Study on Regulatory Approaches of Electricity TSO & DSO Network Tariff Structures among ERRA Member Organizations

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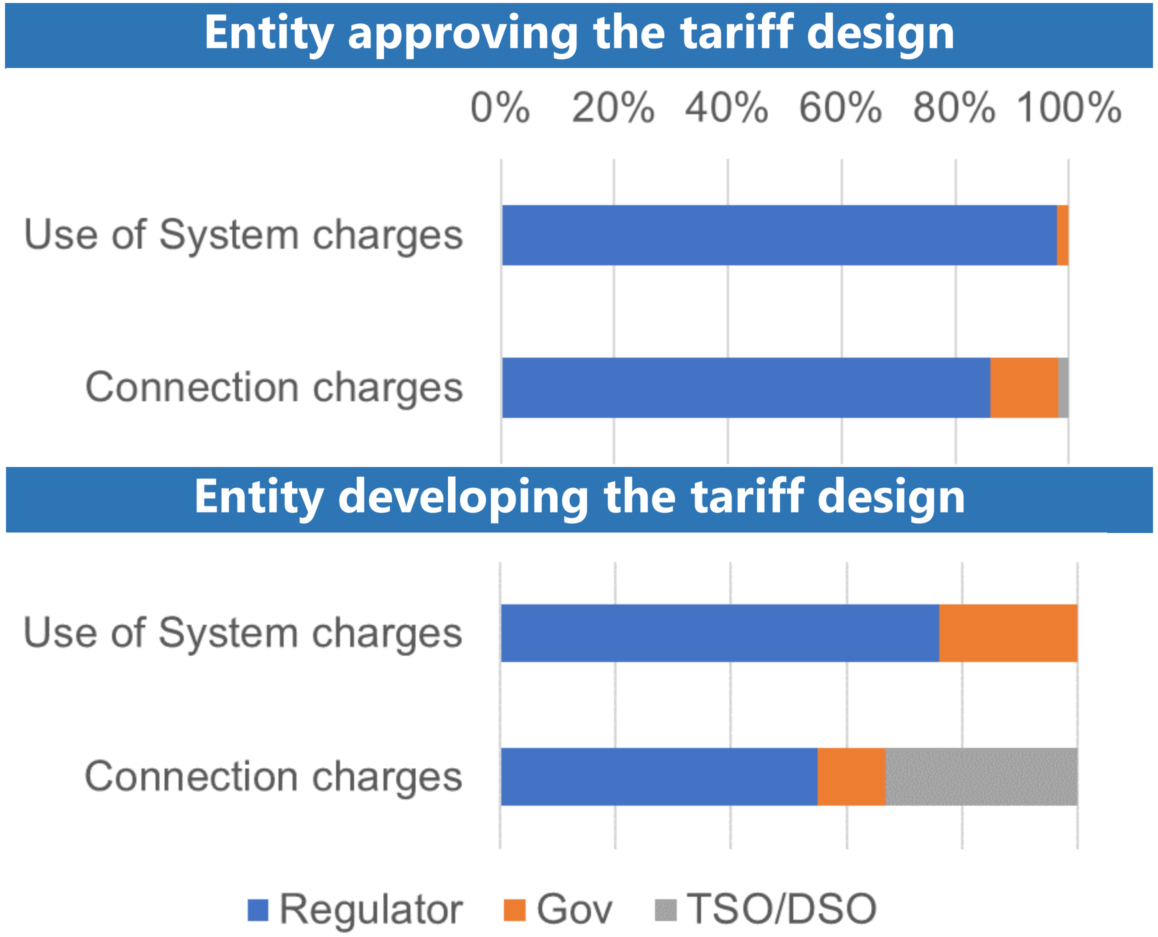
Contents

This presentation summarises findings for the tariff design of network use-of-system and connection charges among MOs

Scope and objectives	The scope was to **collect information** from ERRA Member Organisations (MOs) in relation to electricity **network tariff designs** to deliver a study for: • **Benchmarking / knowledge sharing** of transmission and distribution use of system (UoS) and connection charges tariff designs and policy developments. • Deliver an **insight** for other institutions **for further analysis on tariff designs**.
Approach	The study draws on survey **data collected from 26 MOs of ERRA** (out of 32 surveyed) and covers network UoS and connection charges tariff designs. The concepts unravelled included: • Regulations and principles adopted for the design of charges • Drivers for grouping customers to tariff categories • Locational signals embedded in the tariff designs and treatment of generators versus load • Treatment of losses in the charging approach • Types of charges that are being used (energy, capacity, fixed, time-of-use, etc) • Depth of connection charges and payment method • Use of special tariff designs for emerging technologies • Present level of charges

The typical approach is for Regulators to develop and approve the tariff design

- Network charges were completely unbundled in all MOs except in four cases. (Dubai, Algeria, Thailand and Czechia)
- In the sample of 26 MOs analysed, most MOs had only one TSO (92%), while most MOs had more than three DSOs (50%).
- Regulators are mostly responsible for approving and developing the tariff designs.
  - In some MOs, TSOs and DSOs develop the use-of-system or connection charge.
- The approval of tariff designs rests exclusively with Regulators or the Government.



