follows:

		Without state support	With state support
Energy charge (€/kWh)		0.785	0.443
Power charge[10] (€/kW/month)		2.2	
Electrical networks energy charge (€/kWh)	for cosϕ=1	0.02744	
	for cosϕ≠1	0.02574	
Electrical networks power charge (€/kVA^{ALE}/year)	for cosϕ=1	2.72	
	for cosϕ≠1	3.98*cosϕ	
Special charge for RES promotion (€/kWh)		0.017	
Special consumption charge (€/kWh)		0.005 (excl. agriculture businesses)	
Rest charges (€/kWh)		0.00007	
Fixed charge (€/month)		1.5	

2. Double rate low voltage industrial use tariffs

These tariffs (Product G23) are applicable to Low Voltage electricity customers. It actually refers to office buildings, large shops, medium industries. The charges for the supply of electricity are applied every 4 months as follows:

		Without state support	With state support
Energy charge during on-peak period[11] (€/kWh)		0.837	0.233
Energy charge during off-peak period[11] (€/kWh)		0.747	0.143
Electrical networks charge (<25 kVA) (€/kWh)		0.02744	
Electrical networks energy charge (>25 kVA) (€/kWh)	On-peak for cosϕ=1	0.02744	
	On-peak for cosϕ≠1	0.02574	
	Off-peak	0	
Electrical networks power charge (€/kVA^{ALE}/year)	On-peak for cosϕ=1	2.72	
	On-peak for cosϕ≠1	3.98*cosϕ	
	Off-peak	0	
Special charge for RES promotion (€/kWh)		0.017	
Special consumption charge (€/kWh)		0.005 (excl. agriculture businesses)	
Rest charges (€/kWh)		0.00007	
Fixed charge (€/month)		1.5	

[10] The maximum measured absorbed power within 30 days is used for this charge.

[11] On-peak periods are 08:00-15:00 and 17:00-02:00 for winter and 07:00-23:00 for summer. All other hours are defined as off-peak periods.

3. 4-month low voltage commercial use tariffs

These tariffs (Product G21) are applicable to Low Voltage electricity customers, with an approved Load Entitlement lower than 25 kVA. It actually refers to offices, shops, small industries, and garages with a low energy and power demand. The charges for the supply of electricity are applied every 4 months as follows:

	Without state support	With state support
Energy charge (€/kWh)	0.800	0.196
Electrical networks energy charge (€/kWh)	0.02744	
Electrical networks power charge (€/kVA^{ALE}/year)	1.46	
Special charge for RES promotion (€/kWh)	0.017	
Special consumption charge (€/kWh)	0.005 (excl. agriculture businesses)	
Rest charges (€/kWh)	0.00007	
Fixed charge (€/month)	1.5	

3.2.2 Tariffs for domestic use

Domestic Use tariffs are applicable where the electricity is solely used for domestic purposes to private dwellings.

1. Single Rate Domestic Use Tariff (as of 09/2022)

The 4-monthly charges for the supply of electricity based on this tariff are given below:

	Without state support	With state support
Energy charge for consumption 0–500 kWh (€/kWh)	0.788	0.149
Energy charge for consumption >500 kWh (€/kWh)	0.800	0.161
Electrical networks energy charge (€/kWh)	0.02974	
Electrical networks power charge[12] (€/kVA^{ALE}/year)	0.52	
Special charge for RES promotion (€/kWh)	0.017	
Special consumption charge (€/kWh)	0.0022	
Rest charges (€/kWh)	0.00007	
Fixed charge (€/month)	3.5	

[12] Calculated based on the approved load entitlement of the domestic installation that is usually 8 kVA.

2. **Double Rate Domestic Use Tariff (as of 09/2022)**

The 4-monthly charges for the supply of electricity based on this tariff are given below:

		Without state support	With state support
Energy charge for consumption during on-peak period (€/kWh)	0–500 kWh	0.788	0.149
	>500 kWh	0.800	0.161
Energy charge for consumption during off-peak period (€/kWh)		0.747	0.108
Electrical networks energy charge (€/kWh)		0.02974	
Electrical networks power charge (€/kVA^{ALE}/year)		0.52	
Special charge for RES promotion (€/kWh)		0.017	
Special consumption charge (€/kWh)		0.0022	
Rest charges (€/kWh)		0.00007	
Fixed charge (€/month)		3.5	
Fixed charge for DSO (€ for 8kVA/year)		4.16	

* Consumed energy charges deviate among electricity providers. All other costs (network, special, etc.) are identically charged to the customers of all providers.

3.3 Israel

Traditionally, economic incentives were provided through electricity feed-in tariffs, which were determined by the Israeli Electricity Authority. These tariffs were designed to ensure adequate profit for entrepreneurs, create business certainty through long-term agreements, and apply uniform rates based on various parameters.

To achieve the government's target of 30% renewables by 2030, additional incentives beyond existing regulations are necessary, particularly targeting sectors and technologies with high potential for renewable energy deployment. The Electricity Authority is gradually transitioning towards tariff payments based on benefits rather than costs, reflecting the increasing use of renewable energy.

On the consumer side, dynamic tariffs, also known as time-of-use tariffs, are being explored to incentivize energy efficiency and load shifting. These tariffs involve varying electricity prices based on the time of day or grid demand, encouraging consumers to shift their energy usage to off-peak hours and reduce strain on the grid.

Israel's electricity sector is undergoing significant reforms, including introducing smart meters and advanced metering infrastructure (AMI), laying the foundation for the potential future implementation of dynamic tariffs or other demand-response mechanisms. The recently introduced selective time-of-use (ToU) tariff allows customers to align their tariffs with their specific consumption patterns, providing flexibility and control over electricity expenses. This option encourages customers to be mindful of their electricity consumption and potentially shift usage to off-peak hours, promoting grid efficiency and optimal resource utilization.

By combining economic incentives with technological advancements and demand-side management initiatives, Israel aims to create a sustainable and efficient energy sector that encourages renewable energy adoption and responsible consumption practices.

3.3.1 Public Utility Authority

In Israel, the Public Utility Authority (PUA) https://www.gov.il/, is the regulatory authority for setting the electricity tariffs, as well as the method for their update. The Israeli electricity consumption is divided into three sectors:

(a) household sector with 21.7 TW consumption per year (2020),

(b) commercial sector with 16.2 TW consumption per year (2020), and

(c) the industrial sector with 14.3 TW consumption per year (2020).

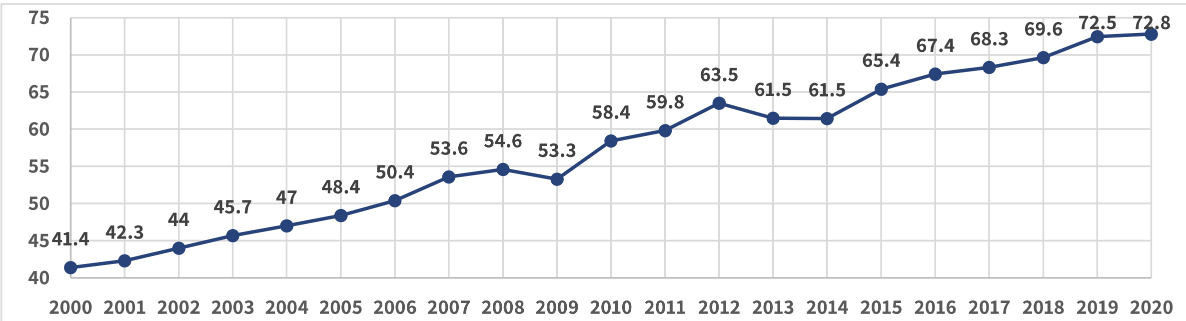


Figure 1: Consumption in Israel between 2000-2020 in billion kWh generation

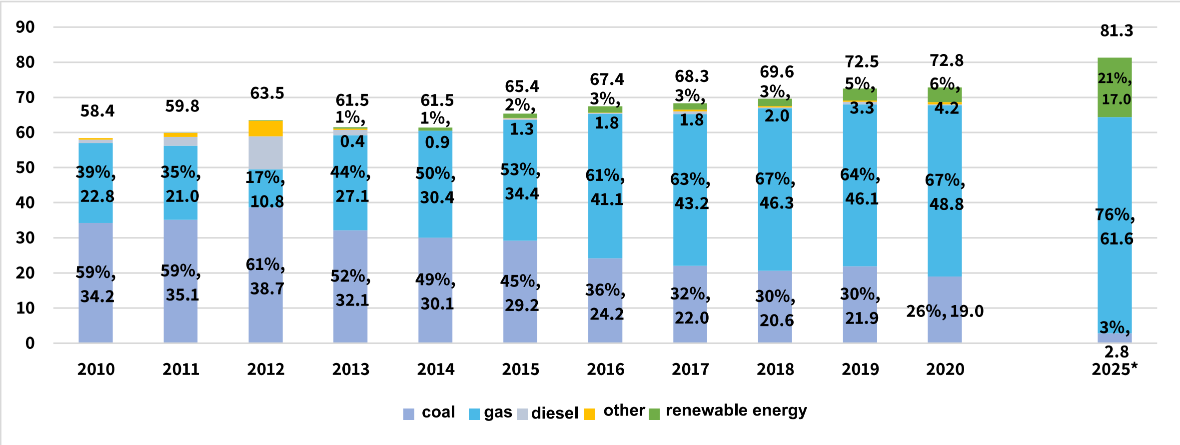


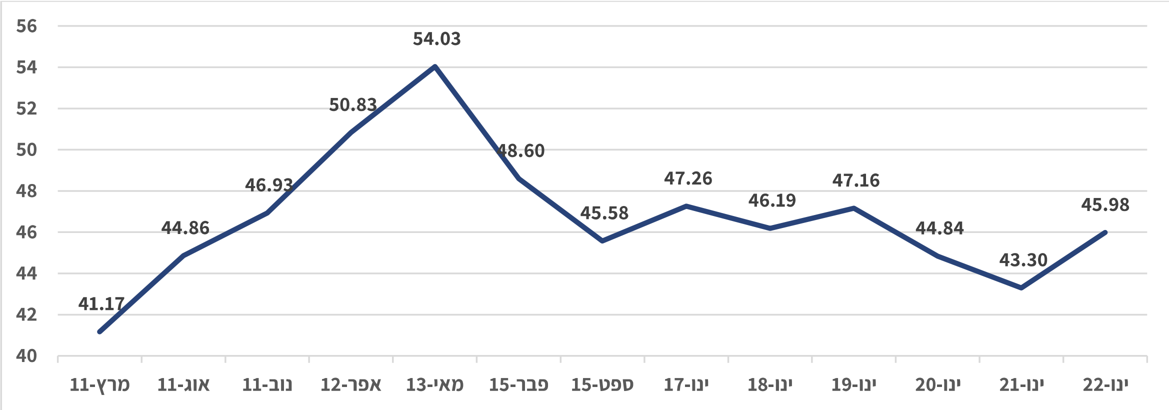
Figure 2: The energy generation in Israel relies on three main resources: natural gas, coal, and renewable energy (the combined electricity generation in TWs per hour is shown)

3.3.2 Electricity Producers

In June 2018 the government decided on creating a new reform in the electricity market in Israel. According to the reform, the electric company would sell five natural gas power plants until June 2023, with total capacity of 4500 MW (25% of the total country capacity).

Until 2019, the household tariff was a combination of two parts: the unchanged, steady part and the part that relies on consumption. The steady part is based on the services provided by the Electric Company (IEC). The consumption price is set according to the type of consumer, and the type of connection to the electricity grid. The consumption price is the tariff that the consumer pays for the consumption.

In January 2019 another price was added, which is based on the size of the connection of the consumer to the grid.



Difference %	Difference	2022	2021	
6.2%	0.027	45.98	43.3	**Household triff (Agorot per kWh)**
6.2%	17.9	306.5	288.7	**Household cost per representing 8'000 kWh/year (NIS/Month)**
-2.2%	-0.1	4.5	4.6	**Household Connection Capacity tariff for 3X25 A (NIS/Month)**
1.4%	0.3	21.3	21.0	**Household Delivery tariff for 3X25 A (NIS/Month)**
5.7%	**18.1**	**332.3**	**314.3**	**Total Per Month**

Figure 3: Tariffs in agorot (cents) for the consumption price alone

3.3.3 Household and public

The household tariff was updated in August 2022. It was set at €0.14/kWh (unchanged over the day or season). The general tariff was also updated in August 2022, and is intended for commercial, industrial, tunnels, hospitals, and other uses. It was set at €0.1478/kWh (unchanged over the day or season). The streetlighting tariff was also updated in August 2022. It was set at €0.125/kWh (unchanged over the day or season).

3.3.4 Storage

At the beginning of 2023 a new complementary FIT was decided in order to encourage store installation behind the meter. The new decision set a defence mechanism that will compensate PV system owner that are up to 630 kW installed. The mechanism allows to install storage systems behind the meter and receive additional FIT when the PV FIT is lower than the consumption tariff, the PV owner will receive the difference between the two minus 15% of the consumption tariff up to 300 kW PV systems and minus 30% of the consumption tariff for PV systems above 300 kW. The decision is implemented fully since April 2023 and needs few more month to examine its role in assimilation of PV with storage. Nonetheless, this regulation can help the project to receive approval for the PV and BESS.

3.4 Italy

In Italy, at the end of the year, the Authority ARERA updates the tariffs for the provision of electricity transmission, distribution, and measurement services for **domestic** and **non-domestic** customers to be applied in the next year. Electricity prices include the basic price, as well as transmission, system services, distribution, and other services. Prices include all taxes, levies, and VAT. The national average tariff covering transmission, distribution and metering costs for the year 2021 is 28.64 c€/kWh (27.57 c€/kWh for 2020), and it is strongly increased in 2022 (30.7 c€/kWh in March 2022) [Source: ARERA].

Moreover, the charges of electrical energy are highly volatile due to the energy crisis, and Social Bonuses have been introduced by ARERA with an automatism: 2021 was the first year during which the new system of automatic recognition of social electricity, gas, and water bonuses, to help address the economic difficulties, came into effect (introduced with the 2020 Tax Decree). The automatism became operative starting 1 July for supplies of gas and electricity (including for customers served by condominium supplies). The introduction of the automatism has tripled the number of families benefiting from an automatic discount directly on the gas and electricity bills.

Indeed, Italy's regulated household electricity prices will increase by 59% in the fourth quarter of 2022, announced ARERA, as international conflicts and war impacts energy prices across Europe. The change, which reflects a spike in wholesale energy prices, concerns 41.5% of Italian households, according to ARERA's 2021 data. Market conditions would have dictated a far higher price hike of "about 100%", but ARERA intervened exceptionally to dampen the increase.

3.4.1 Tariffs for non-domestic use

'Non-household' refers to medium-sized consumers with an annual consumption of between 500 MWh and 2 000 MWh. In 2021, the average Italian price for non-household consumers was 15,84 c€/kWh, without taxes (energy, supply, and network taxes). Figure 4 shows the average electricity price for non-household consumers in Italy in 2019, by voltage level. According to the graph, the price was inversely correlated with the voltage level. Indeed, while low voltage level corresponded to a cost of about 210.8 €/MWh, the price high voltage electricity was equal to 81.7 €/MWh.

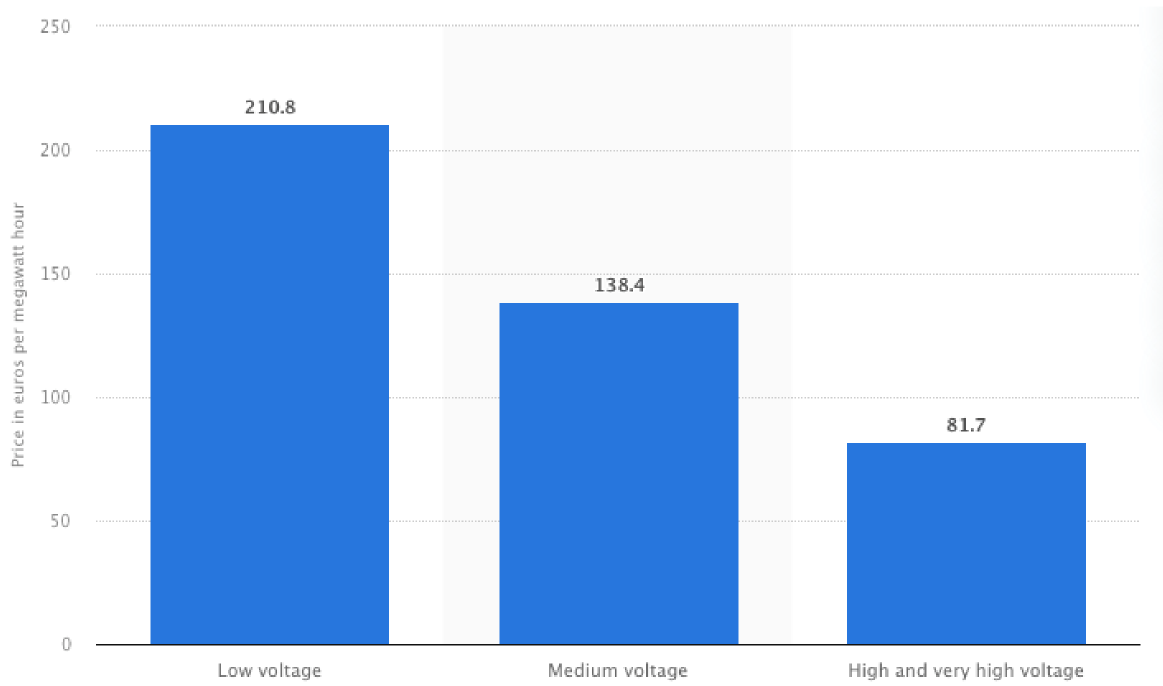


Figure 4: Average electricity price for non-household consumers in Italy in 2019, by voltage level, in €/MWh [Source: Statista Research Department]

Economic conditions for non-household customers of the Higher Protection regime (IV quarter 2022)

Three different periods (peak, middle and off-peak) are considered in the tariffs:

- Band **F1**: from 8 to 19 from Monday to Friday, excluding national holidays.
- Band **F2**: from 7 to 8 and from 19 to 23 from Monday to Friday and from 7 to 23 on Saturdays, excluding national holidays.
- Band **F3**: from 11pm to 7am from Monday to Saturday and all hours on Sundays and national holidays.

The charges for the supply of electricity based on the Protection regime are given below for customers connected in Low Voltage with contractual power up to 15 kW.

Table 8: Economic conditions for customers of the Higher Protection Service (IV quarter 2022, tax excluded) [Source: ARERA]

- for P lower than or equal to 1.5 kW

1 Oct. - 31 Dec 2022	**Energy**			**Transport and meter management**	**System charges ***
Energy charge consumption (euro/kWh)	*F1*	*F2*	*F3*		
Oct. 2022	0.53276	0.54858	0.46868	0.00932	0.000000
Nov. 2022	0.58770	0.59257	0.49994		
Dec. 2022	0.54276	0.57053	0.48442		
Fixed charge (euro/year)	106.2693			23.6276	0.0000
Power charge (euro/kW/year)	-			28.2832	0.0000
Electronic bill discount	*Customers who receive their bills in electronic format and pay it automatically will receive a discount of 6.60 €/year.*				

- for P greater than 1.5 kW and less than or equal to 3 kW

1 Oct. - 31 Dec 2022	**Energy**			**Transport and meter management**	**System charges ***
Energy charge consumption (euro/kWh)	*F1*	*F2*	*F3*		
Oct. 2022	0.53276	0.54858	0.46868	0.00932	0.000000
Nov. 2022	0.58770	0.59257	0.49994		
Dec. 2022	0.54276	0.57053	0.48442		
Fixed charge (euro/year)	106.2693			23.6276	0.0000
Power charge (euro/kW/year)	-			26.7867	0.0000
Electronic bill discount	*Customers who receive their bills in electronic format and pay it automatically will receive a discount of 6.60 €/year.*				

- for P greater than 3 kW and less than or equal to 6 kW

1 Oct. - 31 Dec 2022	**Energy**			**Transport and meter management**	**System charges ***
Energy charge consumption (euro/kWh)	*F1*	*F2*	*F3*		
Oct. 2022	0.53276	0.54858	0.46868	0.00932	0.000000
Nov. 2022	0.58770	0.59257	0.49994		
Dec. 2022	0.54276	0.57053	0.48442		
Fixed charge (euro/year)	106.2693			23.6276	0.0000
Power charge (euro/kW/year)	-			29.7797	0.0000

Electronic bill discount	*Customers who receive their bills in electronic format and pay it automatically will receive a discount of 6.60 €/year.*

- for P greater than 6 kW and less than or equal to 10 kW

1 Oct. - 31 Dec 2022	**Energy**			**Transport and meter management**	**System charges ***
Energy charge consumption (euro/kWh)	*F1*	*F2*	*F3*		
Oct. 2022	0.53276	0.54858	0.46868		
Nov. 2022	0.58770	0.59257	0.49994	0.00932	0.000000
Dec. 2022	0.54276	0.57053	0.48442		
Fixed charge (euro/year)	106.2693			24.0758	0.0000
Power charge (euro/kW/year)	-			29.7797	0.0000
Electronic bill discount	*Customers who receive their bills in electronic format and pay it automatically will receive a discount of 6.60 €/year.*				

- for P greater than 10 kW and less than or equal to 15 kW

1 Oct. - 31 Dec 2022	**Energy**			**Transport and meter management**	**System charges ***
Energy charge consumption (euro/kWh)	*F1*	*F2*	*F3*		
Oct. 2022	0.53276	0.54858	0.46868		
Nov. 2022	0.58770	0.59257	0.49994	0.00932	0.000000
Dec. 2022	0.54276	0.57053	0.48442		
Fixed charge (euro/year)	106.2693			24.0758	0.0000
Power charge (euro/kW/year)	-			29.7797	0.0000
Electronic bill discount	*Customers who receive their bills in electronic format and pay it automatically will receive a discount of 6.60 €/year.*				

3.4.1.1 Tariffs for industrial use

Electricity prices for industrial consumers with consumption between 500 MWh and 2,000 MWh tended to pay higher prices than industrial user with consumption greater than 20,000 MWh in Italy. As of 2021, electricity prices without taxes (energy, supply, and network taxes) for these consumers amounted to 15.84 c€/kWh and 10.61 c€/kWh, respectively (Figure 5). For an annual consumption of less than 2,000 MWh, the prices for electricity peaked in 2014 at 17.28 c€/kWh, while electricity price for energy-intensive industries peaked at 13.62 c€/kWh.

In 2018, the Italian government approved a tax relief reform, targeted at over 3 thousand energy-intensive industries, to reduce electricity costs for the industries that were most exposed to international competition. This measure was meant to promote energy efficiency in the industry sector as well as boost Italian competitiveness abroad. Compared to most European countries, Italian industries paid significantly more for electricity. The average electricity price for the French industrial sector, for example, was much lower throughout the observed period.

A key aspect is due to the Italy's dependency on gas. In 2018, natural gas accounted for 45% of the country's electricity production. Overall, Italy relied on gas imports for over 90% of its demand. This means that the price of gas largely depends on the wholesale price rather than the domestic market. Italy's main supplier was Russia, with over 28 billion cubic meters imported in 2020, while the domestic production amounted to 4.4 billion cubic meters.

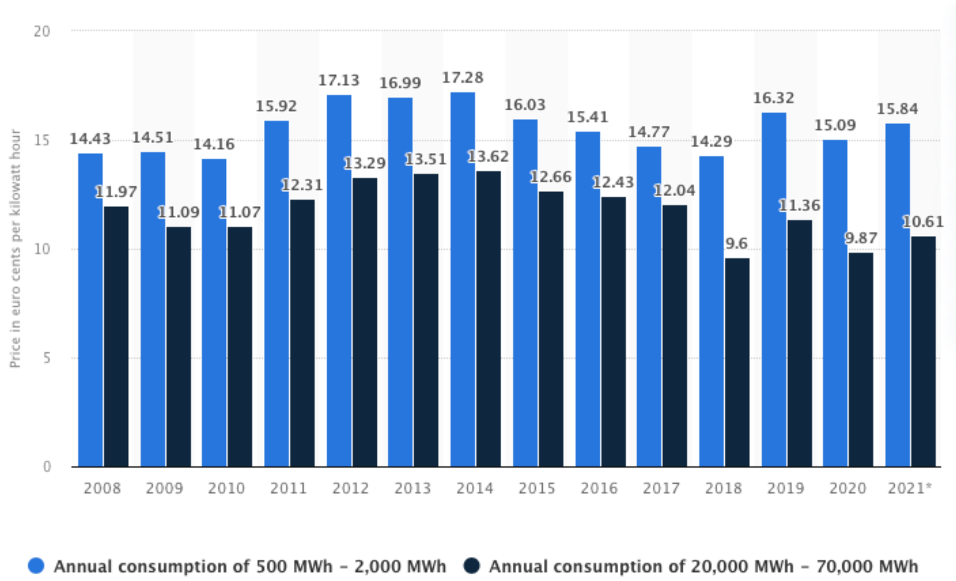


Figure 5: Prices of electricity for industry in Italy from 2008 to 2021 in c€/kWh [Source: Eurostat; Statista Research Department] *provisional data

Table 9: Electricity prices for industrial uses in 2021 (net and gross, in c€/kWh) in Italy [Source: Eurostat]

CONSUMERS BY YEARLY CONSUMPTION RANGE (MWh)											
< 20		20-500		500-2.000		2.000-20.000		20.000-70.000		70.000-150.000	
NET	GROSS	NET	GROSS	NET	GROSS	NET	GROSS	NET	GROSS	NET	GROSS
18.92	32.73	13.21	22.97	11.71	19.90	10.79	16.54	10.60	13.95	11.62	13.46

3.4.2 Tariffs for domestic use

With regard to Italian households, in December 2021, 12.4 million were served under the protection regime offer and 17.5 million on the **free market**: the surpassing by the free market of the **protection regime** offers, which had begun in 2020, therefore continued. The average percentage of domestic points served on the free market rose to 58.5% in 2021, as compared with 54.3% in 2020.

In 2021, Sardinia was the only region in which the portion of families purchasing electricity on the free market did not reach 50%; in all the other 19 regions more than half of families purchase electricity on the free market. Family switching has grown further, with acceleration stimulated by expectations surrounding the removal of price protection, now expected for January 2024 for households and, in all likelihood, to look for more favourable economic conditions for the extraordinary growth of prices starting from the second half of 2021.

Households covers medium-sized consumers with annual consumption of between 2 500 kWh and 5 000 kWh. In 2021, electricity prices for Italian households with an annual consumption between 1,000 and 2,500 kWh averaged 25.58 c€/kWh, without taxes (energy, supply, and network taxes). Regarding households with an annual consumption up to 5,000 kWh, their electricity price was slightly cheaper, at 22.59 c€/kWh (Figure 6).

Between 2016 and 2021, the most remarkable price increment occurred between the 3rd and the 4th quarter of 2018, when the electricity price for an average household customer increased by 7.6%. In 2018, the regions with the greatest annual household expenditure on electricity were Sardinia, Veneto, and Trentino-South Tyrol. Sardinia was among the regions with the greatest amount of electricity generated from wind and with the highest wind power installed capacity.

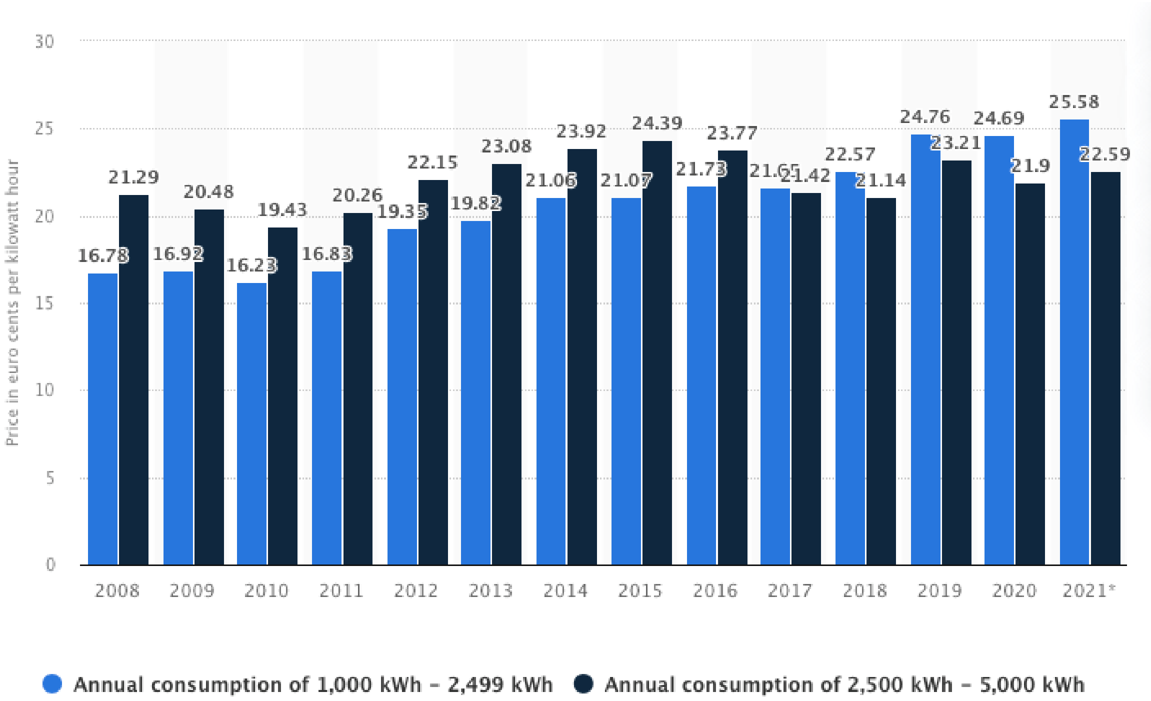


Figure 6: Household prices of electricity in Italy from 2008 to 2021 in c€/kWh [Source: Eurostat; Statista Research Department]

Economic conditions for household customers of the Higher Protection regime (IV quarter 2022)

A single-rate tariff and a double-rate tariff, based on peak (F1) and off-peak (F23) periods are considered. The charges for the supply of electricity based on the Protection regime are given below for domestic customers with and without registered residence.

Table 10: Economic conditions for household customers of the Higher Protection Service (IV quarter 2022, tax excluded) [Source: ARERA]

A) Houses of registered residence

1 Oct. - 31 Dec. 2022	Energy			Transport and meter management	System charges
	Single rate	Double rate			
		F1	*F23*		
Energy charge consumption (euro/kWh)	0.53451	0.55436	0.52484	0.00873	0.0000
Fixed charge (euro/year)	51.5400			19.4400	-
Power charge (euro/kW/year)	-			20.2800	-
Electronic bill discount	*Customers who receive their bills in electronic format and pay it automatically will receive a discount of 6 €/year.*				

B) Houses other than registered residence

1 Oct. - 31 Dec. 2022	Energy			Transport and meter management	System charges
	Single rate	Double rate			
		F1	*F23*		
Energy charge consumption (euro/kWh)	0.53451	0.55436	0.52484	0.00873	0.0000
Fixed charge (euro/year)	51.5400			19.4400	0.0000
Power charge (euro/kW/year)	-			20.2800	-
Electronic bill discount	*Customers who receive their bills in electronic format and pay it automatically will receive a discount of 6 €/year.*				

These tariffs are applicable to Low Voltage electricity supplies. The charges for the supply of electricity in a family with 3 kW of committed power and 2,700 kWh of annual consumption are as follows.

Table 11: Economic conditions for household customers of the Higher Protection Service [c€/kWh] (Year 2022, P=3kW, E=2700kWh/year) [Source: ARERA]

Domestic Use	c€/kWh			
	I 2022	**II 2022**	**III 2022**	**IV 2022**
Energy Charge per unit (kWh)	37.2	32.93	33.08	55.36
Network Charge and metering per unit (kWh)	3.84	3.84	3.85	3.85
System Charge per unit (kWh)	0	0	0	0
Taxes	4.99	4.57	4.58	6.8
TOTAL	**46.03**	**41.34**	**41.51**	**66.99**

4 Static vs. dynamic tariffs

Static tariffs do not encourage the widespread of RES without large incentives. However, such large incentives transfer the RES costs to non-RES owners. On the other hand, dynamic tariffs provide a fairer charging, and thereby they are more attractive to prosumers. This is because they have significant advantages, namely:

(1) They provide a balance between supply vs. demand, which leads to reduced grid stability-related costs.
(2) They favour the integration of RES-based systems in the central power grid, which helps to reduce carbon emissions.
(3) They increase overall economic efficiency since they have the capability of reflecting time-varying costs of power supply.

Since it is not fair for the utility to charge every customer with fixed costs that relate to the utilization of RES, it is more justifiable to charge only those customers that generate energy from RES and apply added fixed costs for the use of the central power network to:

- Export their generated electricity.
- Import electricity to satisfy/supplement their consumption load profile, when RES-based electricity is unavailable or insufficient, i.e., during cloudy or rainy days, and night-time.

Dynamic tariff rates may vary during the day based on the electricity demand and RES type. Moreover, the purpose of the application of dynamic tariffs is to provide an active role to prosumers via the enabling of DSM methods, which can help towards the reduction of the peak load. This can in turn help decrease the required system components' capacity, and simultaneously increase the overall efficiency of the network. The dynamic tariff types that can be utilized in combination with DSM are the following: (a) Time-of-Use (ToU), (b) Real-Time Pricing (RTP), (c) Critical Peak Pricing (CPP), and (d) Peak-Time Rebate (PTR).

Baseload power (i.e., when demand is low) is covered through onsite PV electricity (when solar energy is directly available), or battery storage units (when solar energy is unavailable). High demand power periods mean that in addition to baseload power, there is a need for additional (peak) power, which must/can be supplied by every available onsite source (in this case: PVs and batteries), but also through power imports from the central power grid.

5 Development of new dynamic tariffs for the buildings of the BERLIN pilots

To develop a dynamic tariff scheme, it is necessary to use historical consumption data for the buildings of the BERLIN pilots. In this manner, the proposed dynamic tariff will be realistic and effective in terms of satisfying the required demand since they can closely match the future consumption patterns of the serviced buildings. For this purpose, datasets from each pilot site have been collected to develop the dynamic tariff for each pilot.

5.1 Characteristics of the BERLIN pilots

The BERLIN pilots include the followings characteristics:

- Buildings with a certain consumption load profile
- PV modules
- Battery energy storage units
- Smart meters

These elements provide operational flexibility to prosumers, which are independent (the network can be considered to be one consumer). Therefore, high levels of self-consumption and self-sufficiency can be achieved through the proposed ToU tariffs which utilize practical techniques such as DSM & Demand Response. For this purpose, the specific capacities of PV modules and BESS of each pilot will be considered in the analysis.

5.2 Demand Side Management

For the purposes of the BERLIN project, the selected dynamic tariff must be formulated in a way that encourages prosumers to apply DSM. This is because DSM allows different prosumers to modify their load profile pattern to accomplish multiple targets, such as peak clipping, flexible load, valley shifting, valley filling, load building, and load conservation (see Figure 7). Different load shaping combinations can be adopted to match the electricity generation as much as possible. DSM also allows flattening of the demand, which can help in the reduction of the capacity of system components that are used to fulfil the peak demand (in this case, PV modules and battery units). This also helps in the maximization of the load factor and the system efficiency. Since the target of the BERLIN project is to utilize a DSM method based on cost, the most appropriate dynamic tariff types are CPP, ToU and RTP. For this purpose, two smart meters have already been installed in each pilot site to record the amount of PV generation and energy consumption. Additionally, In-House-Displays (IHD) have been installed in the pilot locations to allow users to collect online information of their energy consumption.

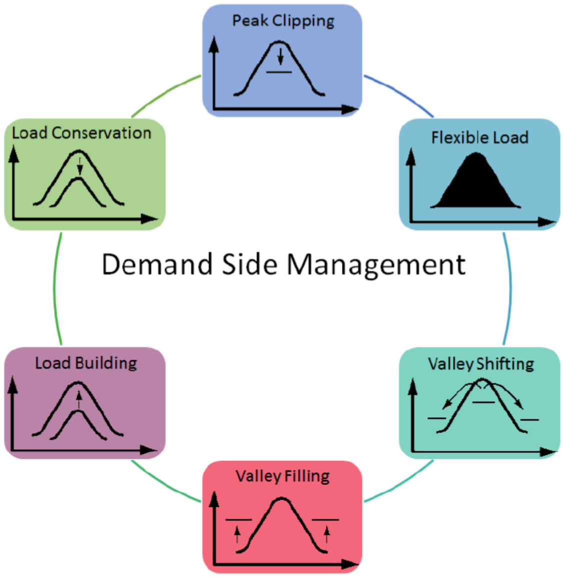


Figure 7: Use of Demand Side Management to fulfil different requirements.

In the lines of the aforementioned objectives, some specific Demand Response (DR) practices can be utilized during on-peak periods when electricity consumption is high and electricity is expensive, namely:

- For refrigerators, and air conditioning units operating in cooling mode, increase the thermostat setting by 2°C for a limited amount of time (done automatically)
- For air conditioning units operating in heating mode, decrease thermostat setting by 2°C for a limited amount of time (done automatically)
- Turn-off non-essential lighting
- Avoid charging equipment that can be charged at other times
- Utilize available storage units, i.e., discharge batteries to reduce electricity consumption from the network

On the other hand, during off-peak hours, when electricity is cheap, users can shift their electric usage as follows:

- Increase consumption as much as possible by programming the operation and run all equipment that can operate unsupervised outside office hours (e.g., shift deferrable loads and operate unattended equipment w/ timers) to shift demand high tariff rate periods to low tariff rate periods
- Charge BESS units and any other appliances and equipment (e.g., EVs) at their maximum extend

- Install timers on electric water heaters and recirculation pumps so they operate mainly during off-peak hours
- Consider utilizing heating/cooling inertia by operating electric heat pump units during off-peak hours when electricity is cheap (e.g., early in the morning at 04:00-06:00)

Additionally, users can plan attended consumption on Mondays and days after other non-working days when batteries are fully charged.

5.3 Selection of the type of tariff

For the implementation of a new dynamic tariff suitable for the pilots of the BERLIN project, the chosen tariff type is ToU, since it has been identified as the most appropriate one, based on past experience (see SmartPV project[13]). This is because ToU tariffs promote pricing distinction in the following ways:

- Throughout the day (morning vs. afternoon vs. night)
- Between working day vs. non-working day, and
- Between seasons (summer vs. mid-season vs. winter)

Therefore, the unit cost of electricity (€/kWh) depends on the time, day, or season when electricity is consumed. Such provisions aim to encourage/discourage electricity consumption in different time periods, with the ultimate aim of saving money and reducing peak demand.

Definition of pricing range:

- *On-Peak*: Energy demand and cost are high.
- *Mid-Peak*: Energy demand and cost are moderate.
- *Off-Peak*: Energy demand and cost are low.

Usually, periods and prices are known well in advance, but prices can also be defined on an average basis for different time periods. In this way, users can vary demand from on-peak to off-peak time periods and/or reduce on-peak demand, targeting reduction of system costs and efficiency maximization. Another advantage of ToU tariffs is the fact that they do not require complicated two-way communication systems (as in the case of RTP), which allows a more robust communication process in relation to smart meters and data management.

ToU tariffs also acknowledge the variation of energy supply costs very effectively, which is key for the successful implementation of the BERLIN pilots. ToU aims to promote the change of the routine behaviour of end-users to improve base load (e.g., to increase RES uptake). These are predeclared tariffs varying during the different times of the day, that is, high during on-peak hours and low during off-peak hours. Such schemes can stay effective for short- or long-term time periods.

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[13] http://www.smartpvproject.eu/

Overall, ToU tariffs are ideal for residential and small commercial customers, as they give more control over the electricity bill to the customer. This means that by adjusting their usage pattern, ToU pricing enables them to save money during hours when electricity is more expensive. They require smart meters for easy visualization of the consumption at any given instance, as ToU rates fluctuate. Non-working periods are typically priced with off-peak prices since demand at these times is usually low.

5.4 ToU tariff: design specifications, main characteristics, and impact

It is necessary for the applied ToU tariff to be beneficial for all stakeholders, and therefore it must be developed in such a way that maintains a neutral impact on the electricity bill. Specifically, customers must be able to reduce their electricity bills, while utilities reduce peak demand and better manage power generation.

Additionally, the ToU tariff can be considered effective only if it can be combined with DSM strategies which provide important economic incentives to the relevant stakeholders (generators, operators, suppliers, prosumers, etc). In such a scheme, a day is divided into periods of peaks and valleys, according to the load characteristics and the cost values corresponding to each period, respectively.

Design specifications:

- Peak and valley characterization of the load profile. This is crucial because the electricity price corresponds to each period. High power demand means high electricity prices, and vice versa.
- Start- and end-time of the rate zones/duration of each block period. The duration of each time block is essential to fulfil the real needs of flattening the load profile.
- The number of rate zones/period partition. The division of the daily load curve in different time periods is important, since the appropriate number of the different time periods will enhance DSM and facilitate the flattening of the daily load curve.
- The price level of the zones. The price level of each time block provides an incentive to prosumers to shift their demand away from on-peak periods.

Main characteristics:

- Cost neutrality. The tariff must maintain an identical electricity bill as the conventional flat tariff for an average consumer, who does not change the consumption profile and behaviour.
- Cost reflects pricing in all time blocks. The tariff for each period must reflect the total cost of energy generation and supply.
- Tariff structure could be based on the system peak demand, on the average consumer load profile, on annual basis, seasonal basis, etc.
- The tariff should include all market operating costs related to TSO, DSO, ancillary services, tertiary reserve, losses, etc.

Impact:

- Optimization of the objectives and constraints of the electricity provider. ToU enables DSM through load balancing, network stability, profit maximization for all stakeholders, etc.

- Customer response and acceptance. Information and training should be provided to the customers for effective and correct use the tariff.
- Regulatory restrictions. The regulatory authority of each country should audit the process so as to maintain the retail electricity price within fair price limits and respect the tariff zone limits to ensure that all involved stakeholders are fairly treated.

5.5 Methodology for the development of the new ToU tariff

The proposed ToU tariffs aim at enabling price-based DSM schemes that can reduce system cost by considering and analysing the current energy consumption of each pilot in the BERLIN project. This helps establishing the ToU block periods and estimating the ToU rates.

Step 1: Analysis of the energy consumption data for every pilot

The actual energy consumption data for the buildings of every BERLIN pilot have been acquired in preceding activities (see A4.3.1). For this purpose, smart meters have been installed in each pilot to record the consumption and production of energy. The analysis of usage patterns helps identifying peak variations and deciding a DSM policy that will be acceptable and beneficial. It is noted that although the actual consumption data measurements have been taken in 15-min intervals, these have been converted to 1-hour segments to facilitate a clearer indication of the consumption pattern.

Step 2: Establishment of the ToU block periods

To develop the ToU block periods, it is necessary to identify the seasonal electricity demand. The annual load profile is categorized into three seasons:

- *Winter* (December-March)
- *Midseason* (April-May and October-November)
- *Summer* (June-September)

Then the inflection points (i.e., the points on a curve at which the curve changes from being concave downward to convex upward, or vice versa) can be found and can be applied to the Load Duration Curve (LDC) of the seasonal load profile. When the inflection points on the curve change, this indicates a behavioural change in load consumption.

Step 3: Estimation of the ToU rates

The ToU rates (in €/kWh) are calculated based on the function given in Eq. (1), which is used to determine the off-peak rate ($Rate_{low}$), while maintaining a constant difference between the on-peak rate ($Rate_{high}$) and the shoulder rate ($Rate_{medium}$). This arrangement can provide financial incentives to consumers to consider shifting their consumption from consecutive periods. Finally, the constraints given in Eq. (2) and Eq. (3) provide that the on-peak and off-peak rates are always higher and lower than the existing flat rate, respectively. This is an important criterion, because the on-peak period should always represent the highest rate, while the off-peak period the lowest rate (and never vice-versa). The development of the ToU rates is also based on the seasonal average prosumers' load profile (when the flat rate is used), with the constraint of maintaining a neutral electricity bill in the case where the load profile remains unchanged.

$$Rate_{low} = 2Rate_{medium} - Rate_{high} \quad (1)$$

Subject to:

$$Rate_{low} < Rate_{flat} \quad (2)$$

$$Rate_{high} > Rate_{flat} \quad (3)$$

6 Results and Discussion

In this section, the results from the application of the new ToU tariffs to the buildings of the BERLIN pilots are provided for each pilot.

6.1 Determination of the proposed new tariffs

In this section the proposed new ToU tariffs are determined for each pilot based on the methodology described in the previous section. This methodology considers only the available consumption of the buildings, without any consideration of the available capacities of the PV subsystems and the BESS.

6.1.1 Cyprus

For the purposes of this study, the proposed dynamic tariff is based on the existing single rate domestic use tariff, with the following breakdown of charges, and taxes:

- Energy Charge per unit €0.1035/kWh
- Network Charge per unit €0.0302/kWh
- Ancillary Services Charge per unit €0.0065/kWh
- Meter Reading Charge €0.98
- Supply Charge €6.08
- Fuel Adjustment Charge €0.164104/kWh
- Public Utility Obligations Charge €0.00035/kWh
- RES & Energy Savings Fund Charge €0.005/kWh
- Value Added Tax (VAT) 19%

The consumption data for a sample day in summer, midseason, and winter seasons are shown graphically in Figure 8, Figure 9, and Figure 10, respectively.

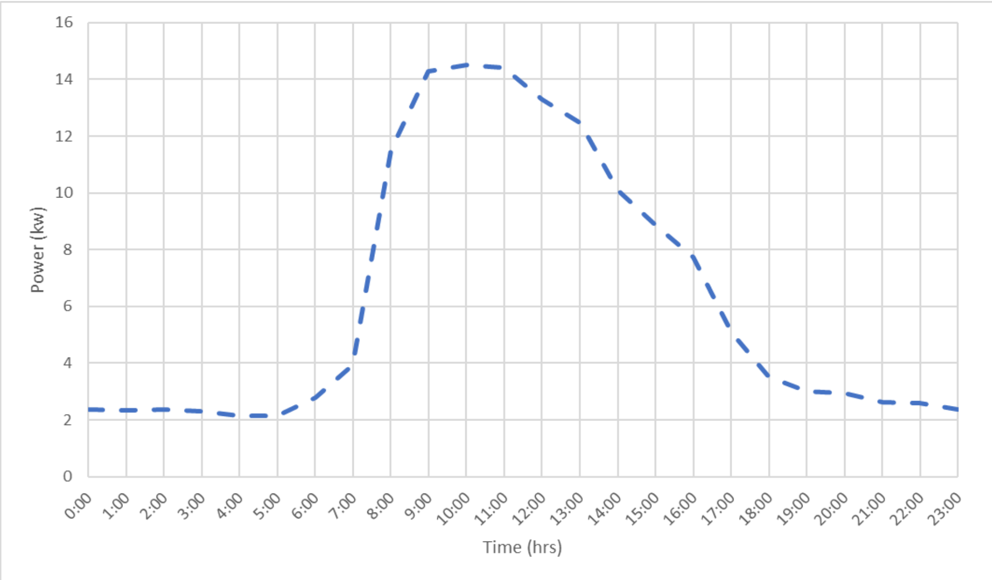

Figure 8: Consumption data for a sample day in the summer season.