Cost-recovery and cost-reflectivity are the most common and important principles among MOs for tariff design

First-order requirements

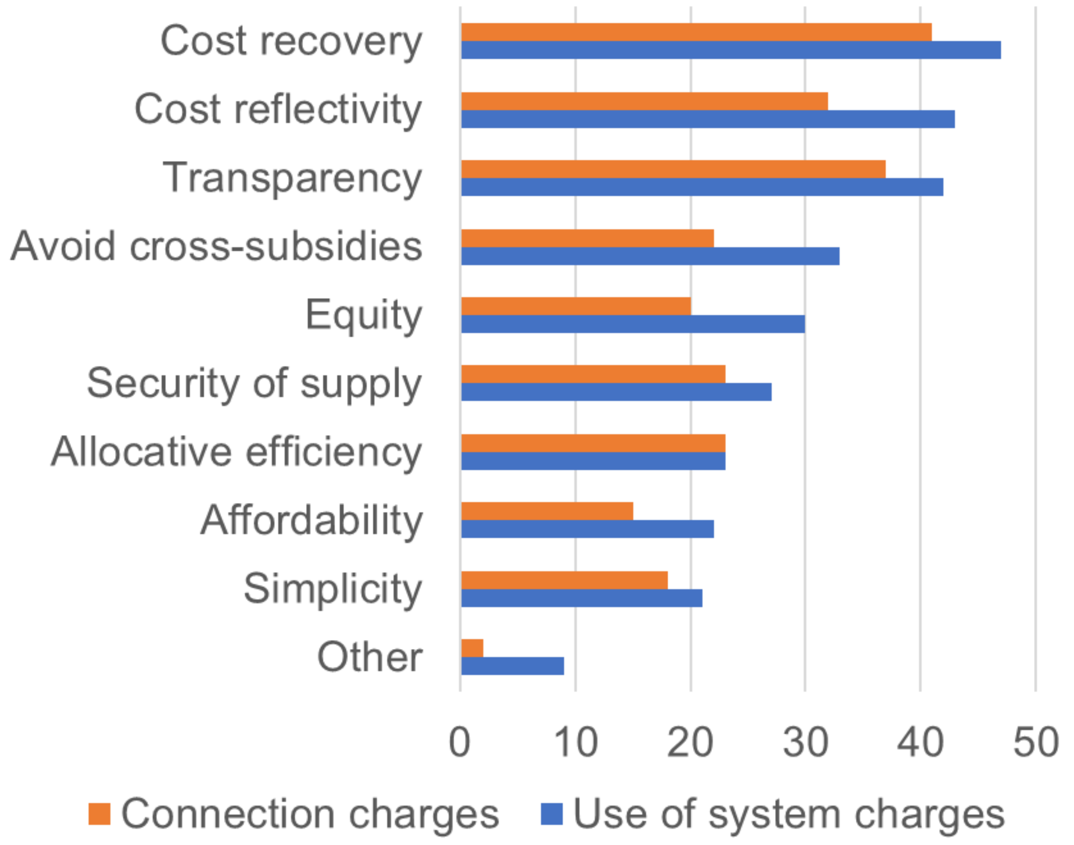
- ***Cost-recovery*** - Tariffs recover total costs
- ***Cost-reflectiveness/Allocative efficiency/ Avoid cross subsidies*** **-** Tariffs reflect the cost of supply

Second-order requirements

- *Transparency* - Tariffs are calculated using published methodologies
- *Simplicity* - Tariffs are easy to understandable
- *Affordability* - Tariffs are affordable by consumers
- *Equity/Fairness* - All consumers are treated equitably and in a non-discriminatory way

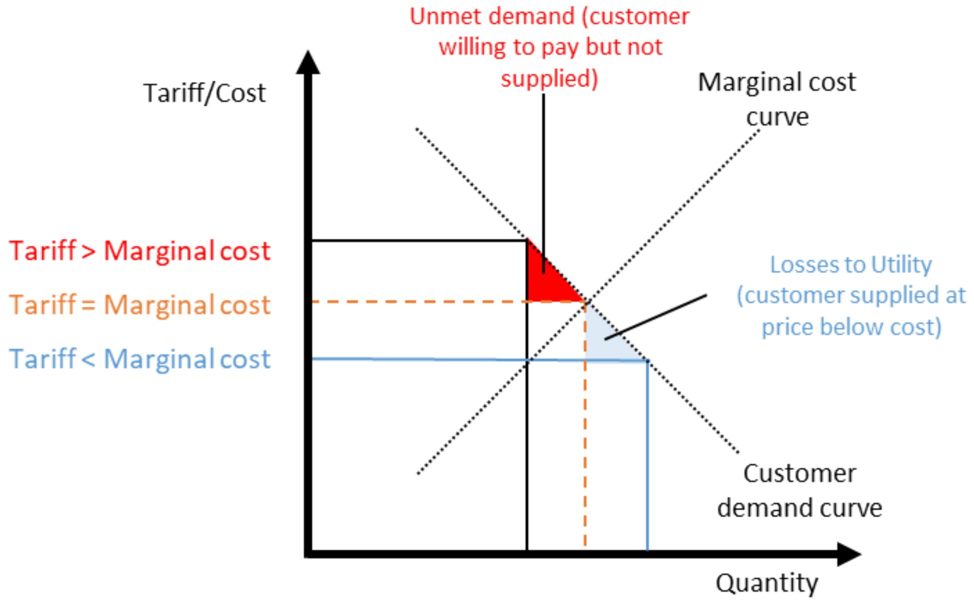
These inevitably come into conflict with each other. Therefore, the tariff design becomes an 'art' of how to balance conflicting objectives.

Guiding principles in regulations for the development of network tariff designs

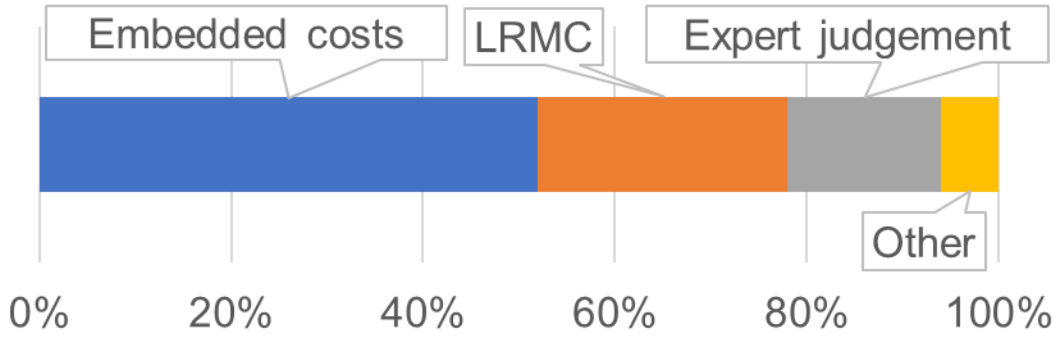


Why is cost-reflectiveness important?