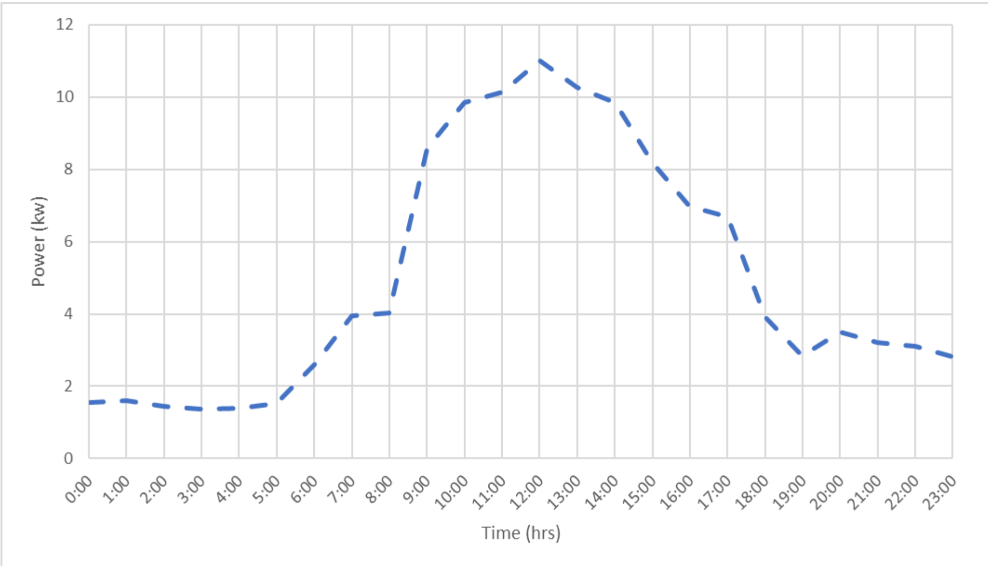

Figure 9: Consumption data for a sample day in the midseason season.

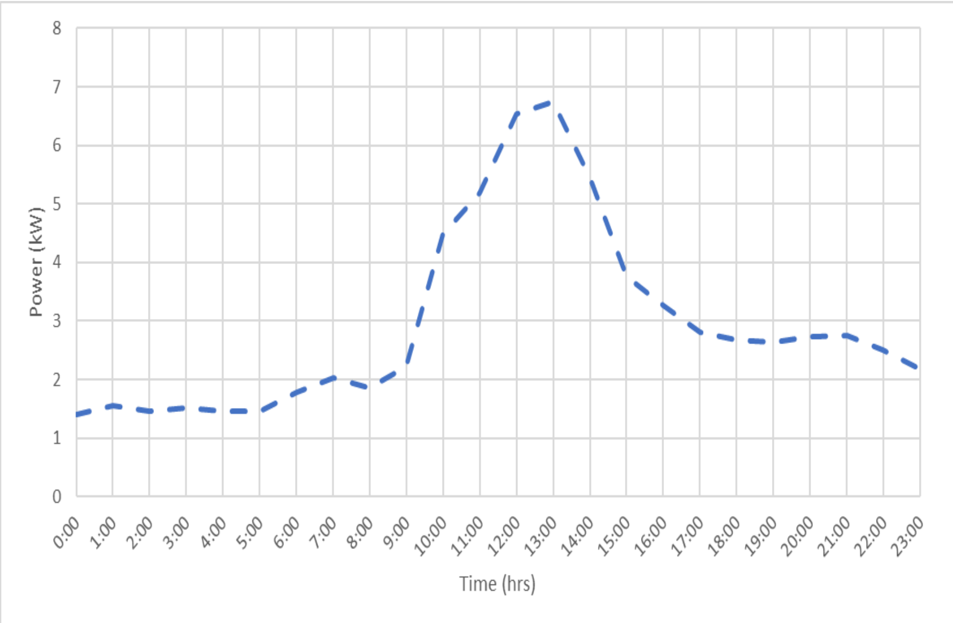

Figure 10: Consumption data for a sample day in the winter season.

The LDCs for the summer, midseason, and winter seasons are shown in Figure 8, Figure 9, and Figure 10, respectively. For example, in the summer season, by observation, four inflection points exist, which means that during this season the load profile can be divided into five load segments.

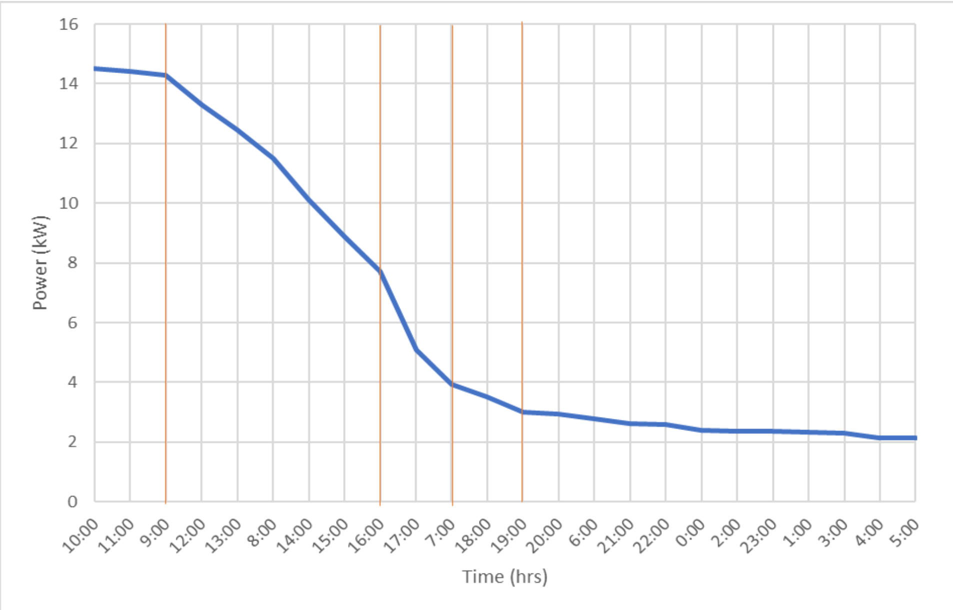

Figure 11: Load Duration Curve (LDC) for a sample day in the summer season.

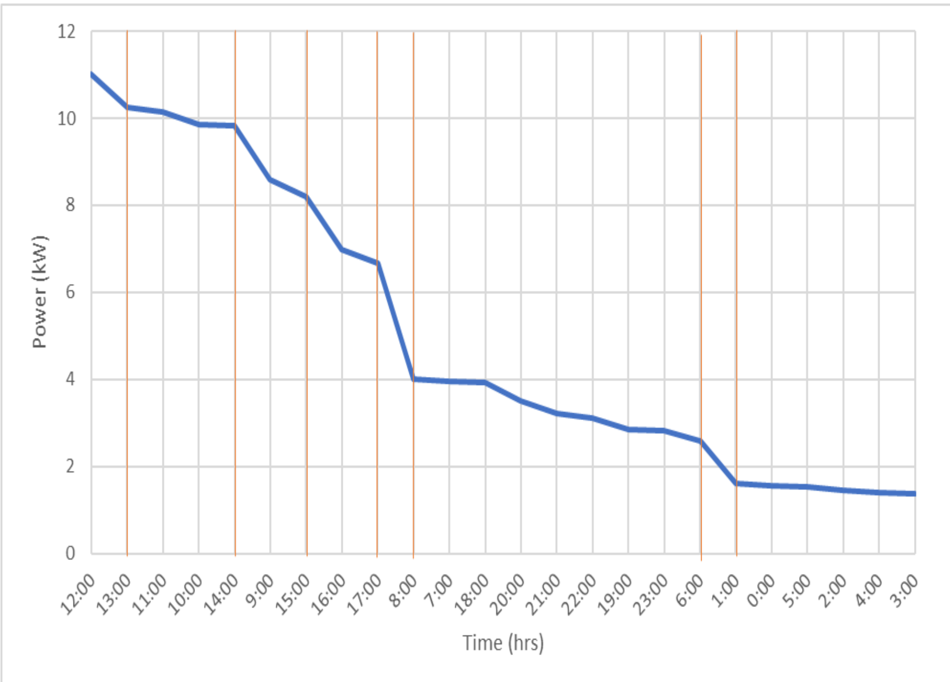

Figure 12: Load Duration Curve (LDC) for a sample day in the midseason season.

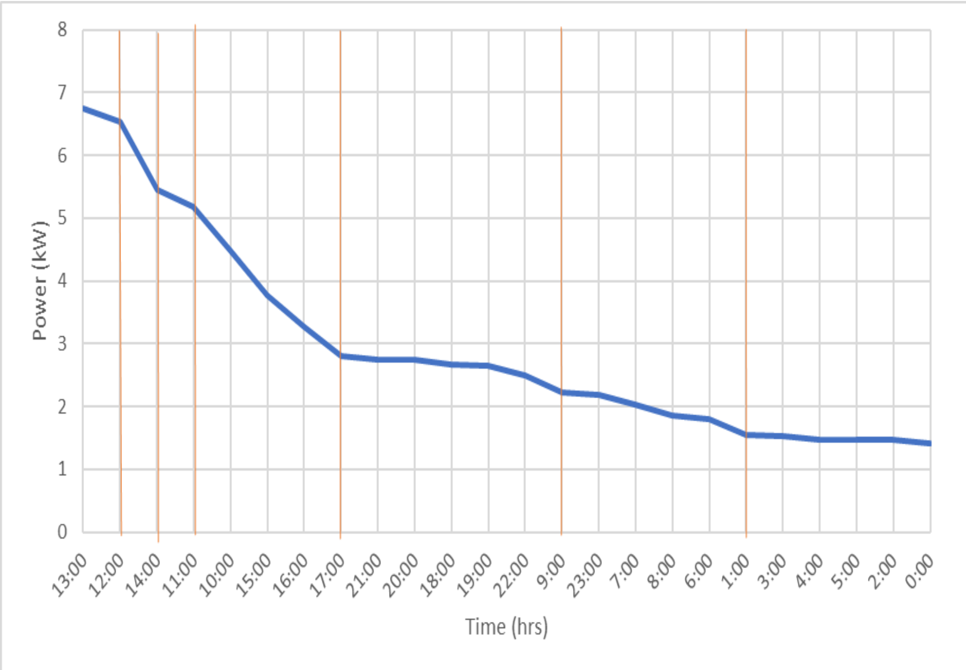

Figure 13: Load Duration Curve (LDC) for a sample day in the winter season.

The resulting ToU blocks are shown in Figure 14, Figure 15, and Figure 16 for the summer, midseason, and winter seasons, respectively. The on-peak consumption period is charged with the highest tariff, while the lowest tariff occurs during the valley period. Another period is clearly identified representing the transitional (shoulder) period from the minima to the maxima and vice-versa, which can be used to smoothen the load profile and avoid shifting the peak to other hours of the day. All plots clearly show three distinct segments for the off-peak, shoulder and on-peak periods.

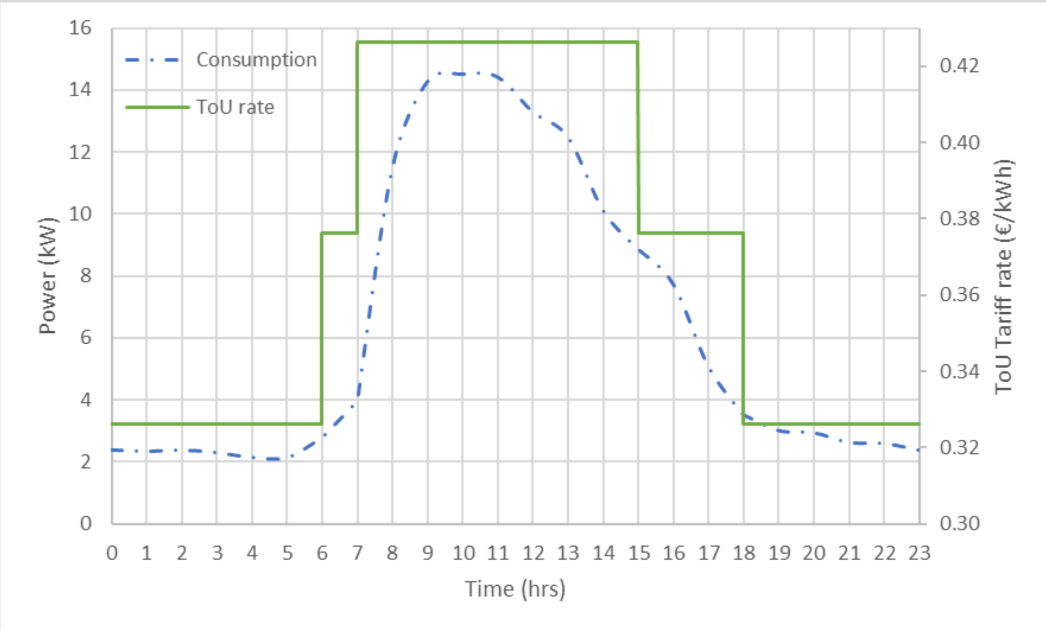

Figure 14: Resulting ToU tariffs for the summer season.

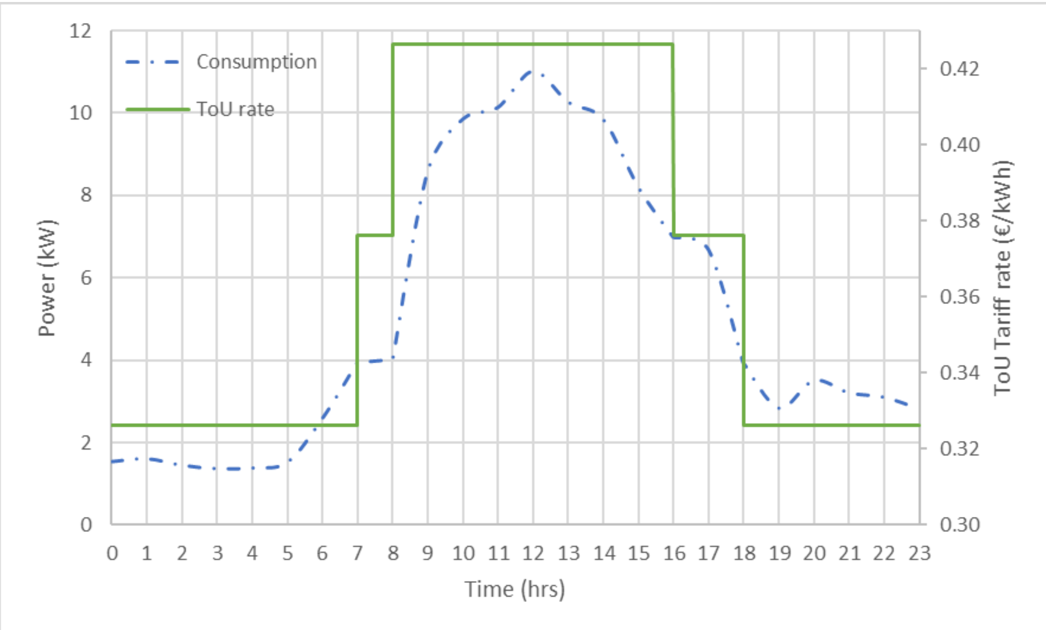

Figure 15: Resulting ToU tariffs for the midseason season.

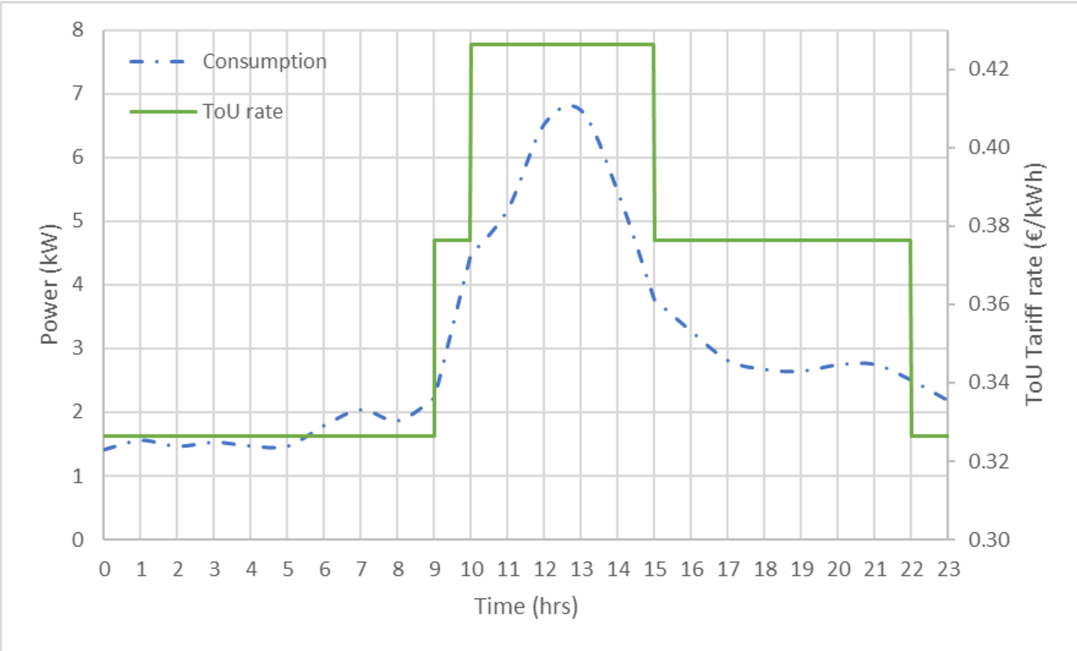

Figure 16: Resulting ToU tariffs for the winter season.

The resulting ToU tariffs and periods for each segment for every season are summarized in Table 12. The value of the peak, shoulder and off-peak price take into consideration the set criteria. In general, from 17:00 to 07:00, demand is low because offices are closed; from 07:00 to 17:00 (office hours) demand is moderate to high, depending on season.

Table 12: Timetable of ToU block periods.

Block	Price (€/kWh)	Summer	Midseason	Winter
Working days				
On-peak	0.4263	07:00-14:59	08:00-15:59	10:00-14:59
Shoulder	0.3763	06:00-06:59, 15:00-17:59	07:00-07:59, 16:00-17:59	09:00-09:59, 15:00-21:59
Off-peak	0.3263	18:00-05:59	18:00-06:59	22:00-08:59
Non-working days				
On-peak	0.4263	-		
Shoulder	0.3763	-		
Off-peak	0.3263	All times		

6.1.2 Greece

6.1.2.1 Dormitories of the University of Western Macedonia

The consumption data for a sample day in summer, midseason, and winter seasons are shown graphically in Figure 17, Figure 18, and Figure 19, respectively.

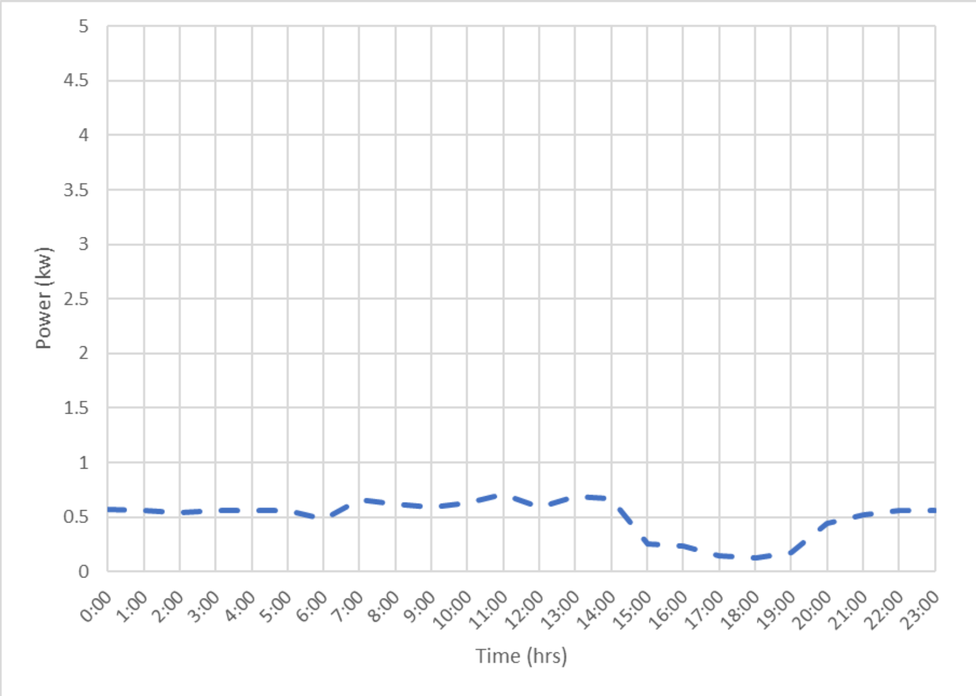

Figure 17: Consumption data for a sample day in the summer season.

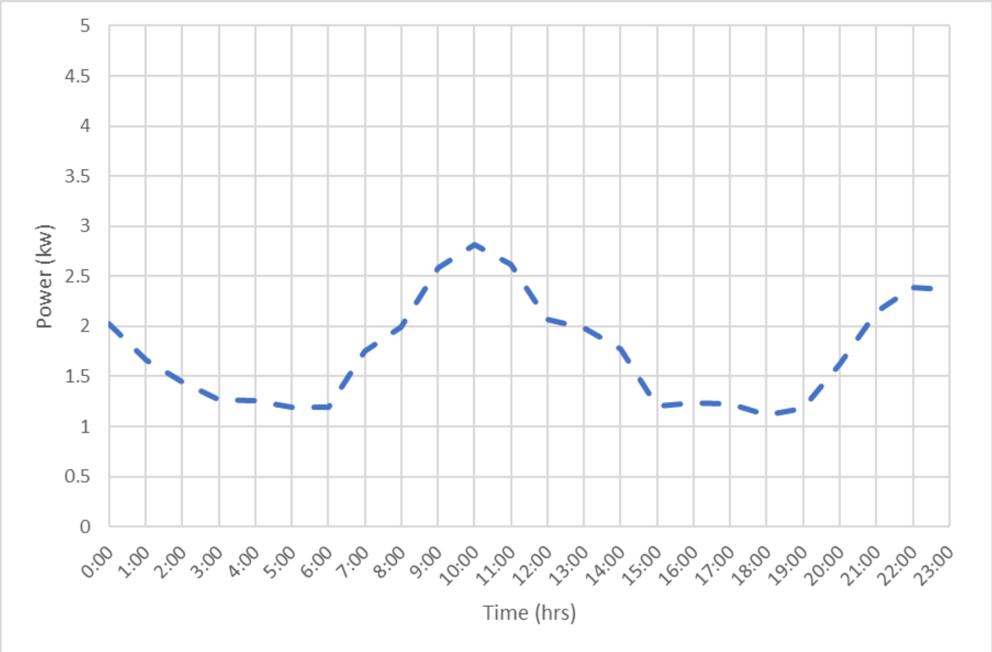

Figure 18: Consumption data for a sample day in the midseason season.

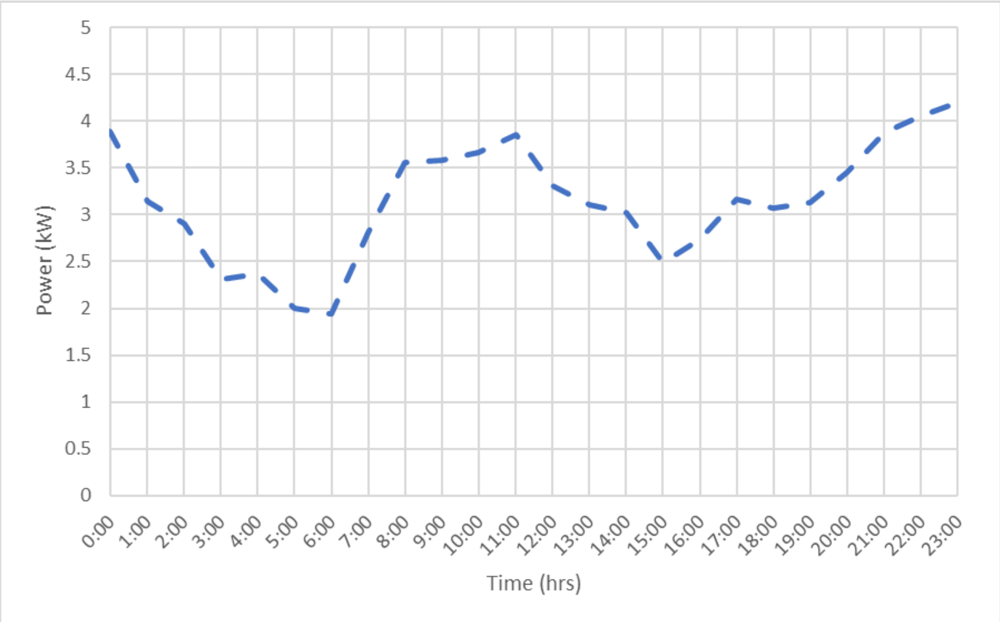

Figure 19: Consumption data for a sample day in the winter season.

The LDCs for the summer, midseason, and winter seasons are shown in Figure 20, Figure 21, and Figure 22, respectively.

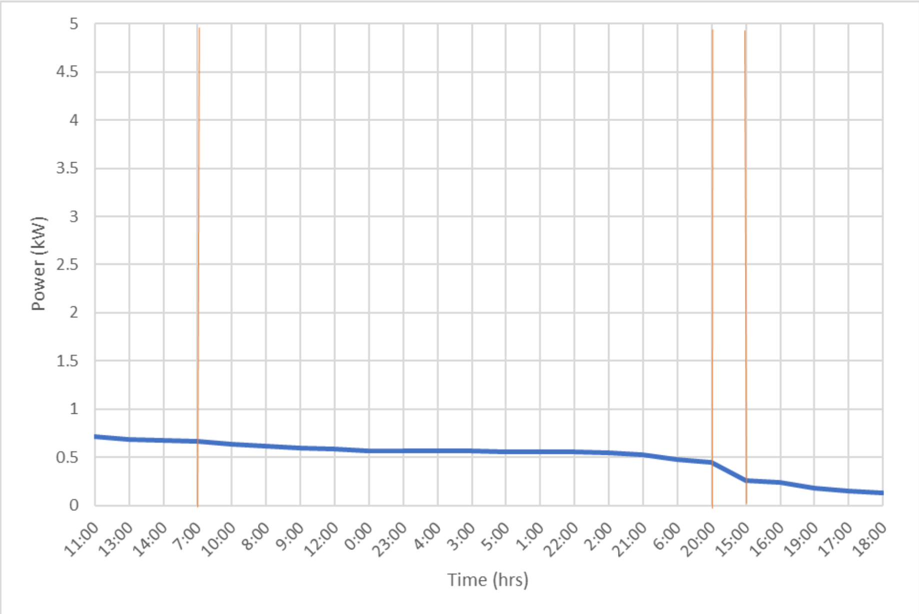

Figure 20: Load Duration Curve (LDC) for a sample day in the summer season.

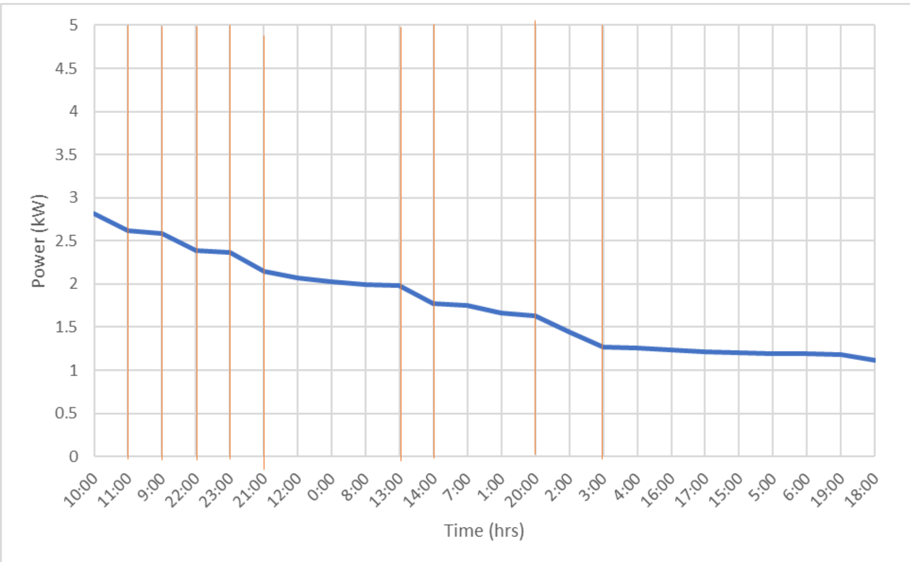

Figure 21: Load Duration Curve (LDC) for a sample day in the midseason season.

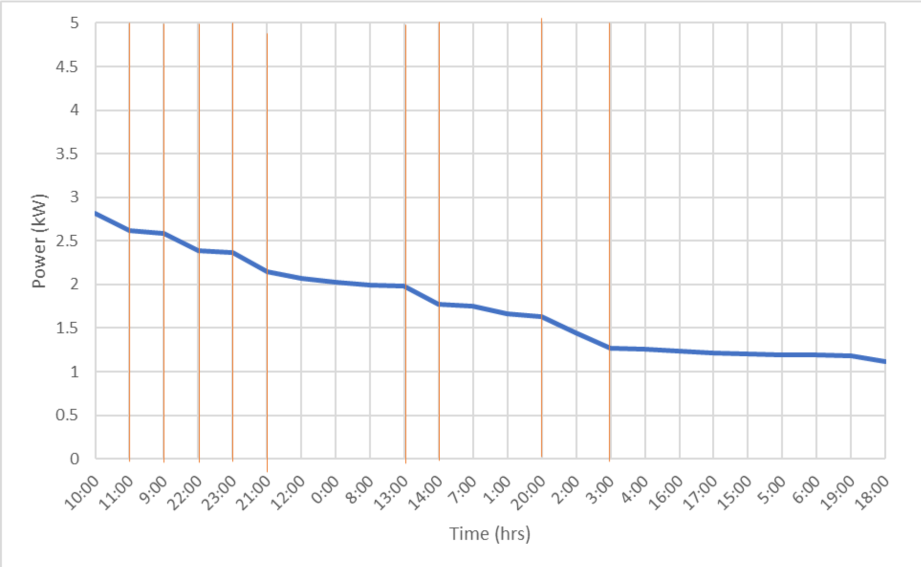

Figure 22: Load Duration Curve (LDC) for a sample day in the winter season.

The resulting ToU blocks are shown in Figure 23, Figure 24, and Figure 25 for the summer, midseason, and winter seasons, respectively. The on-peak consumption period is charged with the highest tariff, while the lowest tariff occurs during the valley period. Another period is clearly identified representing the transitional (shoulder) period from the minima to the maxima and vice-versa, which can be used to smoothen the load profile and avoid shifting the peak to other hours of the day. All plots clearly show three distinct segments for the off-peak, shoulder and on-peak periods.

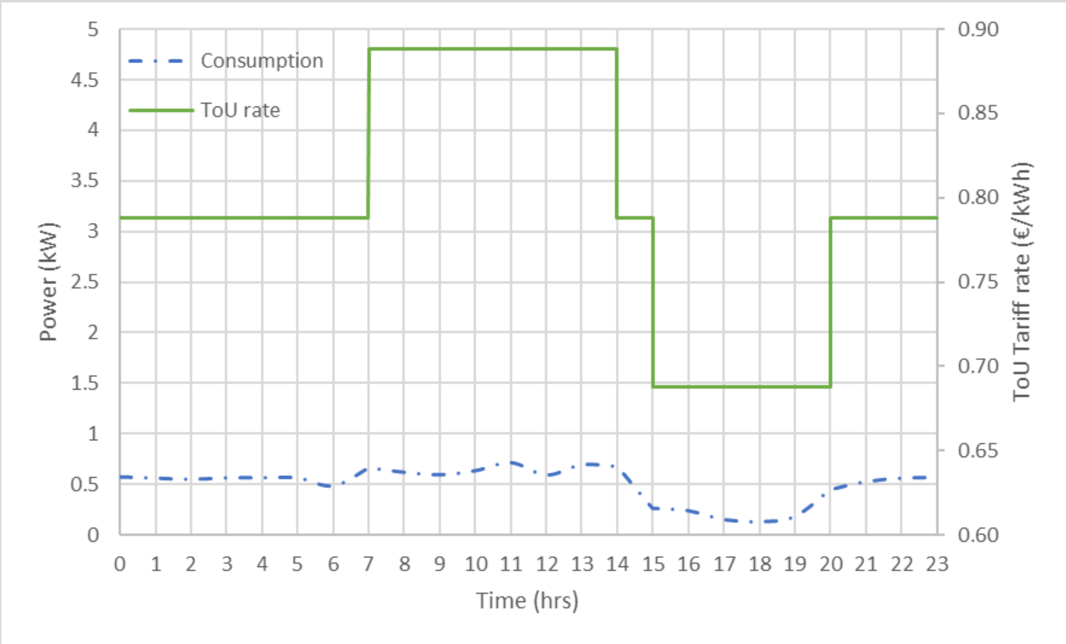

Figure 23: Resulting ToU tariffs for the summer season.

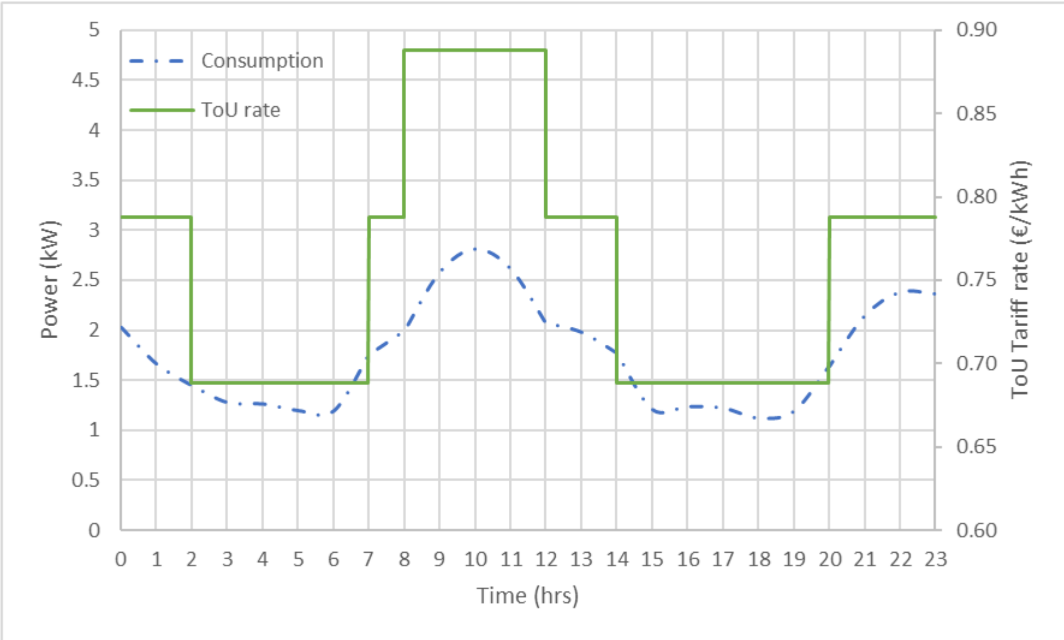

Figure 24: Resulting ToU tariffs for the midseason season.

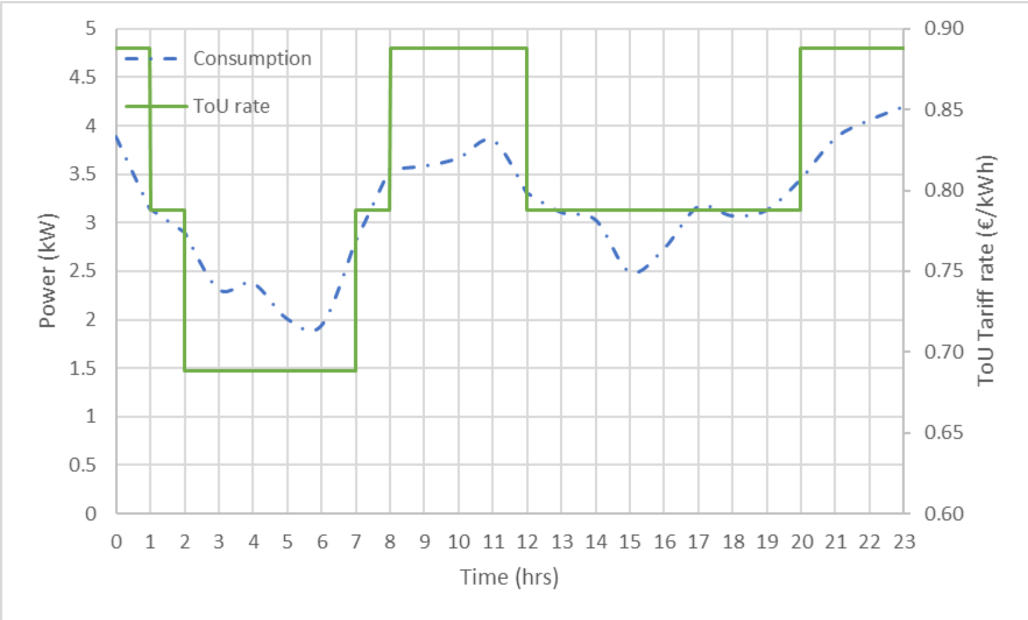

Figure 25: Resulting ToU tariffs for the winter season.

The resulting ToU tariffs and periods for each segment for every season are summarized in Table 13. The value of the peak, shoulder and off-peak price take into consideration the set criteria.

Table 13: Timetable of ToU block periods.

Block	Price (€/kWh)	Summer	Midseason	Winter
Working days				
On-peak	0.878	07:00-13:59	08:00-11:59	08:00-11:59, 20:00-00:59
Shoulder	0.778	14:00-14:59, 20:00-06:59	07:00-07:59, 12:00-13:59, 20:00-01:59	01:00-01:59, 07:00-07:59, 12:00-19:59
Off-peak	0.688	15:00-19:59	02:00-06:59, 14:00-19:59	02:00-06:59
Non-working days				
On-peak	0.878	-		
Shoulder	0.778	-		
Off-peak	0.678	All times		

6.1.2.2 Town Hall of Koilada, Kozani

The consumption data for a sample day in summer, midseason, and winter seasons are shown graphically in Figure 26, Figure 27, and Figure 28, respectively.

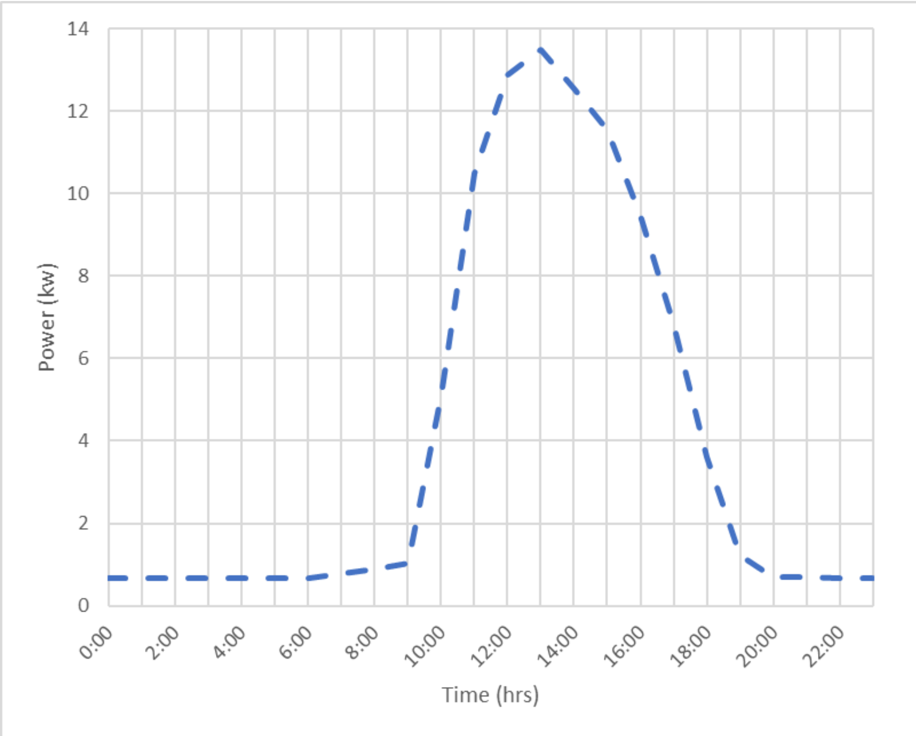

Figure 26: Consumption data for a sample day in the summer season.

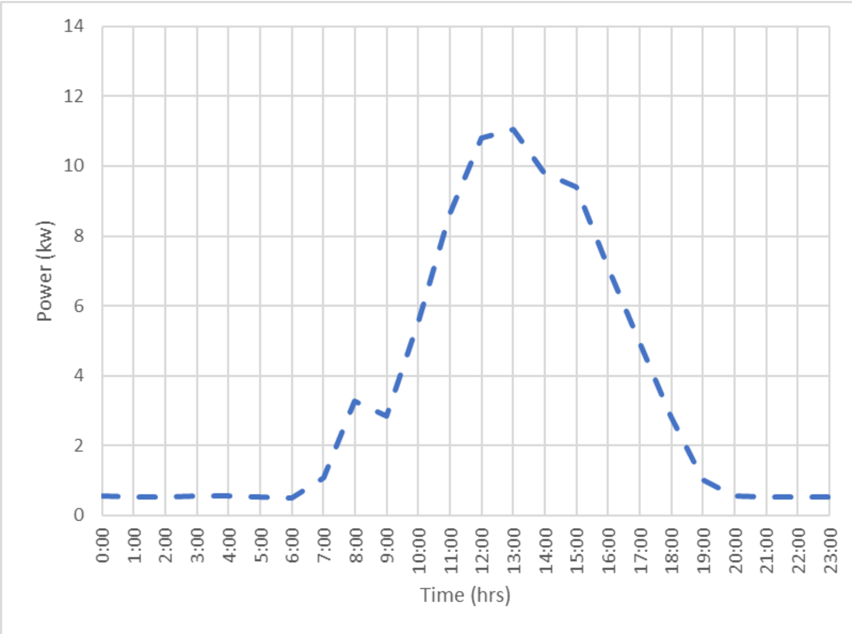

Figure 27: Consumption data for a sample day in the midseason season.

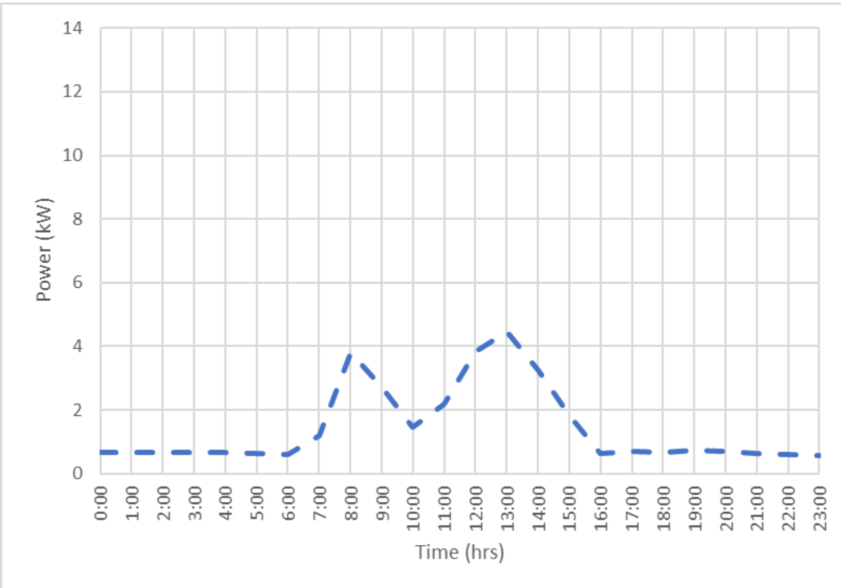

Figure 28: Consumption data for a sample day in the winter season.

The LDCs for the summer, midseason, and winter seasons are shown in Figure 29, Figure 30, and Figure 31, respectively.

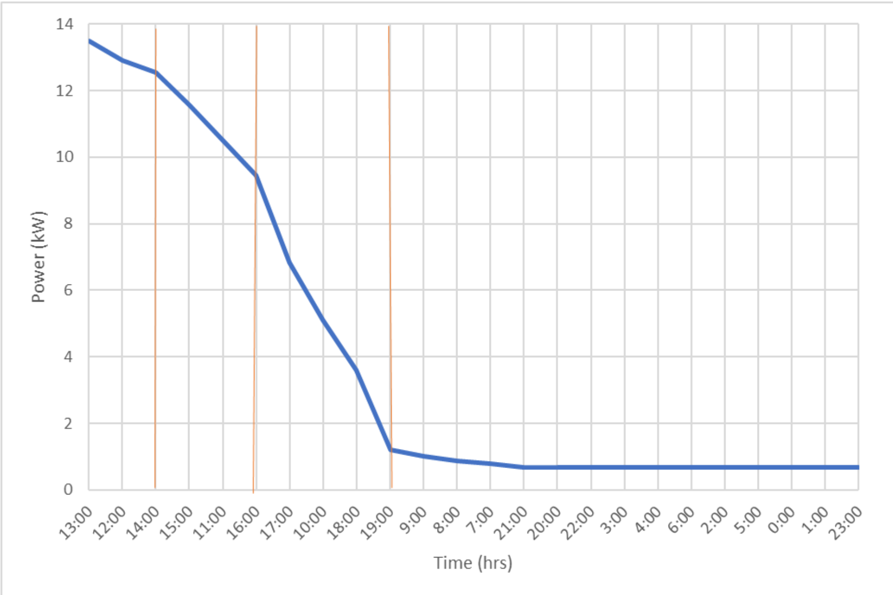

Figure 29: Load Duration Curve (LDC) for a sample day in the summer season.

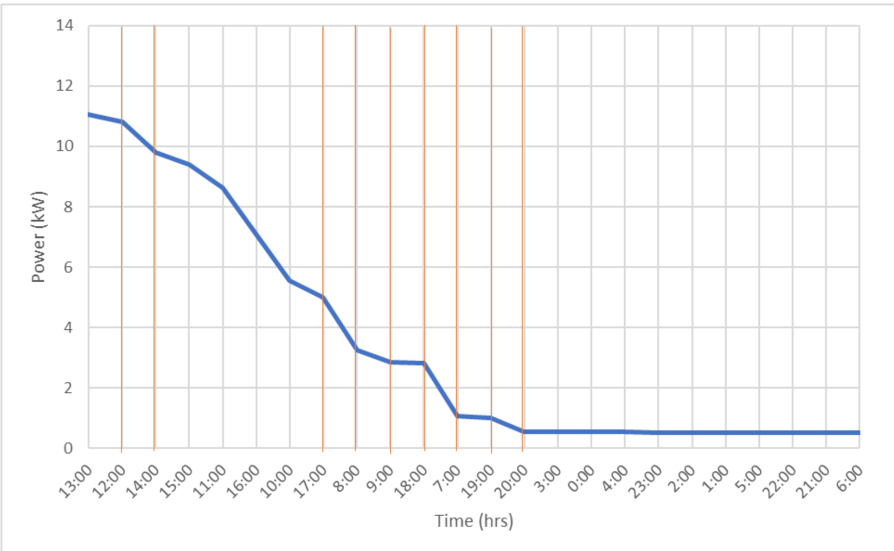

Figure 30: Load Duration Curve (LDC) for a sample day in the midseason season.