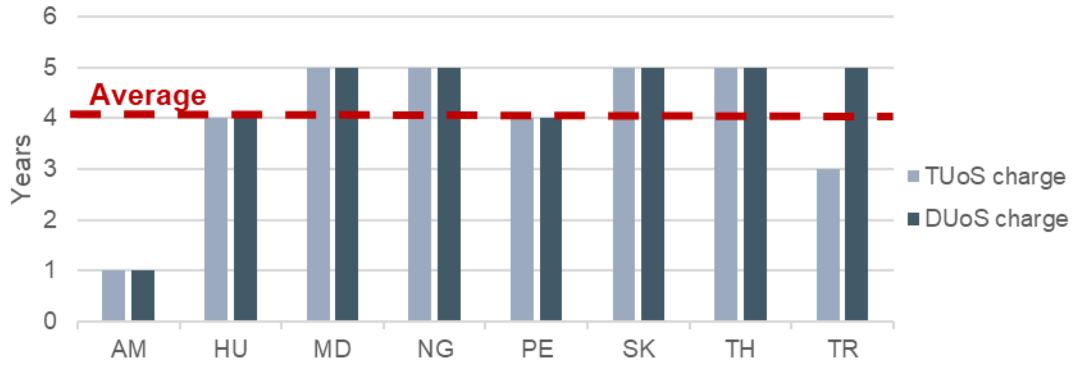
- One of the guiding principles and overall goals of tariff design is to determine cost-reflective tariffs.
- Economically efficient or cost-reflective pricing requires that the tariff paid by a customer should be equal to the marginal costs of supply of that customer. If this is not the case, then the outcome is inefficient.



Approaches for determining cost-reflective tariff designs among MOs



Typical frequency for tariff redesigns is 4-5 years



The key principles to guide categorisation of customers were Simplicity, Cost reflectivity, Subsidies and Ease of identification

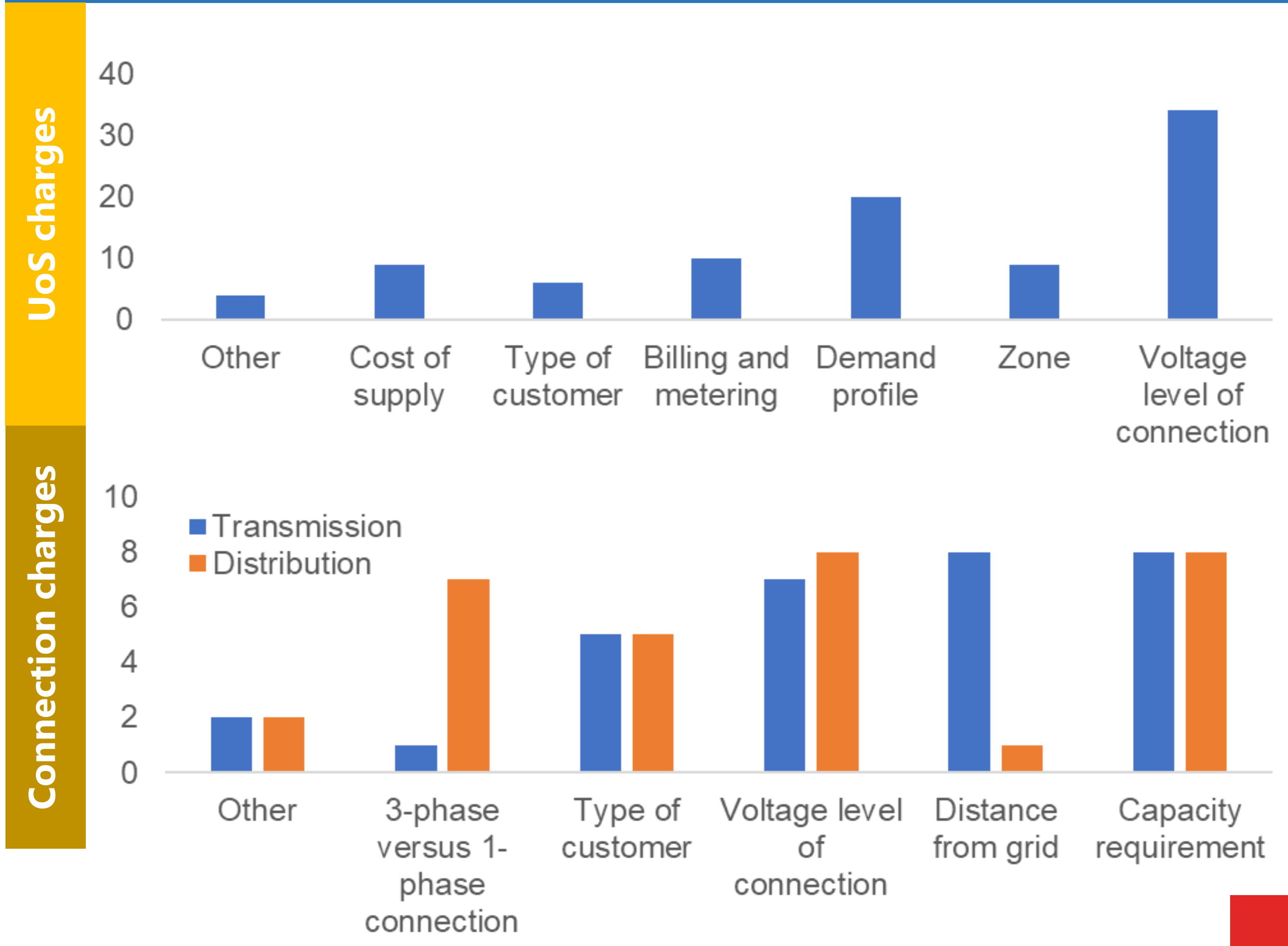
Key principles:

- **Simplicity -** Have as few categories as possible to reduce billing complexity and arbitrage.
- **Cost reflectivity -** Group customers based on the cost of supply.
- **Subsidies -** Separate categories may be needed to allow more efficient direction of subsidies.
- **Ease of identification -** It should be easy to assign customers to a category.

Typical numbers for tariff categories:

- The **average number of tariff categories** for TUoS charges was 3, for DUoS 7 and for connection charges 4.

Most common approach for grouping customers among MOs is the voltage level of supply



Tariff structures should reflect the drivers of costs but in practice tariffs will deviate from this ideal structure for many reasons

Ideally, tariff structures should reflect the drivers of costs.

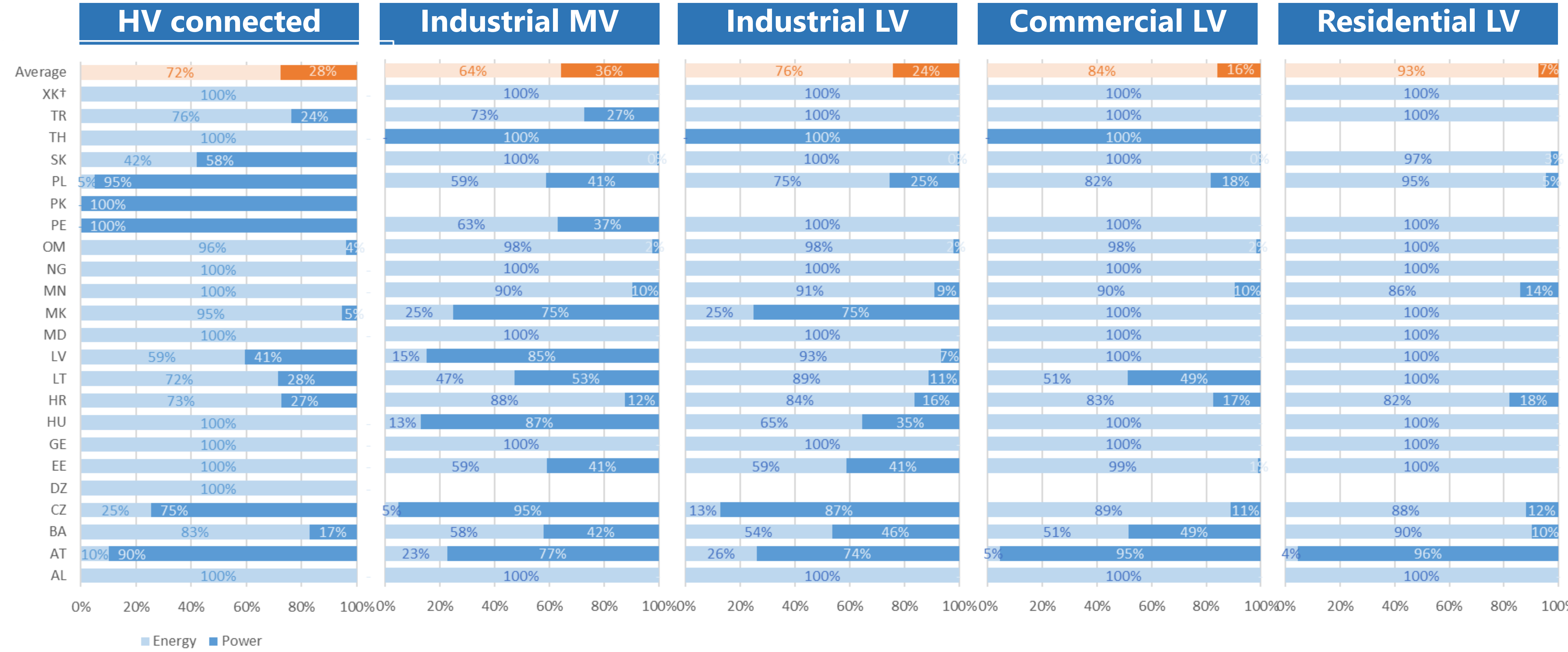
Capacity charges (€ / kW or kVA /period)	Used to recover generation and network capacity costs. Should be based on demand (kW) at time of system peak, as this is the driver of investment needs.
Seasonal and Time-of-Day (STOD) energy charges (€/kWh)	Used to recover the variable costs of electricity supply in each interval.
Fixed or standing charges (€/customer/period)	Used to recover the costs of customer related activities such as metering, billing and collections which do not vary with customer demand or consumption.
Reactive power charges (€/kVArh) or penalties (€ below a power factor)	Used to provide incentives for customers to improve their power factor and, therefore, reduce the costs of supplying them.

In practice, tariffs will deviate from this ideal structure for many reasons including issues of acceptability, simplicity and cost of metering relative to the benefits achieved from more complex tariff structures.

What tariff types and pricing signals MOs use for network use of system charges?