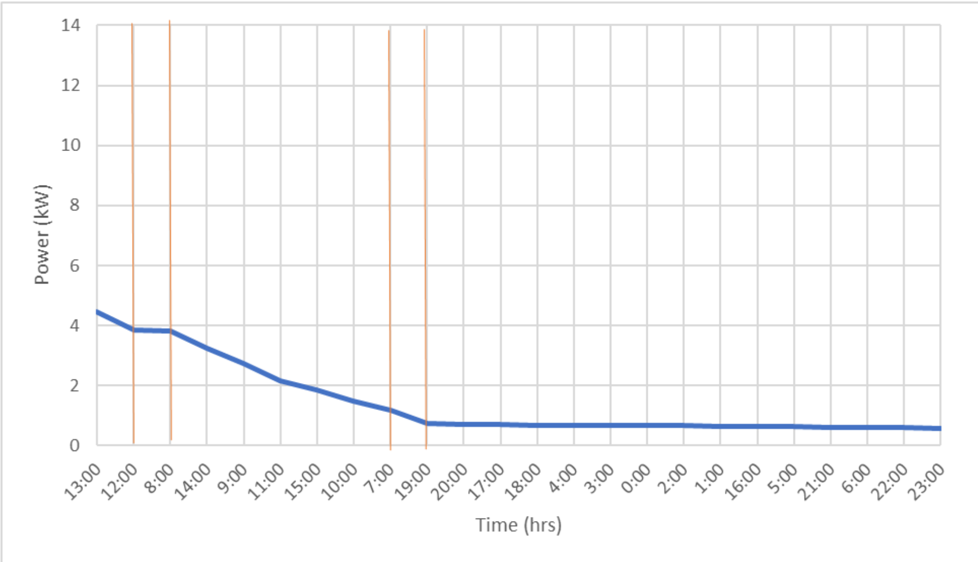

Figure 31: Load Duration Curve (LDC) for a sample day in the winter season.

The resulting ToU blocks are shown in Figure 32, Figure 33, and Figure 34 for the summer, midseason, and winter seasons, respectively. The on-peak consumption period is charged with the highest tariff, while the lowest tariff occurs during the valley period. Another period is clearly identified representing the transitional (shoulder) period from the minima to the maxima and vice-versa, which can be used to smoothen the load profile and avoid shifting the peak to other hours of the day. All plots clearly show three distinct segments for the off-peak, shoulder and on-peak periods.

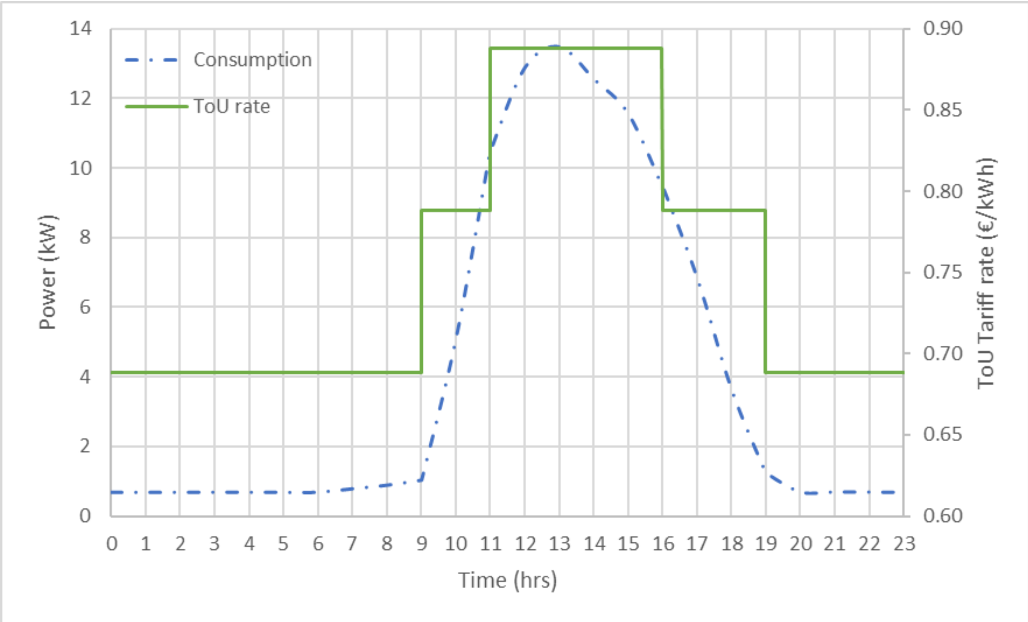

Figure 32: Resulting ToU tariffs for the summer season.

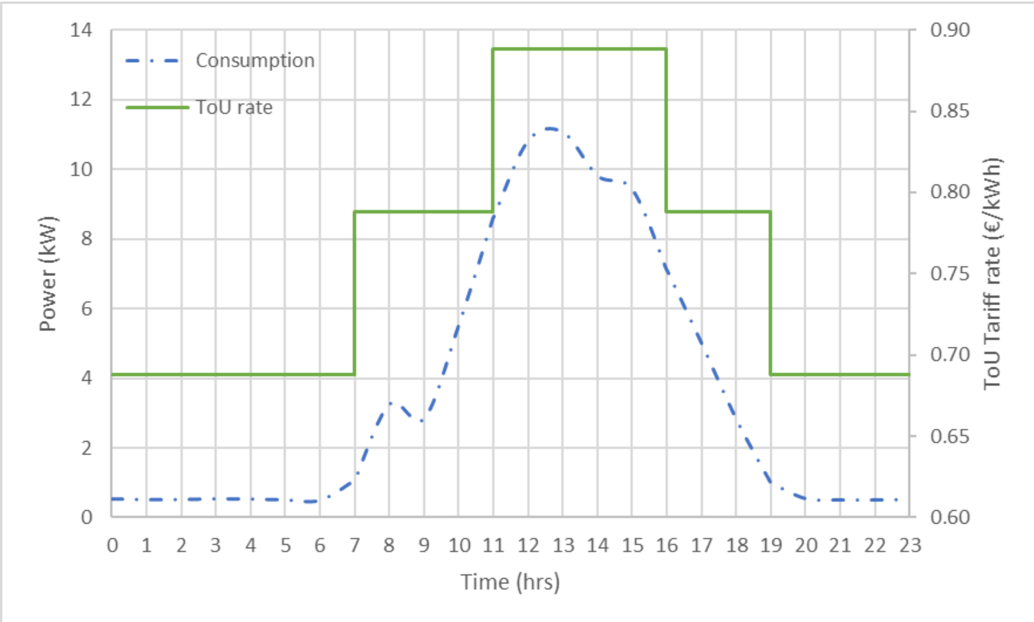

Figure 33: Resulting ToU tariffs for the midseason season.

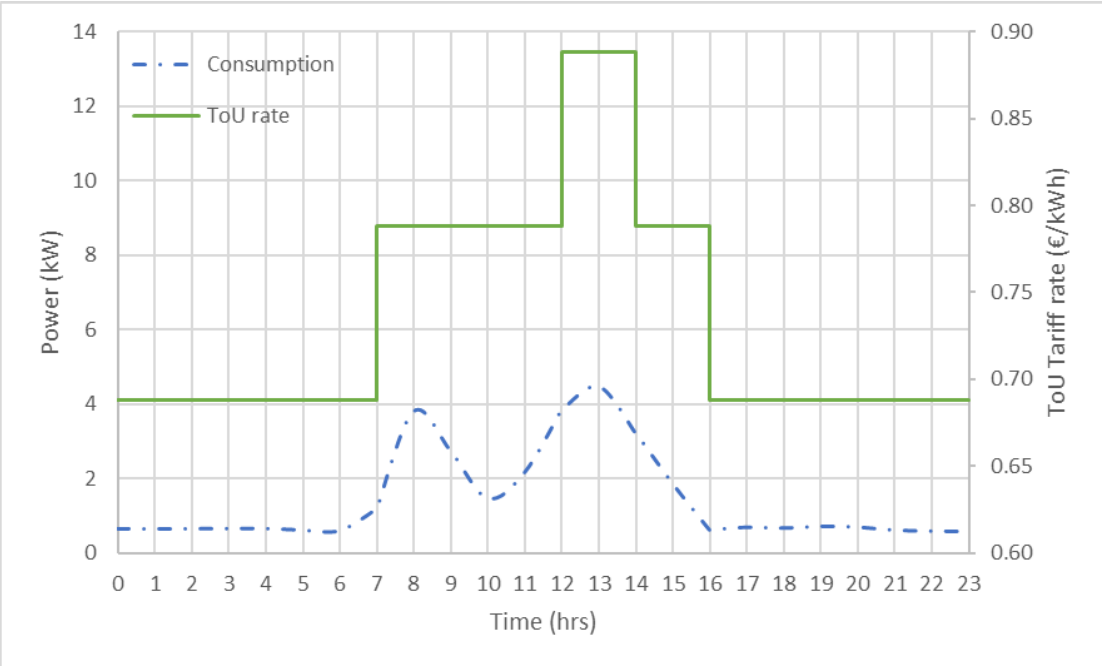

Figure 34: Resulting ToU tariffs for the winter season.

The resulting ToU tariffs and periods for each segment for every season are summarized in Table 14. The value of the peak, shoulder and off-peak price take into consideration the set criteria.

Table 14: Timetable of ToU block periods.

Block	Price (€/kWh)	Summer	Midseason	Winter
		Working days		
On-peak	0.878	11:00-15:59	11:00-15:59	12:00-13:59
Shoulder	0.778	09:00-10:59, 16:00-18:59	07:00-10:59, 16:00-18:59	07:00-11:59, 14:00-15:59
Off-peak	0.688	19:00-08:59	19:00-06:59	16:00-06:59
		Non-working days		
On-peak	0.878	-		
Shoulder	0.778	-		
Off-peak	0.678	All times		

6.1.3 Israel

6.1.3.1 Nof Edom School

The consumption data for a sample day in summer, midseason, and winter seasons are shown graphically in Figure 35, Figure 36, and Figure 37, respectively.

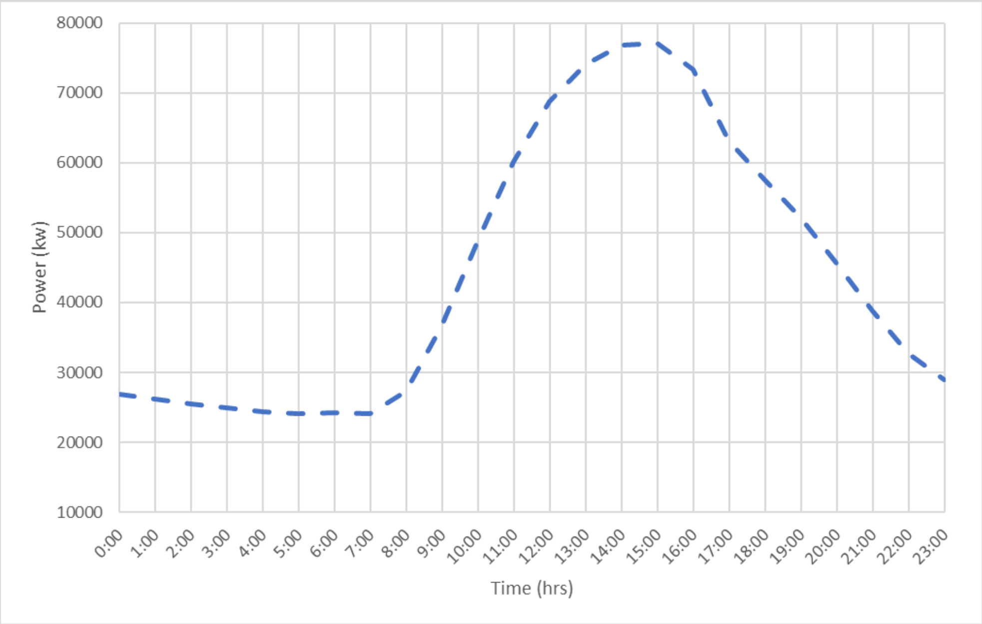

Figure 35: Consumption data for a sample day in the summer season.

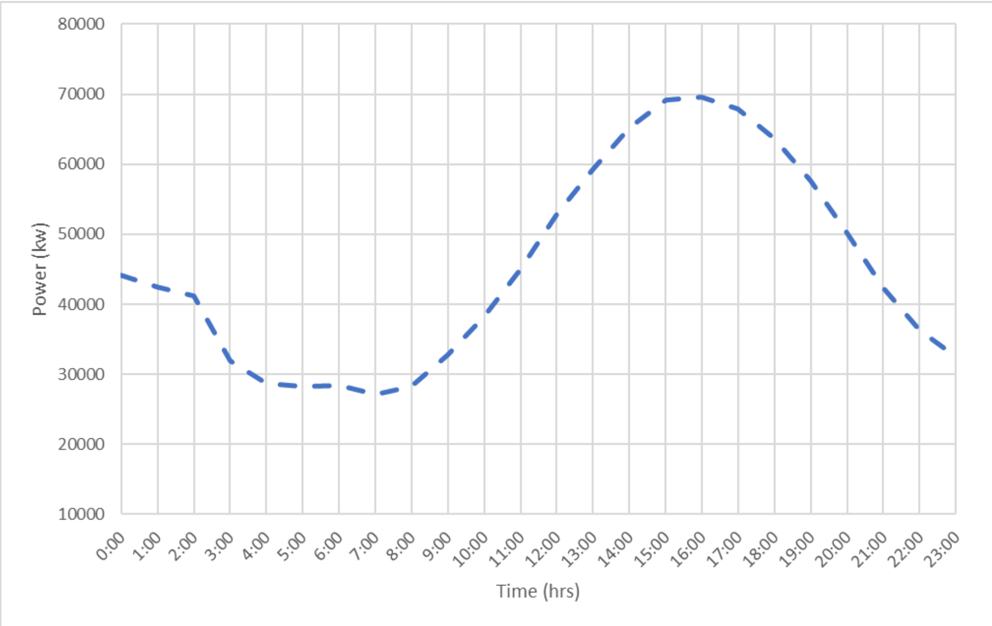

Figure 36: Consumption data for a sample day in the midseason season.

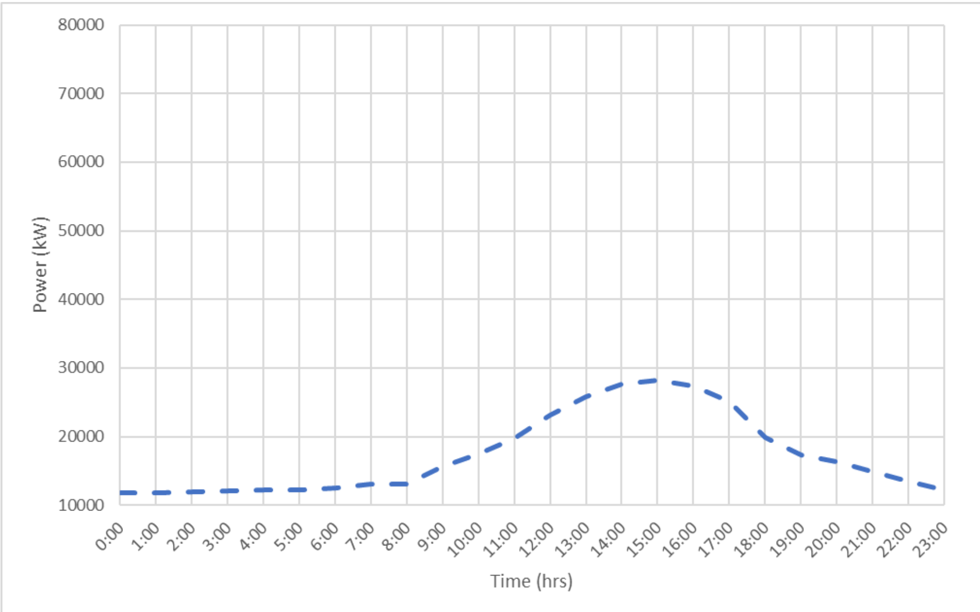

Figure 37: Consumption data for a sample day in the winter season.

The LDCs for the summer, midseason, and winter seasons are shown in Figure 38, Figure 39, and Figure 40, respectively.

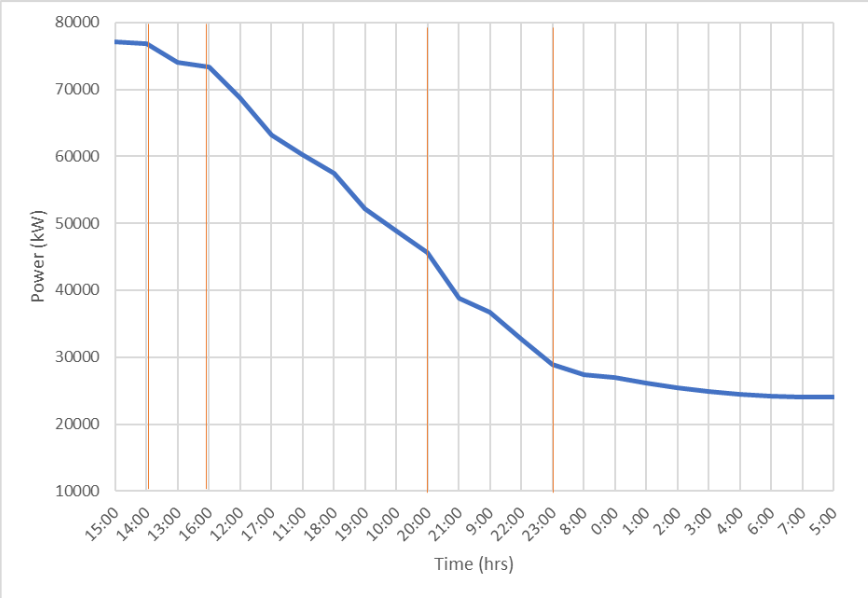

Figure 38: Load Duration Curve (LDC) for a sample day in the summer season.

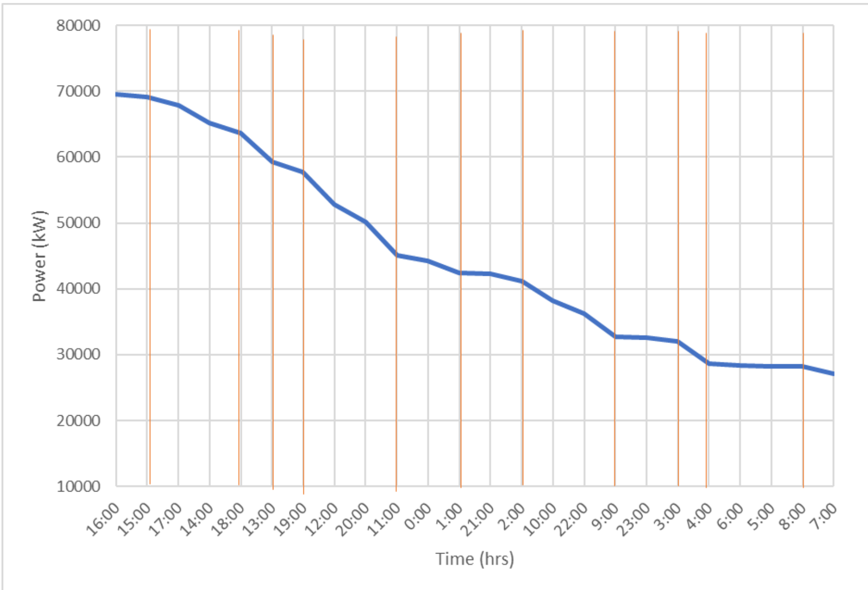

Figure 39: Load Duration Curve (LDC) for a sample day in the midseason season.

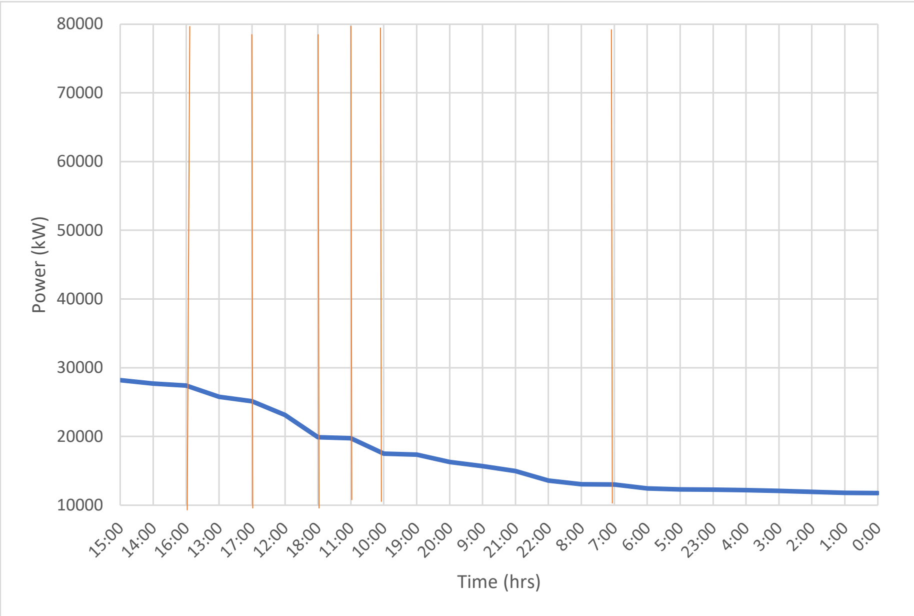

Figure 40: Load Duration Curve (LDC) for a sample day in the winter season.

The resulting ToU blocks are shown in Figure 41, Figure 42, and Figure 43 for the summer, midseason, and winter seasons, respectively. The on-peak consumption period is charged with the highest tariff, while the lowest tariff occurs during the valley period. Another period is clearly identified representing the transitional (shoulder) period from the minima to the maxima and vice-versa, which can be used to smoothen the load profile and avoid shifting the peak to other hours of the day. All plots clearly show three distinct segments for the off-peak, shoulder and on-peak periods.

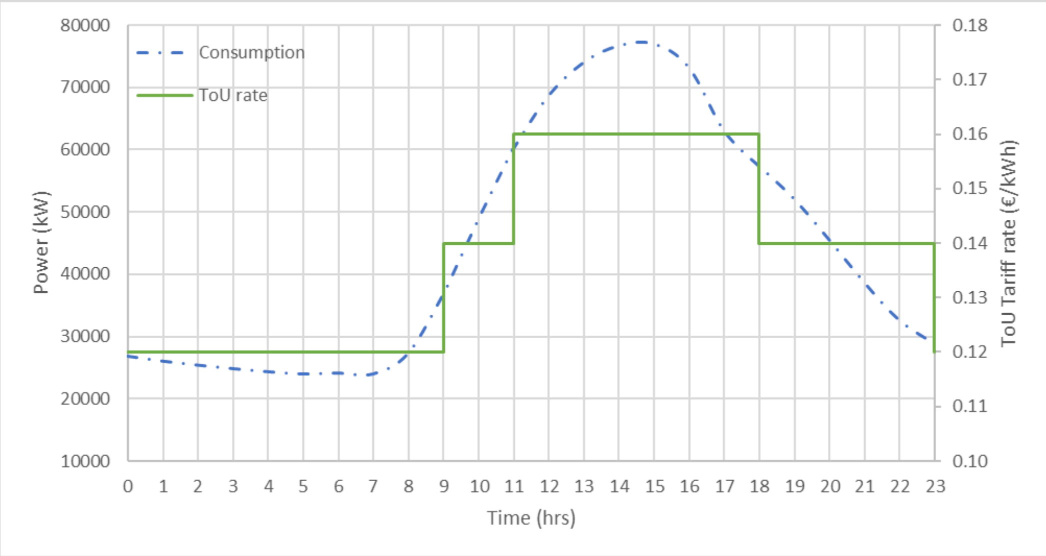

Figure 41: Resulting ToU tariffs for the summer season.