	Transmission UoS charges						Distribution UoS charges					
	Price signal			Charges (for load)			Price signal			Charges		
Country	Seasonal time of day	Location	Load / Generation	Power	Energy	Reactive power	Seasonal time of day	Location	Load / Generation	Power	Energy	Reactive power
Albania	No	No	100% load	100% energy			No	No	100% load	100% energy		
Algeria	No	No	100% load	100% energy			No	No	100% load	Yes	Yes	Only MV-HV
Armenia	No	No	100% load	100% energy			No	No	100% load	100% energy		
Austria	No	Zonal	96%/4%	Yes	Yes	Yes	Yes	No	90%/10%	Yes	Yes	Yes
BiH	No	No	90%/10%	Yes	Yes	No	Yes	No	100% load	Yes	Yes	Yes (not for households)
Croatia	Yes	No	100% load	Yes	Yes	Yes	Yes	No	100% load	Yes (not for households)	Yes	Yes (not for households)
Czechia	No	No	100% load	Yes	Yes	No	Yes (optional)	No	100% load	Yes	Yes	Only MV
Estonia	No (330kV) Yes (<330kV)	No	100% load	No	Yes	Yes (330kV) No (<330kV)	Yes (optional)	No	Not available	Yes (optional)	Yes	Yes (optional)
Georgia	No	No	100% load	100% energy			No	No	100% load	100% energy		
Hungary	No	No	100% load	100% energy (Power charges apply only for non-DSO customers)			No	No	100% load	Yes (optional)	Yes	Yes (optional LV, mandatory MV)
Kosovo	No	No	100% load	Yes	Yes	No	No	No	100% load	100% energy		
Latvia	No	No	96%/4%	Yes	Yes	Yes	Yes (optional)	No	99.8%/0.2%	Yes (optional)	Yes	Yes
Lithuania	No	No	100% load	Yes	Yes	Yes	Yes	No	100% load	Yes (not for households)	Yes	Yes (not for households)
Moldova	No	No	100% load	100% energy			No	No	100% load	100% energy		
Mongolia	No	Zonal	100% load	100% energy			Yes (optional)	Zonal	100% load	Yes (not for households)	Yes	No
Nigeria	No	No	100% load	100% energy			No	No	100% load	100% energy		
North Macedonia	No	No	100% load	Yes	Yes	Yes	No	No	100% load	Yes (not for small LV)	Yes	Yes (not for small LV)
Oman	Yes	No	100% load	Yes	Yes	No	Yes (optional)	No	100% load	Yes (not for households)	Yes	No
Pakistan	No	No	100% load	Yes	No	No	Yes	No	100% load	Yes (not for households)	Yes	No (only for industry)
Peru	No	LMP	50%/50%	Yes	No	Yes	Yes (not for LV)	No	90%/10%	Yes (not for LV)	Yes	Yes (not for LV)
Poland	No	No	100% load	Yes	Yes	Yes	Yes (optional)	No	100% load	Yes	Yes	Yes
Slovakia	No	No	90%/10%	No	Yes	Yes	Yes (optional)	No	100% load	Yes (not for households)	Yes	Only MV, HV
Thailand	No	No	100% load	No	Yes	Yes	Yes (for large customers)	No	100% load	Yes (not for small customers)	Yes	Yes (not for small customers)
Turkey	No	Zonal	50%/50%	Yes	Yes	Yes	Yes (for large customers)	No	96%/4%	Yes	Yes	Yes (not for residential, lighting)
UAE - Abu Dhabi	No	No	100% load	Yes	No	No	No	No	100% load	Yes	No	No
Key: Yes / No	4% / 96%	16% / 84%	24% / 76%	56% / 44%	88% / 12%	40% / 60%	56% / 44%	4% / 96%	16% / 84%	76% / 24%	96% / 4%	60% / 40%

Energy charges are the primary mean for collecting revenues



Note: Estimated using typical consumption profiles for each customer category and the use of system charges submitted by MOs.

Most MOs have not developed yet special tariff designs for emerging technologies

- **Only 7 MOs have developed special tariff designs for (1) Distributed generation and storage, (2) Electric Vehicles charging and (3) Self-generators/Prosumers**

		Austria*	Lithuania	Poland	Slovakia	Turkey
Distributed generation and storage	Seasonal time of day	No	n/a	n/a	No	No
	Energy charge	Yes	n/a	n/a	No	Yes
	Maximum metered demand	Yes	n/a	n/a	No	No
	Maximum contracted capacity	Yes	n/a	n/a	Yes	No
	Reactive power charge/penalty	Yes	n/a	n/a	No	Yes
	Other requirements	Net metering	n/a	n/a	No	No
Electric Vehicles	Seasonal time of day	n/a	n/a	No	No	n/a
	Energy charge	n/a	n/a	Yes	Yes	n/a
	Maximum metered demand	n/a	n/a	Yes	No	n/a
	Maximum contracted capacity	n/a	n/a	No	Yes	n/a
	Reactive power charge/penalty	n/a	n/a	No	No	n/a
	Other requirements	n/a	n/a	No	No	n/a
Self-generators	Seasonal time of day	n/a	No	n/a	n/a	No
	Energy charge	n/a	Yes	n/a	n/a	Yes
	Maximum metered demand	n/a	No	n/a	n/a	No
	Maximum contracted capacity	n/a	Yes	n/a	n/a	No
	Reactive power charge/penalty	n/a	No	n/a	n/a	Yes
	Other requirements	n/a	Net metering	n/a	n/a	No

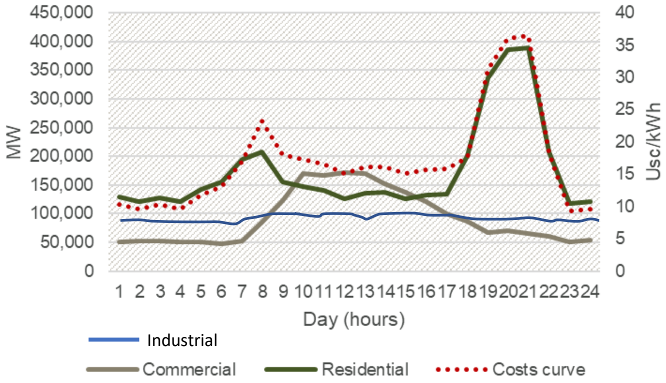
** Applied to pumped storage facilities*