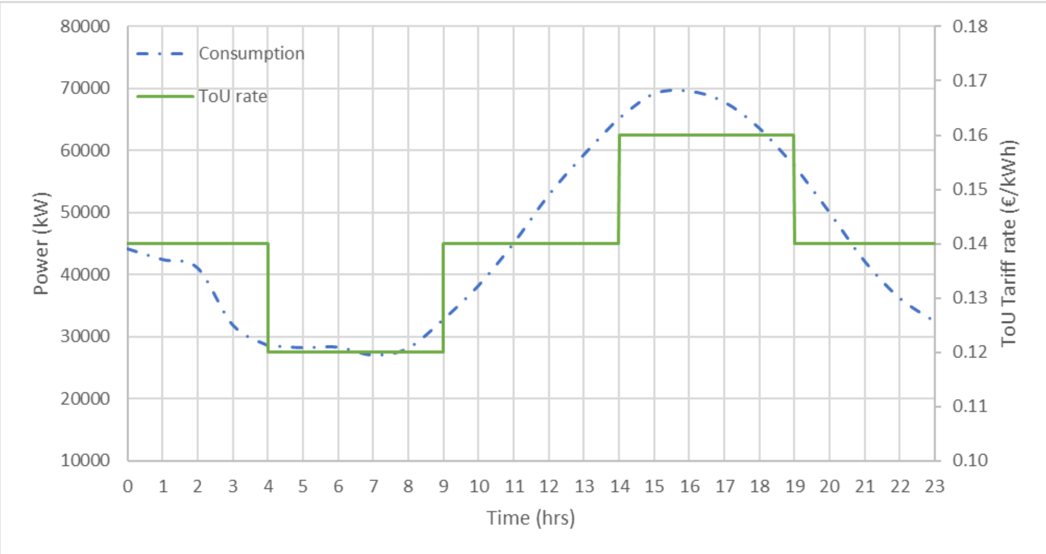

Figure 42: Resulting ToU tariffs for the midseason season.

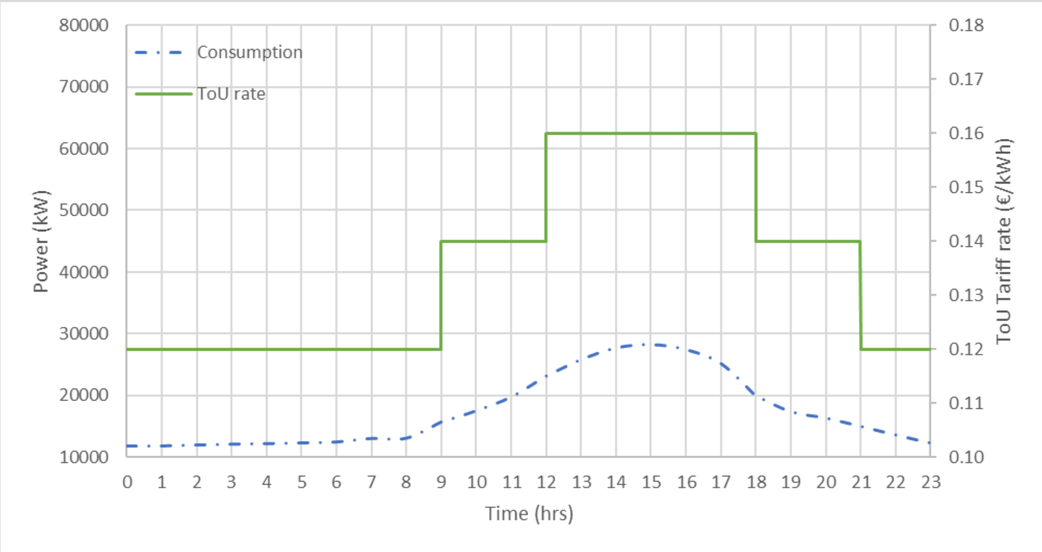

Figure 43: Resulting ToU tariffs for the winter season.

The resulting ToU tariffs and periods for each segment for every season are summarized in Table 15. The value of the peak, shoulder and off-peak price take into consideration the set criteria.

Table 15: Timetable of ToU block periods.

Block	Price (€/kWh)	Summer	Midseason	Winter
Working days				
On-peak	0.16	11:00-17:59	14:00-18:59	12:00-17:59
Shoulder	0.14	09:00-10:59, 18:00-22:59	09:00-13:59, 19:00-03:59	09:00-11:59, 18:00-20:59
Off-peak	0.12	23:00-08:59	4:00-08:59	21:00-08:59
Non-working days				
On-peak	0.16	-		
Shoulder	0.14	-		
Off-peak	0.12	All times		

6.1.3.2 Yeelim School

The consumption data for a sample day in summer, midseason, and winter seasons are shown graphically in Figure 35, Figure 36, and Figure 37, respectively.

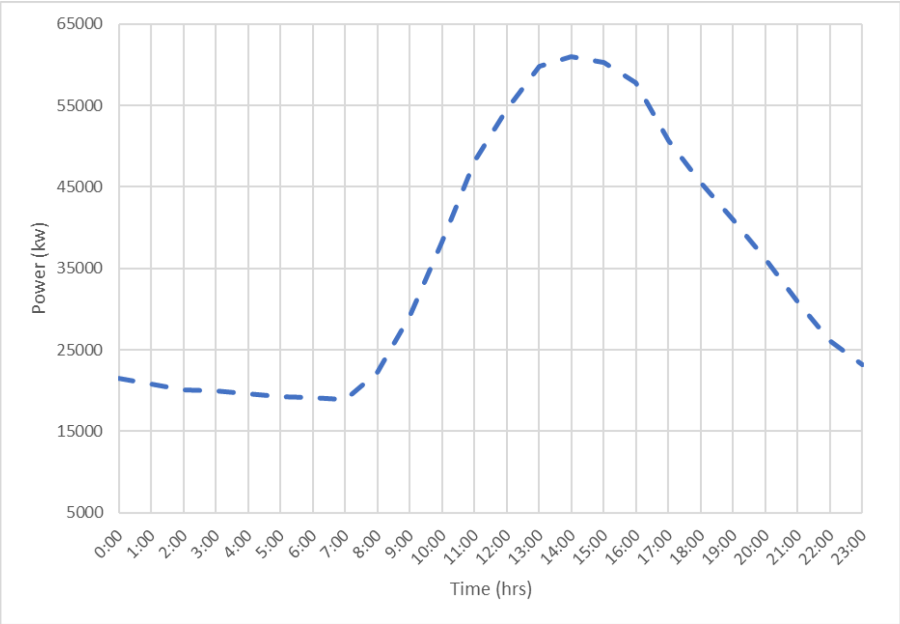

Figure 44: Consumption data for a sample day in the summer season.

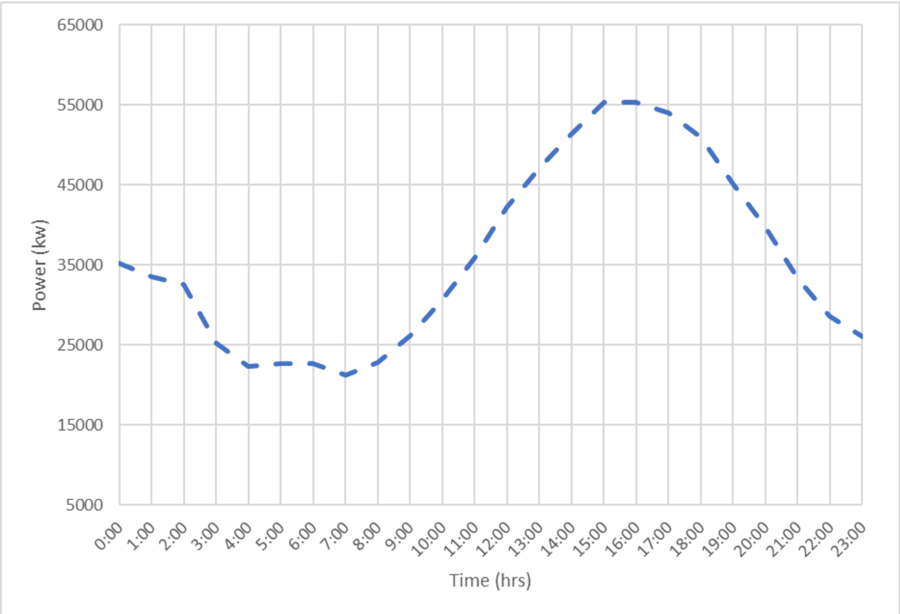

Figure 45: Consumption data for a sample day in the midseason season.

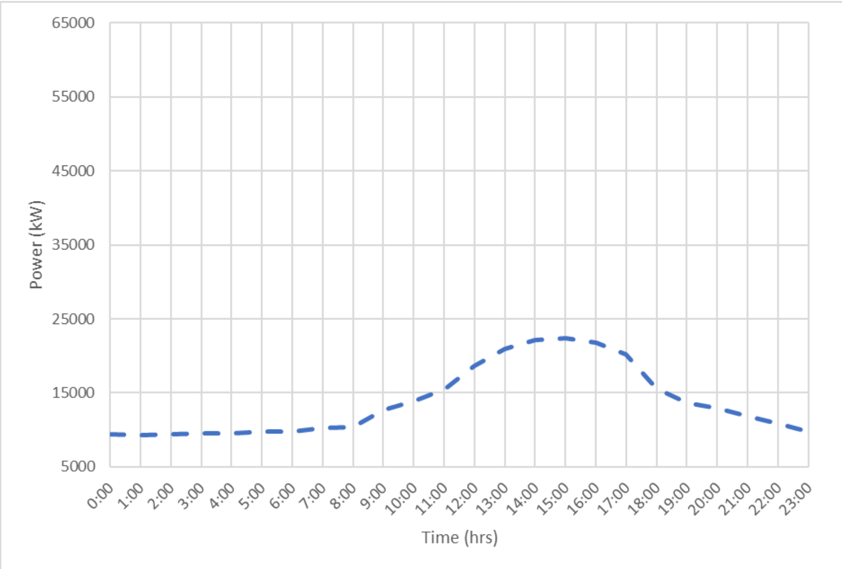

Figure 46: Consumption data for a sample day in the winter season.

The LDCs for the summer, midseason, and winter seasons are shown in Figure 38, Figure 39, and Figure 40, respectively.

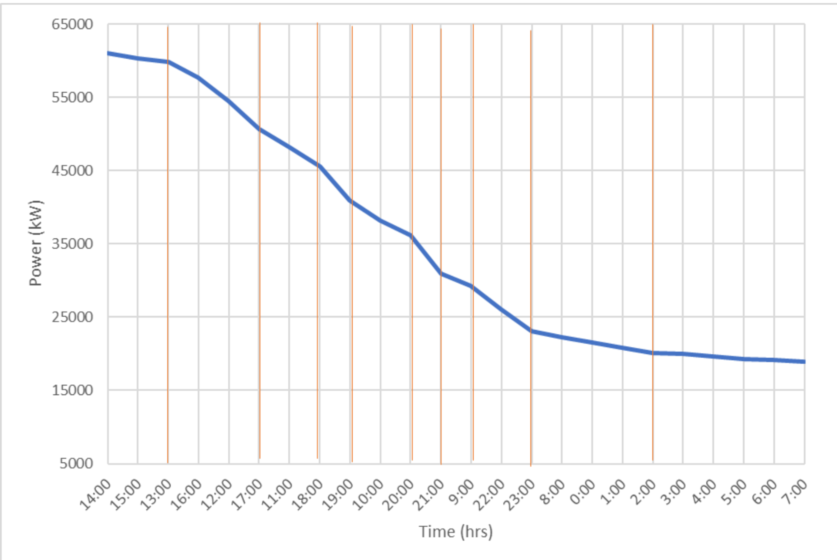

Figure 47: Load Duration Curve (LDC) for a sample day in the summer season.

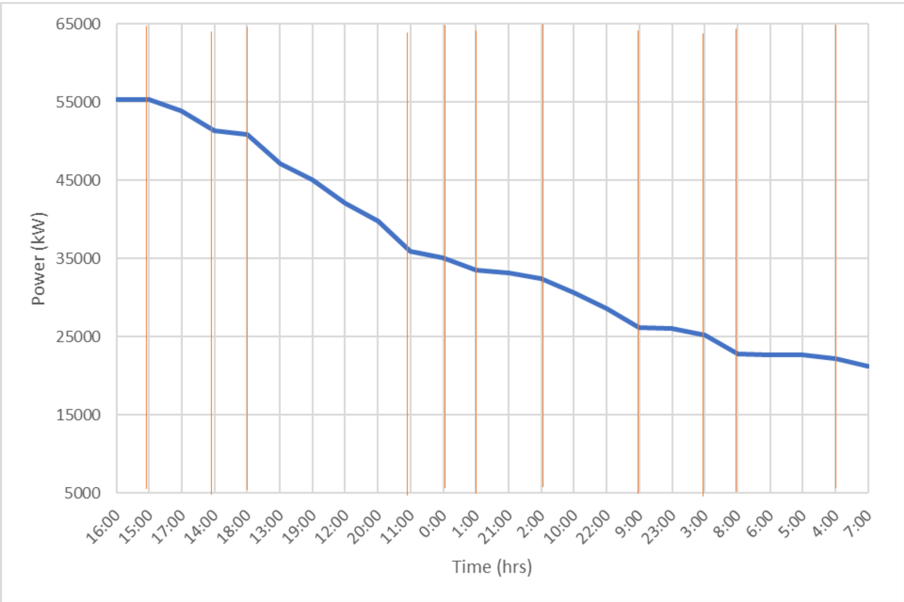

Figure 48: Load Duration Curve (LDC) for a sample day in the midseason season.

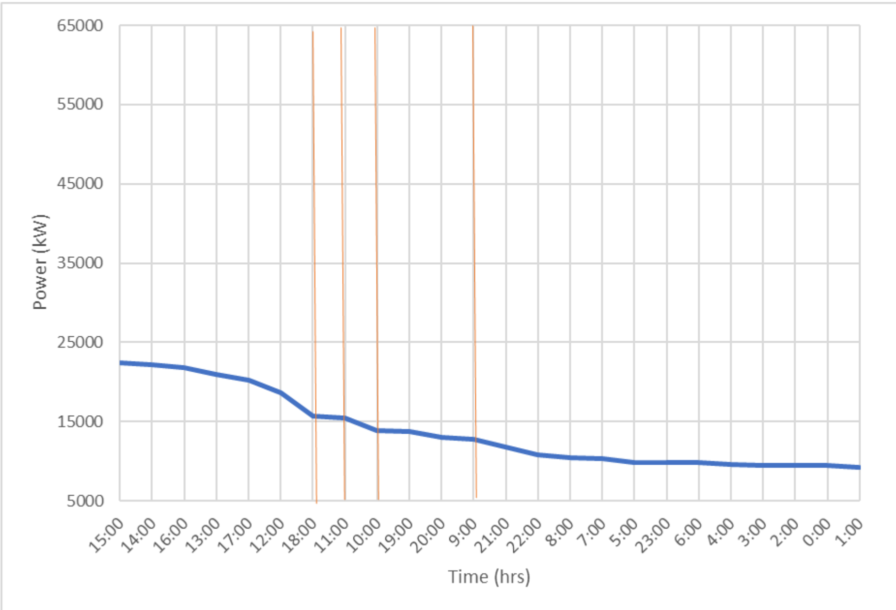

Figure 49: Load Duration Curve (LDC) for a sample day in the winter season.

The resulting ToU blocks are shown in Figure 41, Figure 42, and Figure 43 for the summer, midseason, and winter seasons, respectively. The on-peak consumption period is charged with the highest tariff, while the lowest tariff occurs during the valley period. Another period is clearly identified representing the transitional (shoulder) period from the minima to the maxima and vice-versa, which can be used to smoothen the load profile and avoid shifting the peak to other hours of the day. All plots clearly show three distinct segments for the off-peak, shoulder and on-peak periods.

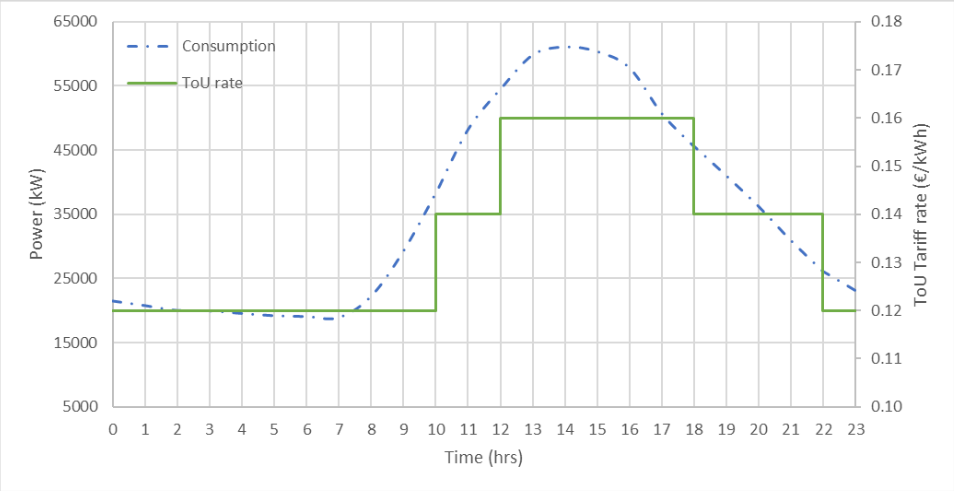

Figure 50: Resulting ToU tariffs for the summer season.

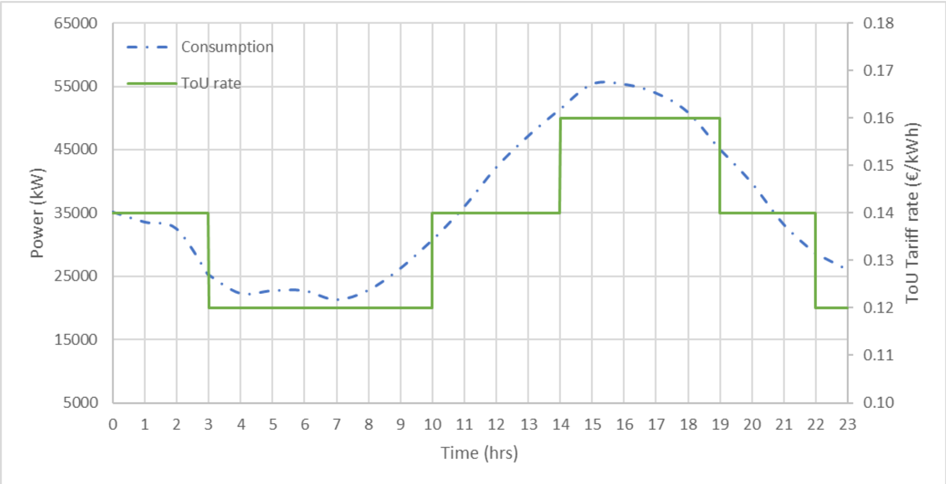

Figure 51: Resulting ToU tariffs for the midseason season.

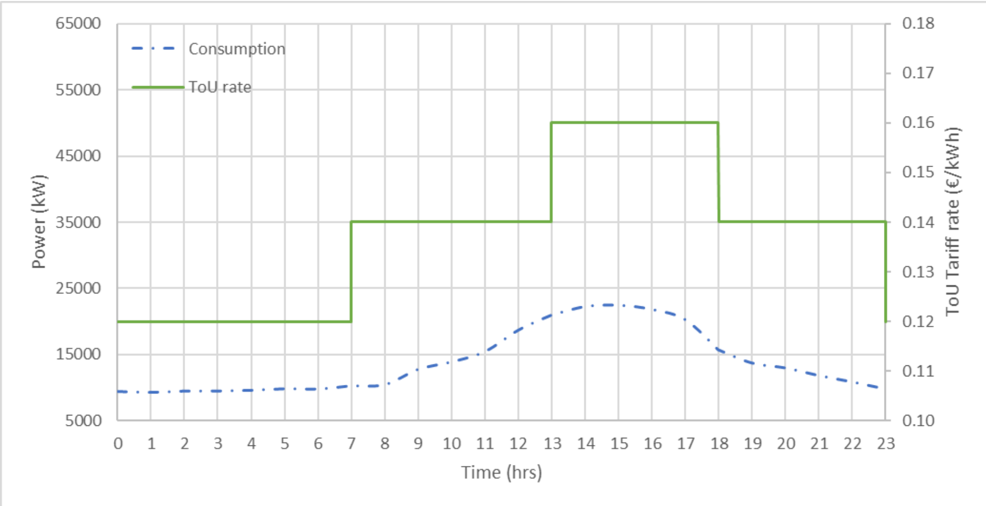

Figure 52: Resulting ToU tariffs for the winter season.

The resulting ToU tariffs and periods for each segment for every season are summarized in Table 15. The value of the peak, shoulder and off-peak price take into consideration the set criteria.

Table 16: Timetable of ToU block periods.

Block	Price (€/kWh)	Summer	Midseason	Winter
		Working days		
On-peak	0.16	12:00-17:59	14:00-18:59	13:00-17:59
Shoulder	0.14	10:00-11:59, 18:00-21:59	00:00-02:59, 10:00-13:59, 19:00-21:59	07:00-12:59, 18:00-22:59
Off-peak	0.12	22:00-09:59	03:00-09:59, 22:00-23:59	23:00-06:59
		Non-working days		
On-peak	0.16	-		
Shoulder	0.14	-		
Off-peak	0.12	All times		

6.1.4 Italy

The consumption data for a sample day in summer, midseason, and winter seasons are shown graphically in Figure 53, Figure 54, and Figure 55, respectively.

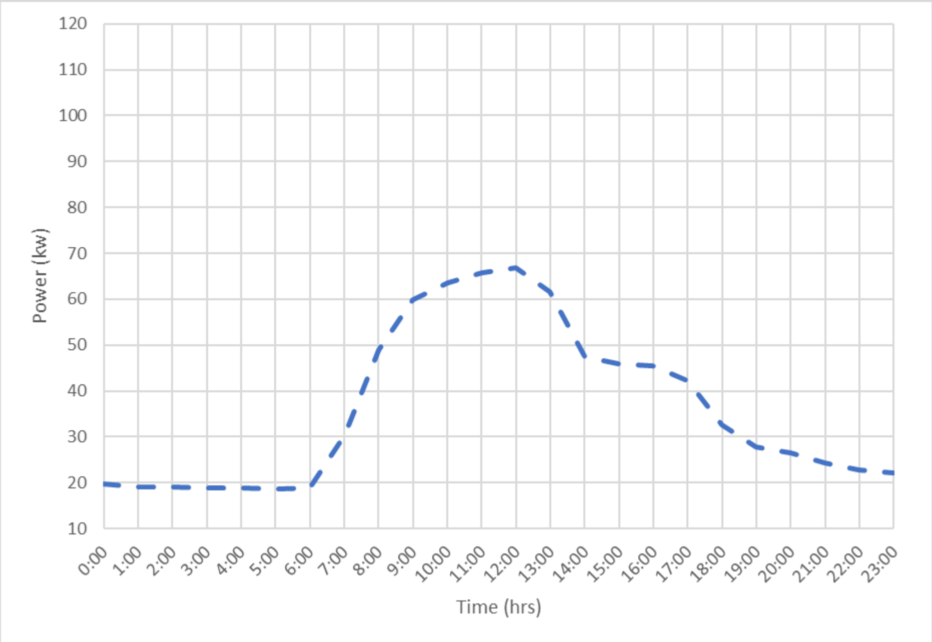

Figure 53: Consumption data for a sample day in the summer season.

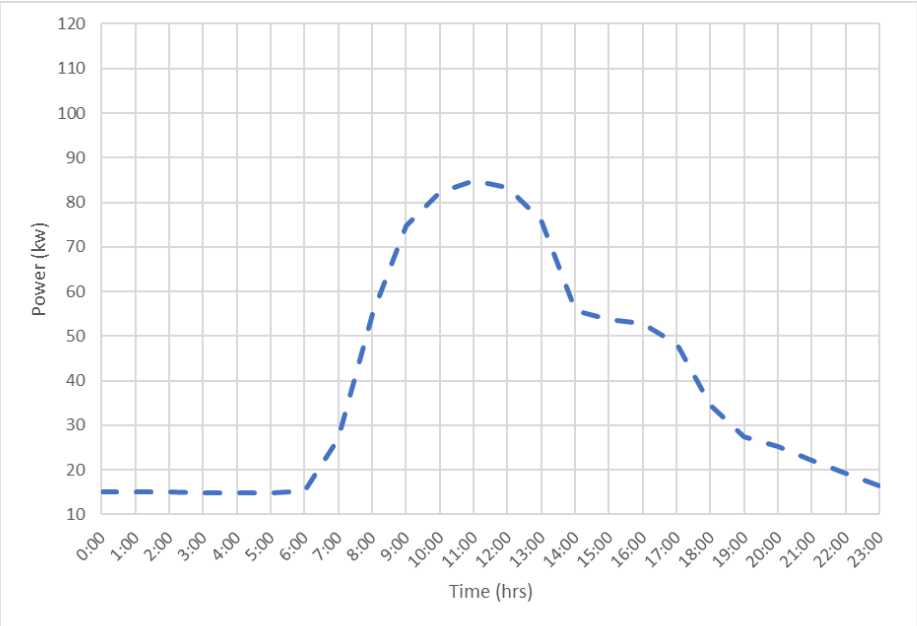

Figure 54: Consumption data for a sample day in the midseason season.

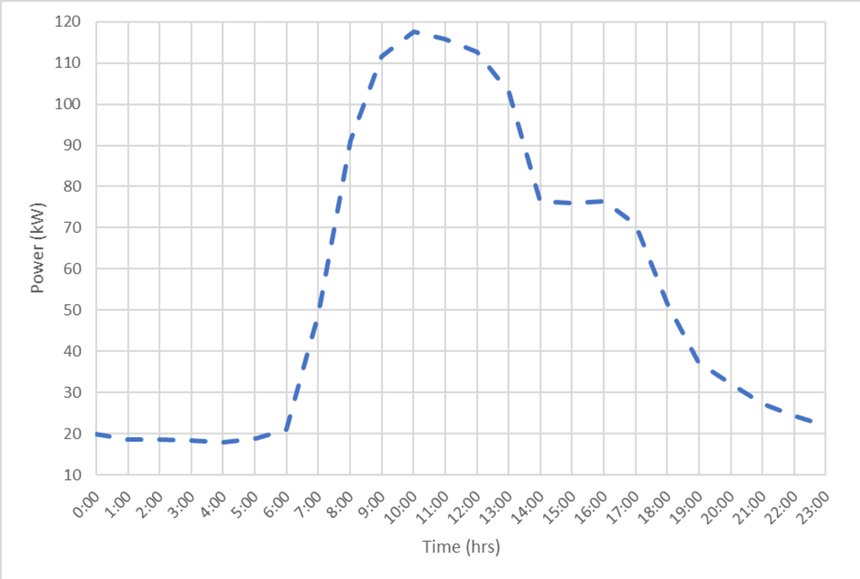

Figure 55: Consumption data for a sample day in the winter season.

The LDCs for the summer, midseason, and winter seasons are shown in Figure 56, Figure 57, and Figure 58, respectively.

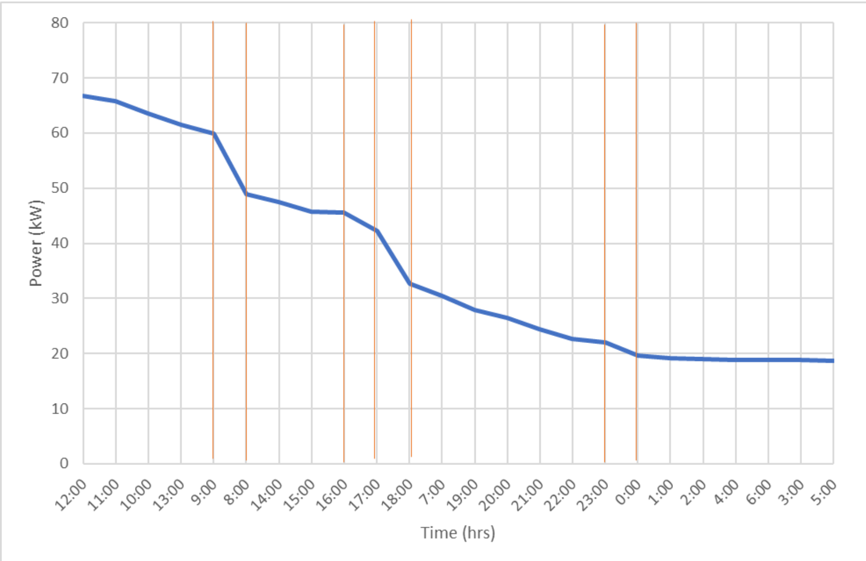

Figure 56: Load Duration Curve (LDC) for a sample day in the summer season.

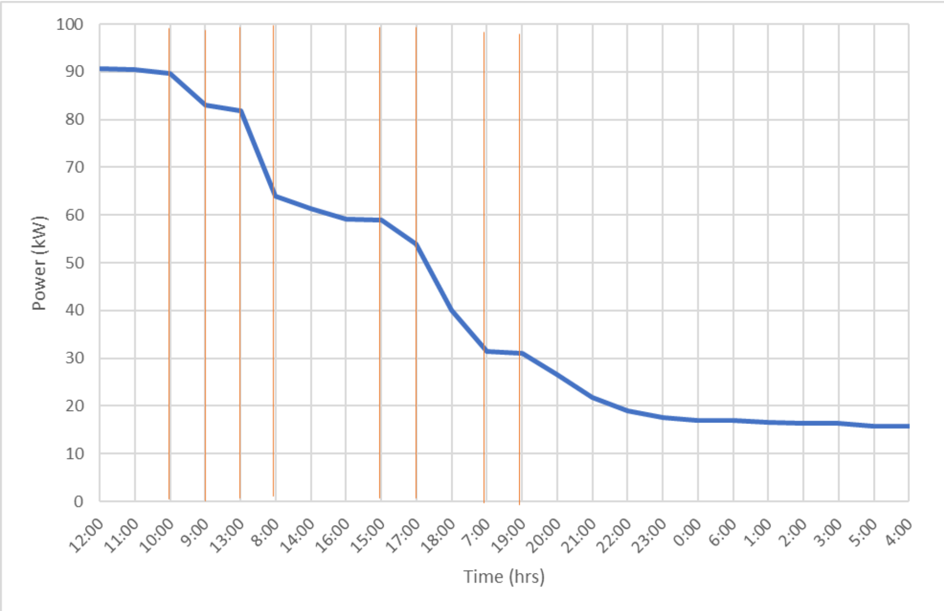

Figure 57: Load Duration Curve (LDC) for a sample day in the midseason season.

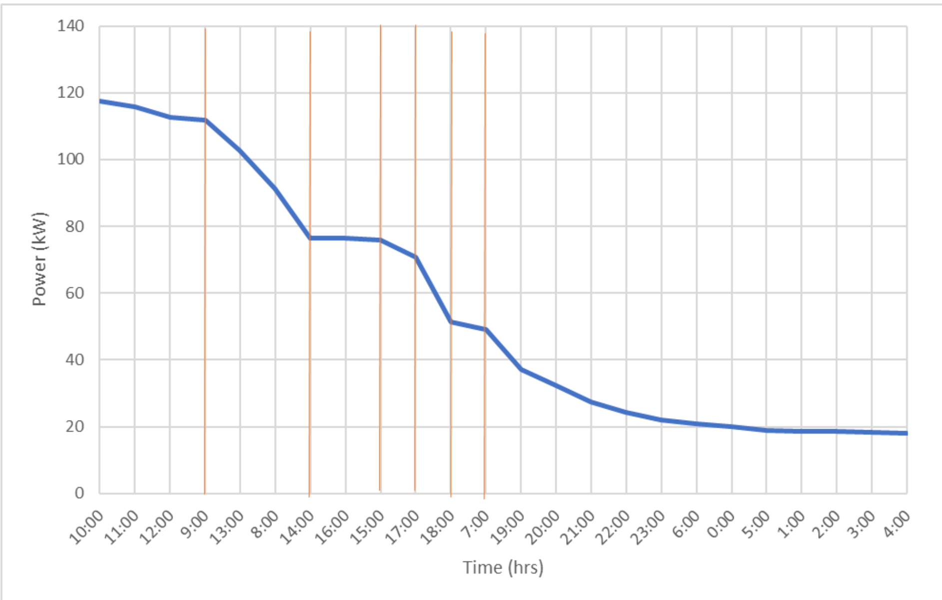

Figure 58: Load Duration Curve (LDC) for a sample day in the winter season.

The resulting ToU blocks are shown in Figure 59, Figure 60, and Figure 61 for the summer, midseason, and winter seasons, respectively. The on-peak consumption period is charged with the highest tariff, while the lowest tariff occurs during the valley period.

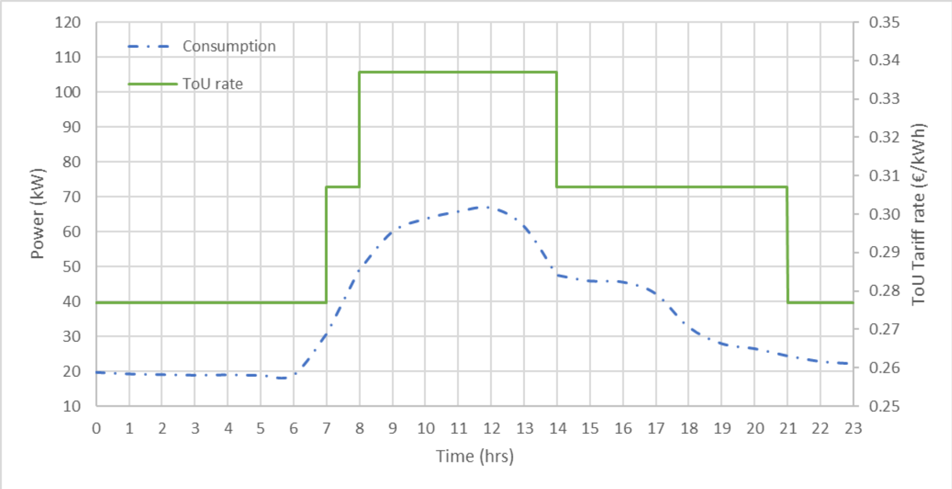

Figure 59: Resulting ToU tariffs for the summer season.

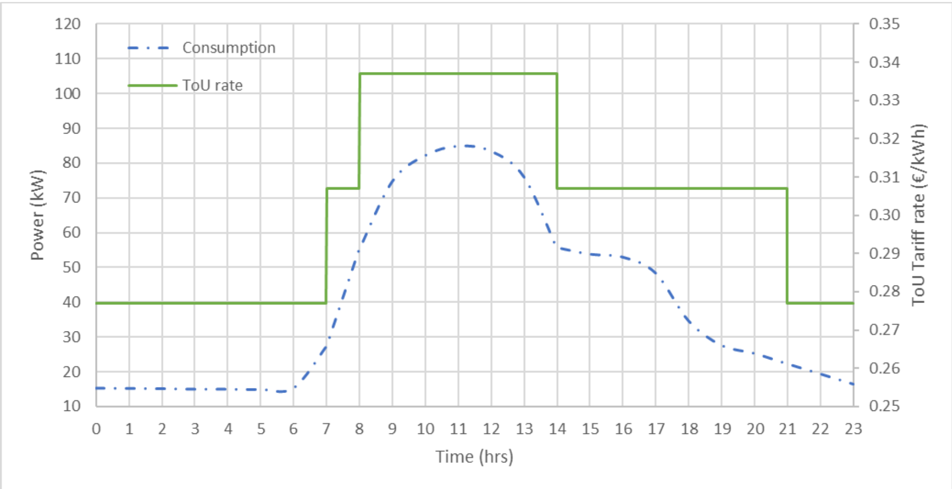

Figure 60: Resulting ToU tariffs for the midseason season.

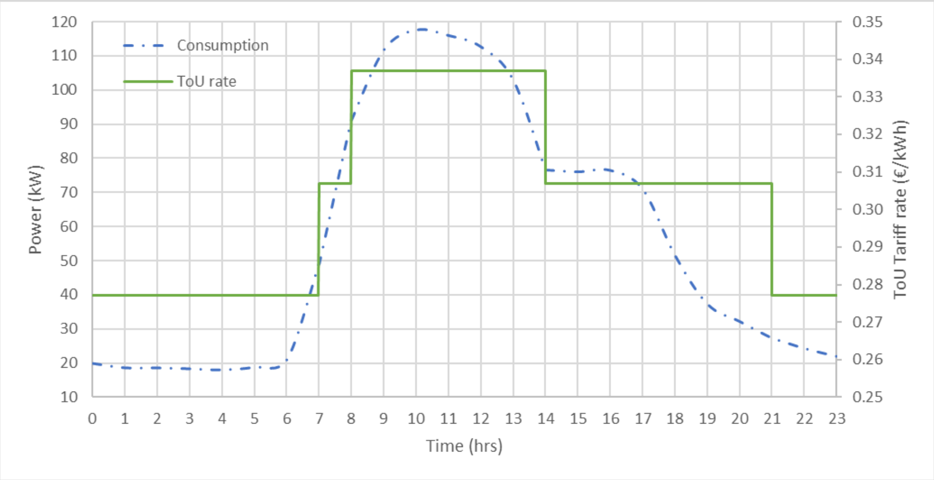

Figure 61: Resulting ToU tariffs for the winter season.

The resulting ToU tariffs and periods for each segment for every season are summarized in Table 17. The value of the peak, shoulder and off-peak price take into consideration the set criteria.

Table 17: Timetable of ToU block periods.

Block	Price (€/kWh)	Summer	Midseason	Winter
Working days				
On-peak	0.337	08:00-13:59	08:00-13:59	08:00-13:59
Shoulder	0.307	07:00-07:59, 14:00-20:59	07:00-07:59, 14:00-20:59	07:00-07:59, 14:00-20:59
Off-peak	0.277	21:00-06:59	21:00-06:59	21:00-06:59
Non-working days				
On-peak	0.337	-		
Shoulder	0.307	-		
Off-peak	0.277	All times		

6.2 Further analysis of the proposed new dynamic ToU tariffs

The analysis in the aforementioned subsection considered only the energy consumption in the load profile of the pilot buildings. However, the proposed new dynamic ToU tariffs can be optimized further if the PV and BESS capacities are included in the analysis. Therefore, in this subsection it is investigated how these capacities affect the time scheduling of the ToU tariffs. Additionally, the effect of Load Shifting (LS) through the DSM methodology is investigated in an effort to increase the self-consumption capability of the nanogrid system.

6.2.1 Investigation of the effect of the preselected PV and BESS capacities on the proposed new tariffs

In addition to the building consumption for the pilot buildings, it is also important to include and consider the effect of the pre-selected PV[14] and BESS capacities in the development of the new ToU tariffs. As an example, the effect of these capacities on the operation of the Cyprus pilot are investigated, with the purpose of determining: (a) the level of self-sufficiency, and (b) the number of battery Electric Vehicles (EVs) that can be charged by the nanogrid system.

To visualize Building consumption vs. PV power generation, graphs for the summer, midseason, and winter sample days are shown in Figure 62, Figure 63, and Figure 64, respectively. For the summer and winter seasons, consumption and PV power generation peak periods seem to coincide, while during the midseason period, PV power generation remains at approximately the levels of the summer season, but consumption is very low due to the very limited needs for heating or cooling during this period. Therefore, it is critical to investigate the level of self-sufficiency in relation to the available BESS capacity. Further on, if the level of self-sufficiency has already been achieved, the number of EVs that can be charged can be determined for each season.

[14] PV power generation for a 40 kW PV system found by approximation, considering the operation of an existing 6 kW PV system at the UCY PV lab.

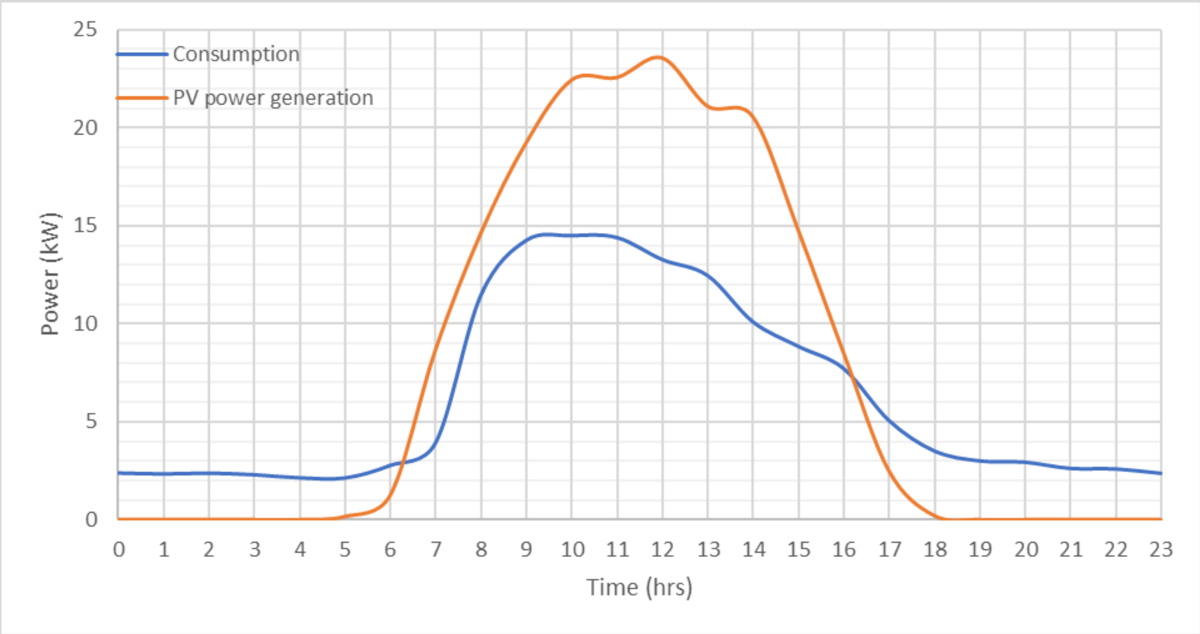

Figure 62: Building consumption vs. PV power generation for a sample day in the summer season.

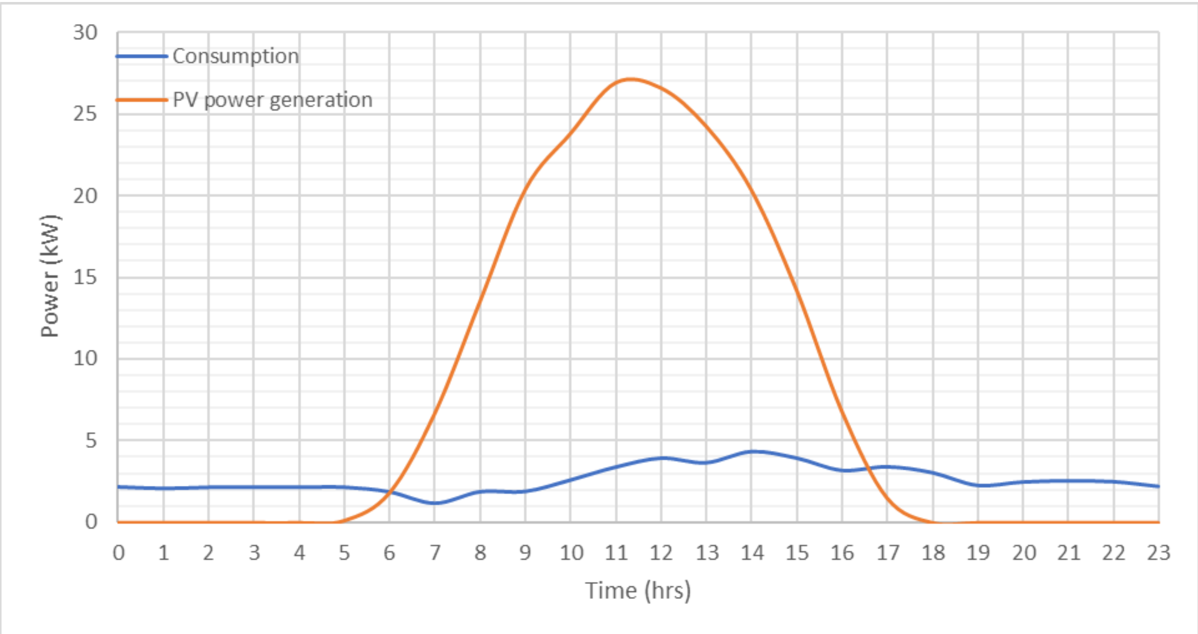

Figure 63: Building consumption vs. PV power generation for a sample day in the midseason season.

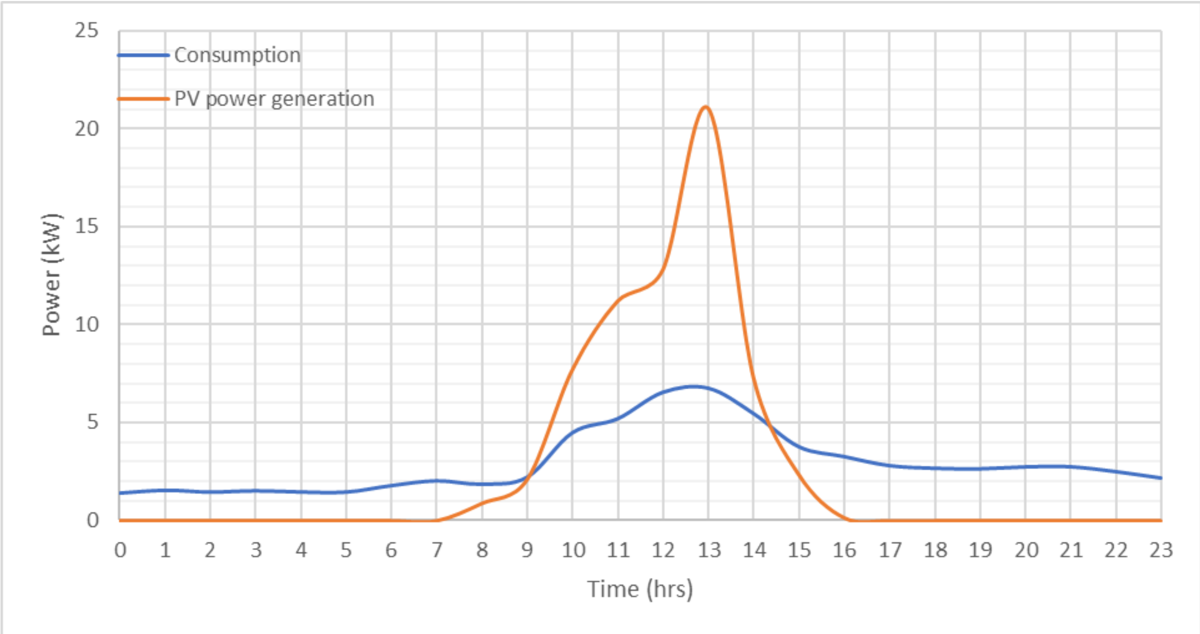

Figure 64: Building consumption vs. PV power generation for a sample day in the winter season.

The hourly energy distribution, which includes Building consumption, PV-generated electricity, EV charging, and BESS, is shown in Figure 65 for the summer season. The BESS reaches its full capacity in the afternoon (around 15:00), while EV charging is assumed to be available from 08:00 to 17:00 (office hours). Proper and careful scheduling of the EV charging is important to keep the battery state-of-charge (SOC) within its actual capacity range[15], while simultaneously avoiding the need of exporting electricity to the central power grid. After around 17:00, when electricity generation from the PV subsystem is very low and eventually stops, the building consumption is covered entirely from the BESS; this pattern continues until the morning hours when electricity generation from the PV subsystem is again available (after around 06:00).

Based on the aforementioned building consumption and PV power generation, the approximate excess (or deficient) PV-generated electricity for the three seasons can be calculated. When there is excess PV power generation, the BESS can supply EVs, while in the case of deficiency it will be necessary to import electricity from the central power grid. For the purposes of this analysis, it is assumed that each EV will be charged with 50 kWh per day[16]. Also, BESS self-discharge losses have been omitted from the analysis, as these are currently difficult to be approximated.

[15] The BESS capacity of the Cyprus pilot is 50 kWh.
[16] This is approximately the 75% BESS capacity of an average, commercially available EV.