Special tariff designs were examined for the following categories:

- *Distributed generation and storage,*
- *Electric Vehicles (EVs),*
- *Self-generators,*
- *Smart technologies,*
- *Independent Power Producers (IPPs)*
- *Economic Development Zones (EDZ))*

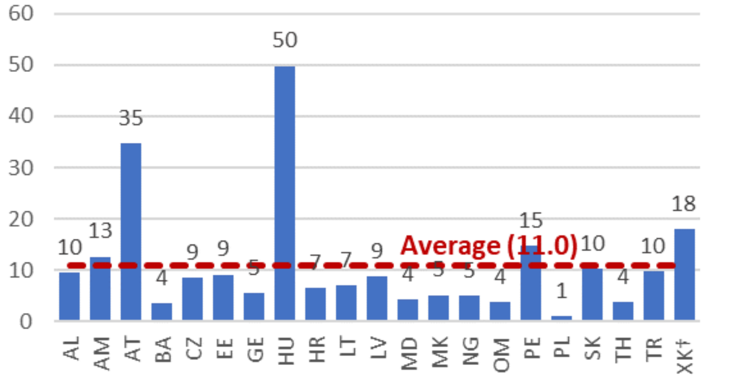
Residential network UoS tariffs are on average 11 times higher than HV industrial, Commercial 10.8 times higher, LV Small industrial 5 times higher and MV industrial 4 times higher

- Customers who consume more during peak hours and contribute most to the system peak typically have higher costs of supply.

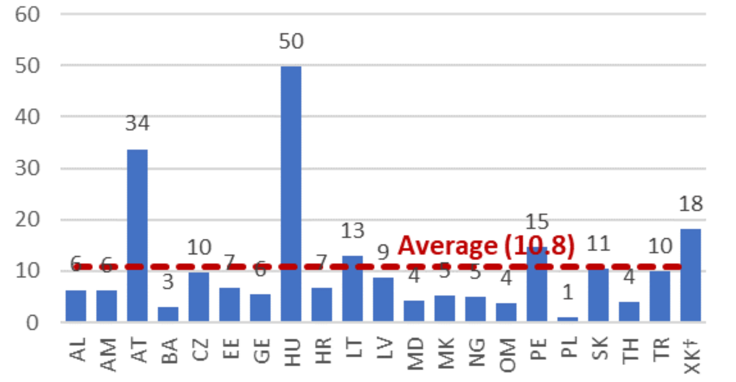


- Also customers connected at higher voltage levels typically have lower costs of supply due to lower cost of losses and lower infrastructure costs
  - In absence of LV connected customers the LV network would be unnecessary.
- Typically the cost of supply for Residential > Commercial> Industrial

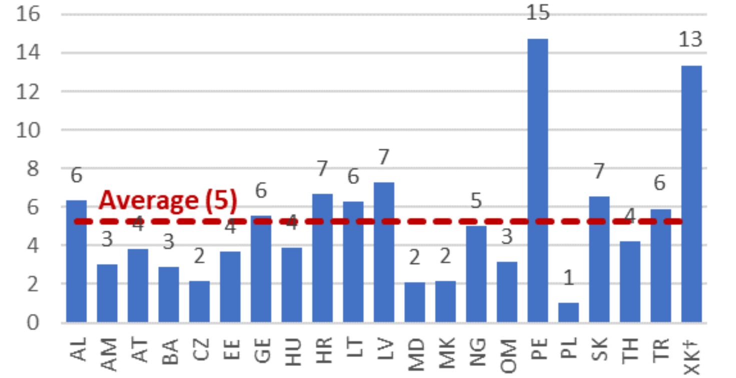
Residential UoS charge relative to HV industrial charge UoS charge



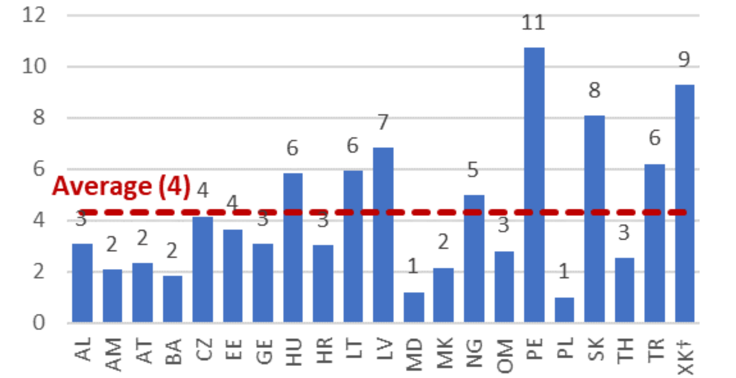
Commercial UoS charge relative to HV industrial charge UoS charge



Small industrial LV UoS charge relative to HV industrial charge UoS charge



Industrial MV UoS charge relative to HV industrial charge UoS charge

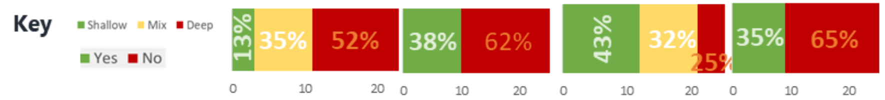


The majority of transmission connection charges is deep and for distribution shallow

- **Generator bus-bar ('shallow')**
- Simple and transparent
- No locational signals
- Effective cross-subsidy from existing to new users
- Costs are socialized through the UoS charge
- What about later connections using the same assets?
- **Reinforcements on existing grid ('deep')**
- Allocates full costs imposed by connection to new users
- Complex and controversial to calculate
- Is this fair to the 'first-mover'?