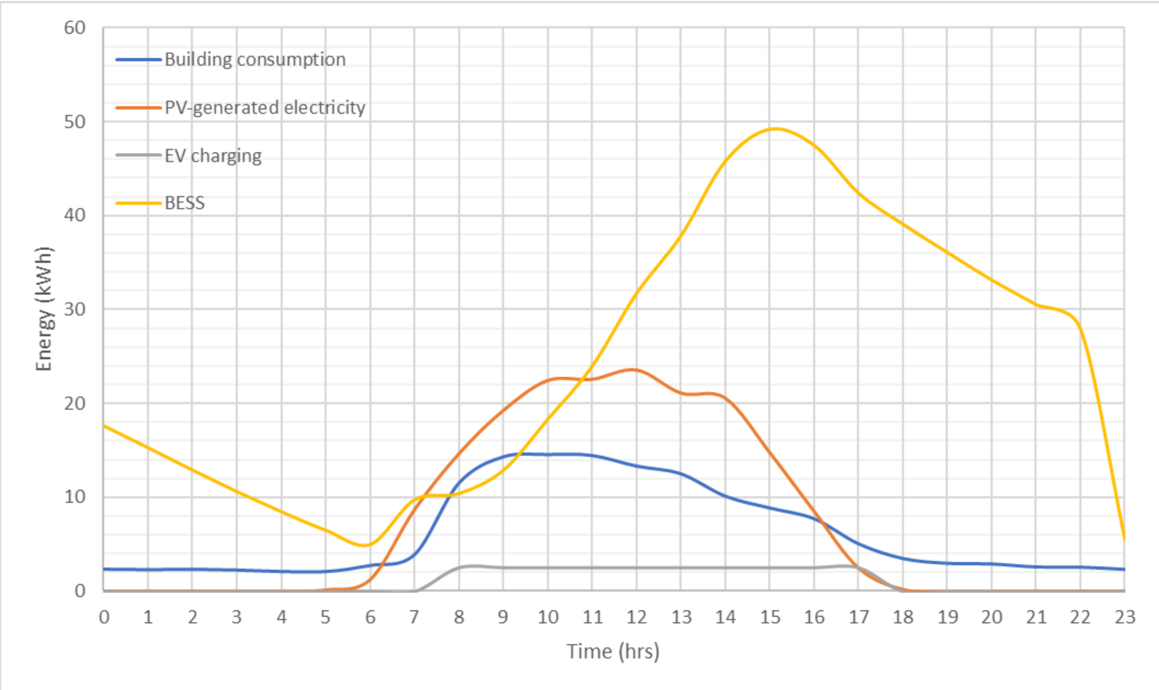

Figure 65: Hourly energy distribution of Building consumption, PV-generated electricity, EV charging, and BESS in the summer season (sample day).

The results indicate that there is excess PV power generation during the summer and midseason seasons, while during the winter season there is some marginal deficiency. Therefore, during summer and midseason the excess power generation can be used to charge EVs. More EVs can be charged during midseason than summer, due to the low building consumption. However, it should be noted that since in this analysis only three sample days (one per season) have been considered, it must be expected that in the actual system operation, there will be some summer days where the system will not be 100% self-sufficient, due to variations in PV power generation and building consumption. Overall, the EV charging capability of the UCY nanogrid is expected to have a low penetration during the summer season, while the penetration will be significantly higher during midseason.

Based on the above findings, the proposed ToU tariff timetable can be revised to include the effect of the PV power generation and BESS, since the PV and BESS capacities cannot be varied. Overall, the following considerations must be included in the development of new ToU tariffs:

- The cost of electricity must be high when PVs are not generating electricity (18:00-06:00), because at these times electricity is supplied only through electricity stored in the BESS. Otherwise, electricity will need to be imported from the central power grid, which will decrease the self-sufficiency rate of the nanogrid system.

- The cost of electricity must be low when PVs are generating electricity to increase consumption during these times, and also avoid exceeding the BESS maximum capacity. Otherwise, electricity will need to be exported to the central power grid or curtailed, which will decrease the self-consumption rate of the nanogrid system.

To include the above considerations in the proposed new ToU tariffs, their timetable is revised, as shown in Table 18. These revised values are also selected in a way that does not affect any of the involved stakeholders (utility vs. consumers), i.e., the total average cost of electricity for flat and new ToU tariffs remains the same (€35.5 per day).

Table 18: Revised timetable of the proposed ToU block periods after inclusion of the projected PV power generation profile with the pre-selected PV and BESS capacities of the Cyprus pilot.

Block	Price (€/kWh)	Summer	Midseason	Winter
Working days				
On-peak	0.4263	17:00-06:99	17:00-05:99	15:00-08:59
Shoulder	0.3763	07:00-09:59, 15:00-16:59	06:00-07:59, 15:00-16:59	09:00-09:59, 14:00-14:59
Off-peak	0.3263	10:00-14:59	08:00-14:59	10:00-13:59
Non-working days				
On-peak	0.4263	-		
Shoulder	0.3763	-		
Off-peak	0.3263	All times		

6.2.2 Load shifting through the application of DSM

The proposed new ToU tariffs promote LS in the context of the DSM methodology. Nevertheless, LS must not only take into consideration the building consumption, but also the PV and BESS capacities, along with the desire to maximize the EV charging capability of the nanogrid system. As an example, the LS potential of the Cyprus pilot is analysed in depth.

Firstly, it can be identified that if the buildings of the Cyprus pilot were supplied entirely with conventional power, where electricity is supplied from the central power grid with electricity generated in large-scale power stations, the target of LS would be to shift loads from on-peak/high demand periods (morning to afternoon, i.e., approximately: 08:00-17:00) to off-peak/low demand periods (night to early morning hours, i.e., approximately: 18:00-07:00).

However, with the nanogrid system of the Cyprus pilot, the above pattern of LS is undesirable since the target is to reach self-sufficiency, while maximizing self-consumption (incl. EV charging potential), with no electricity exports to the central power grid, or curtailment. Specifically, consumption (incl. building consumption and EV charging) should remain high during PV power generation hours (i.e., daytime; roughly 07:00-16:00) and low during the remaining times, when the PV subsystem is not operating (roughly 18:00-06:00). This is necessary for the following reasons:

- During daytime, the BESS must be charged in a way that avoids exceeding its maximum capacity, which would result in the undesirable need to export electricity to the central power grid, which would reduce self-consumption.
- On the other hand, during time periods where the PV subsystem is not generating any electricity, consumption is only satisfied through the BESS. However, the BESS has a limited capacity, and therefore consumption during these times should remain low to avoid draining the batteries, which would result in the need to import electricity from the central power grid, which would in turn reduce self-sufficiency.

Therefore, for the case of the Cyprus pilot, LS from daytime to night-time is undesirable and ineffective. Instead, LS should focus on deferrable loads that can be moved from weekdays to weekends. This is because consumption during weekends is low due to the fact that offices are closed, and for the same reason no EV charging takes place during these times, while PV power generation remains high during daytime (as in weekdays).

LS from weekdays to weekend can be conducted through a parametric study, with the aim of determining quantitatively the projected benefits. In the case of the winter season, the purpose of LS is to maximize self-sufficiency. As mentioned in subsection 6.2.1, during summer and midseason, self-sufficiency has already been achieved without the need of LS. Therefore, the purpose of LS for these seasons is to maximize the EV charging potential.

The results that derive from the application of LS are given in Table 19. In the winter, the level of self-sufficiency has increased from 95 to 98% with a 5% LS (this is the maximum possible level of self-sufficiency that can be achieved, and therefore higher LS values are not applied in the parametric study). In the summer, the number of EVs charging per week are 3.20 before LS and can increase to up to 6.95 with 25% LS. In the midseason the number of EVs charging per week are 7 before LS and can increase to up to 10 with 25% LS.

Table 19: Level of self-sufficiency and EV charging potential before and after the application of LS to the Cyprus pilot.

Season	LS	Energy import from central power grid per week	Level of self-sufficiency[1]	EV charging energy per week	Number of EVs charging per week[2]
Summer	0%	-	100%	160 kWh	3.20
	5%	-	100%	198 kWh	3.95
	10%	-	100%	235 kWh	4.70
	15%	-	100%	273 kWh	5.45
	20%	-	100%	310 kWh	6.20
	25%	-	100%	348 kWh	6.95
Midseason	0%	-	100%	350 kWh	7.00
	5%	-	100%	380 kWh	7.60
	10%	-	100%	410 kWh	8.20
	15%	-	100%	440 kWh	8.80
	20%	-	100%	470 kWh	9.40
	25%	-	100%	500 kWh	10.00
Winter	0%	22 kWh	95%	-	-
	5%	9 kWh	98%	-	-

1: BESS self-discharge losses have been omitted; 2: Weekdays only.

The effect of LS for the Cyprus pilot is shown in Figure 66, Figure 67, and Figure 68, for the summer, midseason, and winter, respectively. As it can be observed from these graphs, LS has the highest potential during midseason. This is because although PV power generation is slightly lower than the summer, the building consumption is significantly lower than the summer. This allows a greater flexibility for LS from weekdays to the weekend.

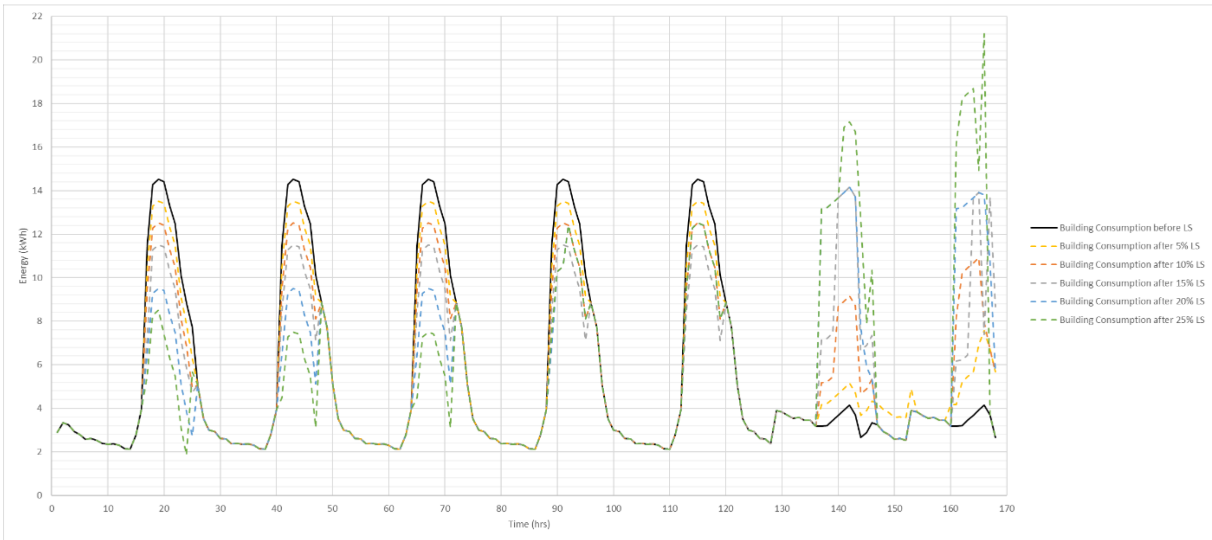

Figure 66: Effect of LS in the summer for the Cyprus pilot.

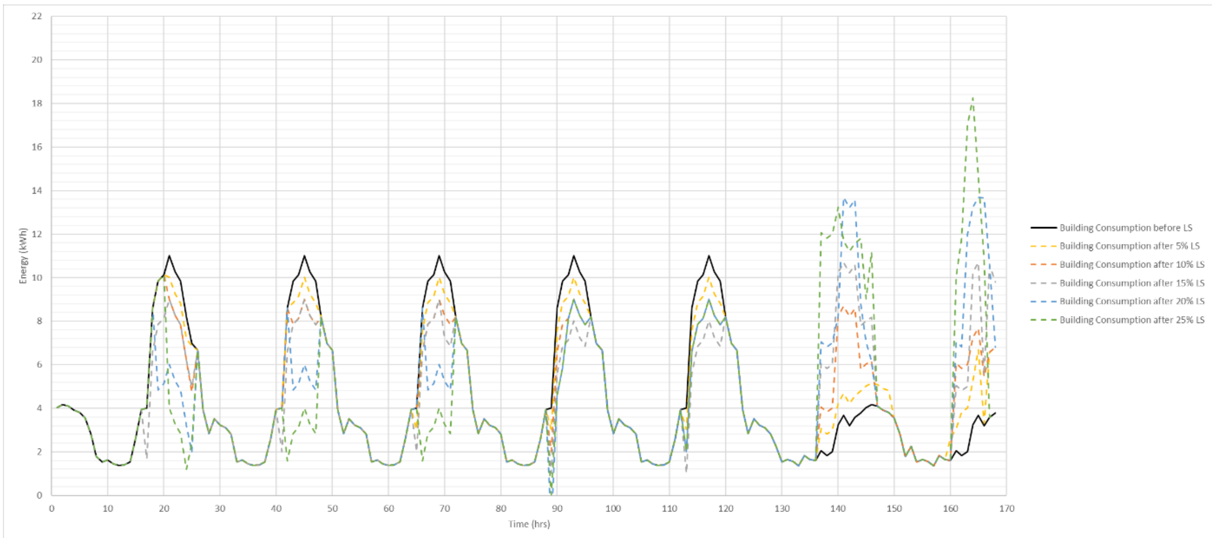

Figure 67: Effect of LS in the midseason for the Cyprus pilot.

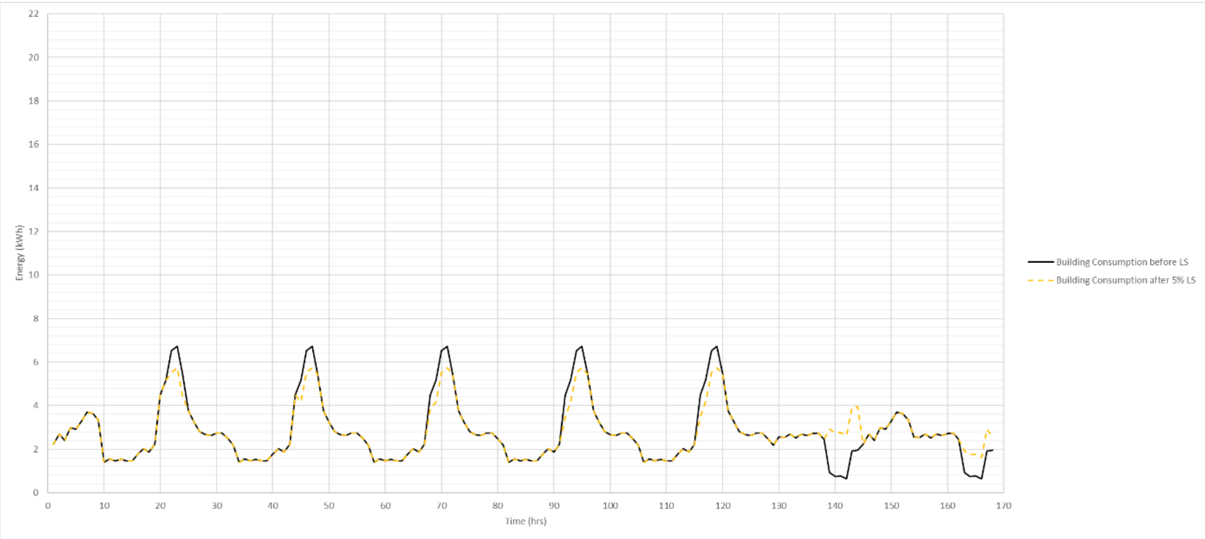

Figure 68: Effect of LS in the winter for the Cyprus pilot.

The effect of LS in the hourly EV charging energy is shown in Figure 69 and Figure 70 for the summer and midseason, respectively. As it can be observed from the graphs, more energy is supplied for EV charging in the beginning of the week, since the BESS has a high SOC after the end of the weekend. This is because consumption in the weekend is very low (low building consumption and no EV charging) in comparison to weekdays. It is noted that EV charging during the winter is unavailable due to the fact that there is no excess electricity.

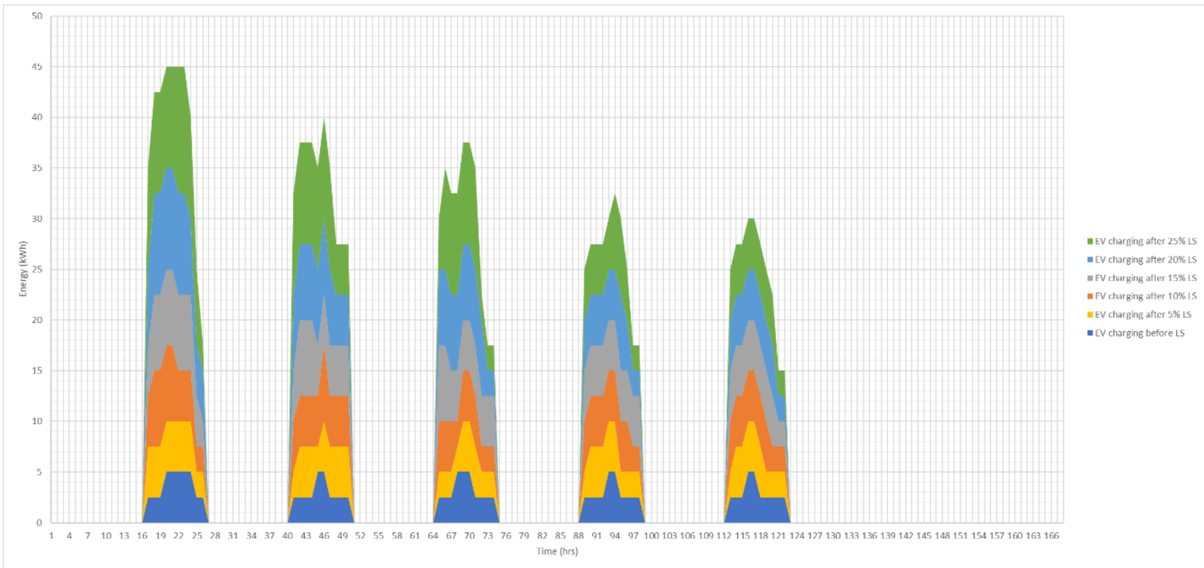

Figure 69: Effect of LS in the hourly EV charging energy in the summer for the Cyprus pilot.

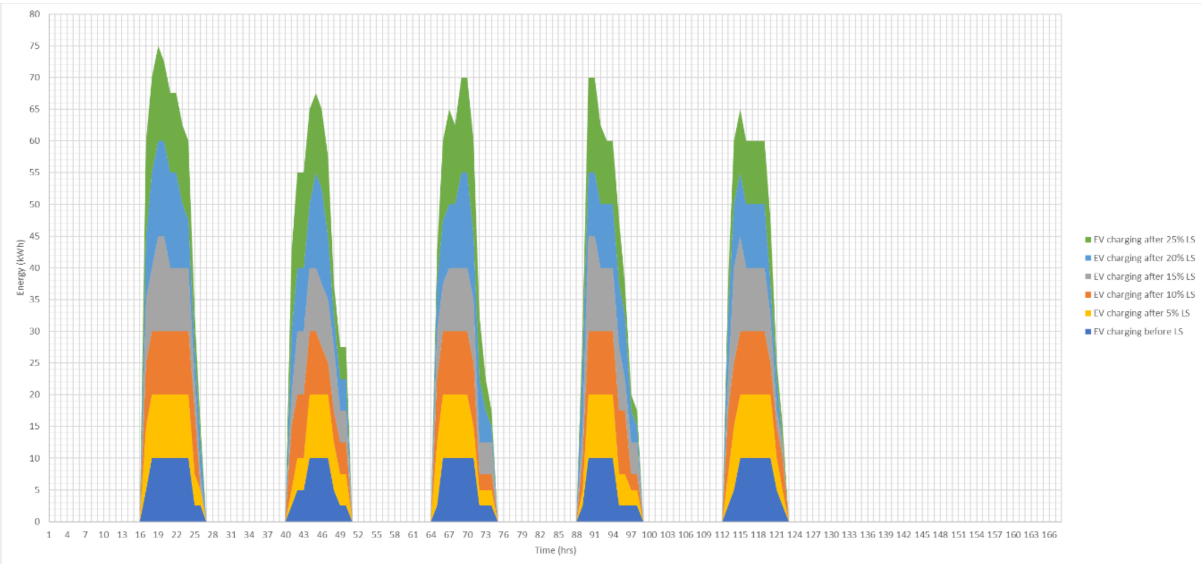

Figure 70: Effect of LS in the hourly EV charging energy in the midseason for the Cyprus pilot.

7 Conclusions

The goal of this activity is to propose new dynamic Time-of-Use (ToU) tariffs that can better reflect the actual dynamic cost of electricity generation in each country (such provision is recommended in the EU's winter package). The developed tariffs will be virtually tested on A3.2.4 at each pilot site. Currently only static (flat) tariffs are available in the four countries participating in the BERLIN project. Dynamic tariffs are desirable because they provide a fairer charging, and thereby they are more attractive to prosumers. They provide an active role to prosumers via the enabling of Demand Side Management (DSM) methods, which can help towards the reduction of peak load. This can in turn help decrease the required system components' capacity, and simultaneously increase the overall efficiency of the network.

For the implementation of a new dynamic tariffs suitable for the pilots of the BERLIN project, the chosen tariff type is ToU, since it has been identified as the most appropriate one, based on past experience. The proposed ToU tariffs aim at enabling price-based DSM schemes that can reduce system cost by considering and analysing the current energy consumption of each pilot in the BERLIN project. This helps establishing the ToU block periods and estimating the ToU rates.

Initially a basic methodology is considered, which includes three main steps: (a) analysis of the energy consumption data for every pilot, (b) establishment of the ToU block periods, and (c) estimation of the ToU rates. This methodology considers only the available consumption of the buildings, without any consideration of the available capacities of the PV subsystems and the BESS.

Then the proposed new dynamic ToU tariffs are optimized further with the consideration of the predefined Photovoltaic (PV) and Battery Energy Storage System (BESS) capacities in the analysis. It is investigated how these capacities affect the time scheduling of the ToU tariffs, and the time blocks are modified accordingly. These revised values are also selected in a way that does not affect any of the involved stakeholders (utility vs. consumers). The outcomes of this analysis are the following:

1. The cost of electricity must be high when PVs are not generating electricity (18:00-06:00), because at these times electricity is supplied only through electricity stored in the BESS. Otherwise, electricity will need to be imported from the central power grid, which will decrease the self-sufficiency rate of the nanogrid system.
2. The cost of electricity must be low when PVs are generating electricity to increase consumption during these times, and also avoid exceeding the BESS maximum capacity. Otherwise, electricity will need to be exported to the central power grid or curtailed, which will decrease the self-consumption rate of the nanogrid system.

Additionally, the effect of Load Shifting (LS) in the context of the DSM methodology is investigated in an effort to increase the self-consumption capability of the nanogrid system. LS takes into consideration the building consumption, the PV and BESS capacities, along with the desire to maximize the EV charging capability of the nanogrid system. As an example, the LS potential of the Cyprus pilot is analysed in depth. For this pilot, LS from daytime to night-time is undesirable and ineffective.

Instead, LS must focus on deferrable loads that can be moved from weekdays to weekends. This is because consumption during weekends is low due to the fact that offices are closed, and for the same reason no Electric Vehicle (EV) charging takes place during these times, while PV power generation remains high during daytime (as in weekdays).

LS from weekdays to weekend is conducted through a parametric study, with the aim of determining quantitatively the projected benefits. In the winter season, the purpose of LS is to maximize self-sufficiency, while during summer and midseason, self-sufficiency has already been achieved without the need of LS, and therefore the purpose of LS is to maximize the EV charging potential. After the application of LS, in the winter, the level of self-sufficiency has increased from 95 to 98%, while in the summer, the number of EVs charging per week increase from 3.95 to up to 6.95. In the midseason the number of EVs charging per week have increased from 7 to up to 10.

LS has the highest potential during midseason, because although PV power generation is slightly lower than the summer, the building consumption is significantly lower than the summer. This allows a greater flexibility for LS from weekdays to the weekend. Also, more energy is supplied for EV charging in the beginning of the week since the BESS has a high State-of-Charge (SOC) after the end of the weekend. This is because consumption in the weekend is very low (low building consumption and no EV charging) in comparison to weekdays.