- **If generators can be charged the full costs their connection imposes on the network then there is no need for a locational UOS charge.**

	Transmission		Distribution	
	Connection charges		Connection charges	
Country	Depth	Cost sharing	Seasonal time of day	Cost sharing
Albania	Deep	Yes	Deep	No
Algeria	Mix	Yes	Mix	Yes
Armenia	Deep	No	Deep	No
Austria	Shallow	Yes	Shallow	No
BiH	Deep	No	Shallow	No
Croatia	Yes	Yes	Deep	Yes
Czechia	Shallow	No	Shallow	No
Estonia	Deep	Yes	Mix	Yes
Georgia	Shallow	No	Mix	No
Hungary	Deep	Yes	Shallow	Yes
Kosovo	Mix	No	Mix	No
Latvia	Deep	No	Shallow	No
Lithuania	Deep	Yes	Deep	Yes
Moldova	Shallow	No	Shallow	No
Mongolia	Shallow	No	Shallow	No
Nigeria	Mix	No	Shallow	No
North Macedonia	Deep	No	Mix	Yes
Oman	Shallow	No	Shallow	No
Pakistan	-	No	-	-
Peru	Deep	Yes	Deep	Yes
Poland	Shallow	No	Shallow	Yes
Slovakia	Deep	Yes	Mix	-
Thailand	-	Yes	Shallow	No
Turkey	-	No	Shallow	Yes
UAE - Abu Dhabi	Shallow	No	Shallow	No
UAE - Dubai	Deep	No	Deep	No



Other considerations for the connection charges

Who pays for the development of the connection line?	• The standard practice is for the customer to pay for the connection costs (85% of MOs). In some regimes that seek to incentivise new connections the TSO or DSO pay for the connection costs and recover the costs through the UoS charge.
Ownership of assets	• The ownership and operation of the assets typically rests with the network operator (73% of MOs). This approach is typically necessary to ensure safe and reliable operation and maintenance of the assets.
Can the payment be amortised over time?	• The payments are typically one-off payments (85% of MOs) and only 4 MOs allow for amortisation of payments over time (typically up to 5 years).
Is cost sharing allowed and is there a time limit?	• Sharing of costs is necessary when one customer pays to connect to the network and the infrastructure developed is planned to cover the connection of other potential customers in the future as well. It can encourage new connections and it is fair to avoid the problem of the 'first rider'. Cost sharing is allowed in 35% of MOs.
Should generators pay for the connection costs?	• When generators pay for connection costs then the charge can pass location signals regarding the development of new generation. If generation connection costs are socialised through the UoS charge then the locational signal gets lost.

THANK YOU
FOR YOUR ATTENTION!

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Annex 1: Countries surveyed

Regions	Countries	ISO codes
Americas	Peru	PE
Asia	Mongolia, Pakistan, Thailand	MN, PK, TH
Caucasus	Georgia	GE
Europe	Albania, Armenia, Austria, Bosnia and Herzegovina, Czechia, Estonia, Croatia, Hungary, Lithuania, Latvia, Moldova, North Macedonia, Poland, Slovakia, Turkiye, Kosovo*	AL, AM, AT, BA, CZ, EE, HR, HU, LT, LV, MD, MK, PL, SK, TR, XK
Middle East and North Africa (MENA)	United Arab Emirates (Dubai and Abu Dhabi), Algeria, Oman	AE-AZ, AE-DU, DZ, OM
Sub-Saharan Africa	Nigeria	NG

Annex 2: Glossary of terms and definitions used in the study

Access charge	*An access charge is a charge paid by customers for contracted capacity or supply capacity per kW or kVA per period. It may or may not differentiate by time-of-use (eg it may be more expensive in some seasons).*
Allocative efficiency	*An outcome in which production is aligned with consumers' preferences. Economic theory suggests that allocative efficiency is achieved in electricity markets when the charge paid by a customer reflects the marginal cost of supplying an additional unit of energy to that customer.*
Connection charge	*The charge for connecting to the electricity network. The charge is used by TSOs and DSOs to pay for the construction and maintenance of assets used to connect the user to the network.*
Consumption profile	*The hourly profile of an electricity customer's consumption throughout the year. This can be used to see energy and capacity requirements by hourly (or half-hourly) intervals.*
Deep charge	*Connection charges can be categorised by different depths. Charges can fall into one of two extremes, deep and shallow, or intermediate policies. A deep connection charge covers both local and remote costs of connection, ie it also covers any network expansion cost (the cost for expanding the network to the customer's area) and any remote costs (ie upstream costs to the network).*
Demand charge	*A demand charge is a charge paid by customers for use of network capacity. It is based on the metered maximum demand in a given time period (eg kW or kVA per period). It may or may not differentiate by time-of-use (eg it may be more expensive in some seasons).*
Distance-related pricing	*There are several variants of distance-related pricing, including simple distance between generation and load (MW-km), network or contract path (where the incremental flows are modelled for specific generation and load), and point-to-point pricing (which is similar to zonal pricing). This option is mentioned in the literature on network pricing but is seldomly adopted.*
Distributed generation and storage	*Generators and storage facilities connected to the distribution network.*
Dynamic charge	*A network use-of-system charge that offers close to real-time price signals.*
Economic development zone (EDZ)	*Geographical areas that enjoy preferential policies. They are employed as policy instruments to foster economic growth and technological innovation and increase exports and employment.*

Annex 2: Glossary of terms and definitions used in the study

Electric vehicle (EV)	*A vehicle powered by electric motors.*
Electromechanical meter	*An electromechanical watt-hour meter is a traditional electricity meter. It does not have a digital display and must be read manually by a human meter reader on the property. On a single-phase AC supply, the electromechanical induction meter operates through electromagnetic induction by counting the revolutions of a non-magnetic, but electrically conductive, metal disc which is made to rotate at a speed proportional to the power passing through the meter. The number of revolutions is thus proportional to the energy usage.*
Electronic meter	*Electronic meters display the energy used on an LCD or LED display. Unlike a smart meter, it still needs to be read manually by a human meter reader, who has to come on to the property to read it.*
Embedded cost approach	*The embedded cost approach is a method for allocating the cost of service to customers. The embedded cost approach is direct and involves three main steps: (1) splitting costs into functional components (production, transmission, distribution, billing, and customer service); (2) classifying these as demand-related (kW), energy-related (kWh) and customer-related; and (3) allocating these to customer categories based on their load patterns.*
Energy charge	*An energy charge is a charge paid by the customer for each unit of energy consumed (eg per kWh, per kJ, per MWh, etc).*
Expert judgement approach	*The expert judgement approach is a method for allocating the cost of service to customers. The expert judgement approach is, in short, the allocation of costs to different customers based on the judgement of the expert performing the calculation, without performing the detailed calculations associated with a well-known, established approach.*
Fixed charge	*A fixed charge is a constant sum paid by the customer at pre-determined time intervals (eg per day, month, or year) for a service.*
Flat charge	*Some of the charges within the tariff design can differ according to the time the service was used. For example, the demand charge may be higher during peak hours of the day. If the charge does not follow this principle and is constant over time, then the charge can be defined as a flat charge.*
Generators	*A power plant or any similar facility that generates electricity with capabilities for delivering energy to the Transmission System or distribution system and which is connected to the Transmission System or distribution system.*
Independent power producer (IPP)	*Non-utility generators (NUGs) that are typically not owned by the national electricity company or public utility.*

Annex 2: Glossary of terms and definitions used in the study

Locational marginal pricing	*This option describes a market arrangement rather than fixed network charges. As with nodal pricing, the market prices at nodes in the system are determined competitively through offers by generators and bids by buyers (suppliers or large consumers) but subject to constraints between nodes, and this leads to different prices at different nodes. The nodes are physically connected to other nodes and with LMP the capacity of those interconnectors is auctioned. The price that network users are willing to pay for using the interconnectors then depends on the wholesale price differentials between the nodes reflecting both the market price of the interconnector capacity and the wholesale price of generation at the nodes.*
Long-run marginal cost (LRMC) approach	*The LRMC approach attempts to mimic the price that should emerge in a competitive market. It estimates the LRMC for providing power and energy to each consumer group and designs tariffs that reflect marginal costs of supply. The long-run average incremental cost (LRAIC) approach falls into this category - it attempts to estimate the incremental costs for serving an additional unit of capacity.*
Nodal pricing	*Nodal pricing allows different prices at each node on the system.*
Postal pricing	*The simplest network charging structure involves unit (kWh) pricing that is uniform across the network. This is known as postal pricing.*
Power factor	*The ratio of working power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA). Therefore, PF = kW / kVA. Reactive power penalties are often imposed when an entity drops below a pre-specified minimum (min) power factor.*
Prosumers	*Network users who are both electricity consumers and electricity producers.*
Reactive power charge	*A charge expressed in $/kVArh for reactive power.*
Reactive power penalty	*A penalty for deviating from a pre-specified power factor. For example, a common formulation is the customer will pay a penalty for dropping below a power factor of x%, where x is contractually agreed.*
Self-generator	*An entity that generates electricity for its own consumption.*
Shallow charge	*Connection charges can be categorised by different depths. Charges can fall into one of two extremes, deep and shallow, or intermediate policies. A shallow connection charge only covers the local cost of connection, ie the cost from the boundary of the customer's premises to the nearest distribution/transmission network.*

Annex 2: Glossary of terms and definitions used in the study

Smart meter	*A smart meter is an electronic device that records information such as consumption of electric energy, voltage levels, current, and power factor. Smart meters communicate the information to the consumer for greater clarity of consumption behaviour, and electricity suppliers for system monitoring and customer billing. Unlike an electronic meter, smart meters communicate information on the energy used automatically to the utility, meaning a human meter reader does not have to come onto the property to read it manually.*
Smart technology	*A self-monitoring, analysis, and reporting technology (or smart technology) is a technology that offers interaction and control through use of the Internet. In the context of the electricity sector, a smart technology may receive information from the utility company to automatically switch off during times of high prices (eg a freezer may turn off temporarily if prices spike) or to schedule operation for a time of low prices (eg a washing machine may be scheduled to turn on during the night).*
Tariff design	*Tariff design defines the type of charges, the grouping of customers and the relative ratio of charges for electricity consumption.*
Tariff design methodology	*The methodological approach used for defining tariff structures (see definition of tariff design).*
Time-of-use charge	*Some of the charges can differ according to the time the service was used. For example, the demand charge may be higher during peak hours of the day. In this case, the demand charge is a time-of-use charge, in contrast with a flat charge.*
Unbundled	*The separation of two parts of the electricity supply chain. For example, if there is a separate TSO and DSO, then system operation of the transmission and distribution networks is unbundled.*
Use-of-system charge	*A use-of-system (UoS) charge is a charge for using the transmission network or distribution network. The charge is used by TSOs and DSOs to pay for their efficient costs for developing, operating and maintaining these networks.*
Vertically integrated	*The fusion of two parts of the electricity supply chain, such as generation and transmission or transmission and distribution.*
Voltage level of connection	*The voltage level of the network at the point where a customer is connected to the grid. For example, an industrial customer may be connected directly to a high voltage transmission line, while a residential customer is likely to be connected to a low voltage distribution network. Customers are often charged different rates based on their voltage level of connection since this affects how much network infrastructure the customer relies on (and must therefore pay for).*
Zonal pricing	*Zonal pricing aggregates nodes into different zones with uniform prices.*