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International Renewable Energy Agency

NET BILLING SCHEMES

INNOVATION LANDSCAPE BRIEF

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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. **www.irena.org**

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1 BENEFITS

Increase system flexibility by engaging prosumers, by incentivizing:

- self-consumption and injecting electricity in the grid when prices are high
- withdrawing electricity from the grid when prices are low

2 KEY ENABLING FACTORS

- Injected energy valued according to system needs
- Mechanisms to recover network costs
- Advanced metering infrastructure
- Prosumer awareness, empowerment and engagement

3 SNAPSHOT

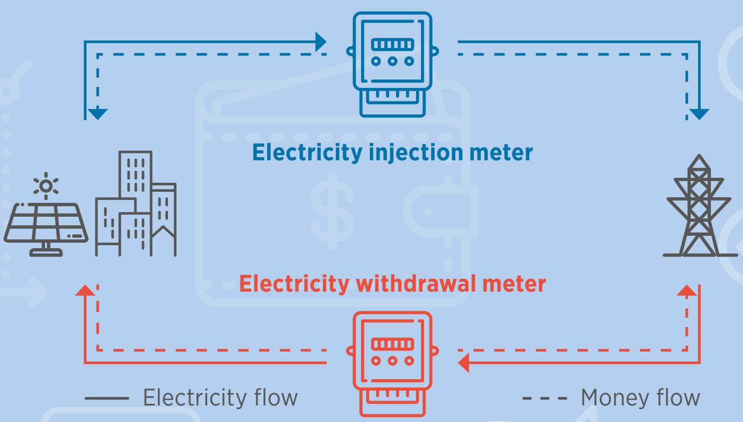
Net billing schemes are used in e.g. Indonesia, Italy, Mexico, Portugal and the USA (NY and AZ).

In New York, a formula was set to compensate the injection of renewable electricity from prosumers, combining the wholesale price with other elements of distributed generation that benefit the grid:

- avoided carbon emissions
- cost savings to other customers
- savings from avoiding capital investments

WHAT IS NET BILLING?

Net billing is a way to **charge but also compensate** prosumers based on the actual market value of electricity, balancing what they consume against what they inject into the grid.



NET BILLING SCHEMES

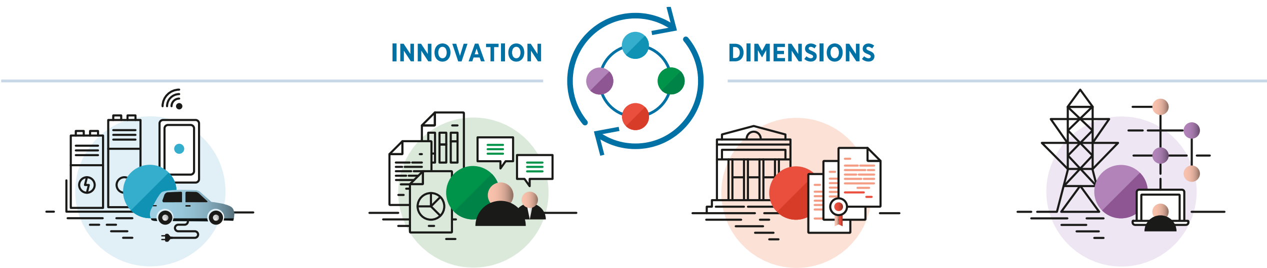
Incentivise prosumers to better interact with the grid.

ABOUT THIS BRIEF

This brief forms part of the IRENA project "Innovation landscape for a renewable-powered future", which maps the relevant innovations, identifies the synergies and formulates solutions for integrating high shares of variable renewable energy (VRE) into power systems.

The synthesis report, *Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables* (IRENA, 2019a), illustrates the need for synergies between different innovations to create actual solutions. Solutions to drive the uptake of solar and wind power span four broad dimensions of innovation: enabling technologies, business models, market design and system operation.

Along with the synthesis report, the project includes a series of innovation landscape briefs, each covering one of 30 key innovations identified across those four dimensions. The 30 innovations are listed in the figure below.



ENABLING TECHNOLOGIES

1 Utility-scale batteries
2 Behind-the-meter batteries

3 Electric-vehicle smart charging
4 Renewable power-to-heat
5 Renewable power-to-hydrogen

6 Internet of things
7 Artificial intelligence and big data
8 Blockchain

9 Renewable mini-grids
10 Supergrids

11 Flexibility in conventional power plants

BUSINESS MODELS

12 Aggregators
13 Peer-to-peer electricity trading
14 Energy-as-a-service

15 Community-ownership models
16 Pay-as-you-go models

MARKET DESIGN

17 Increasing time granularity in electricity markets
18 Increasing space granularity in electricity markets
19 Innovative ancillary services
20 Re-designing capacity markets
21 Regional markets

22 Time-of-use tariffs
23 Market integration of distributed energy resources
24 Net billing schemes

SYSTEM OPERATION

25 Future role of distribution system operators
26 Co-operation between transmission and distribution system operators

27 Advanced forecasting of variable renewable power generation
28 Innovative operation of pumped hydropower storage

29 Virtual power lines
30 Dynamic line rating

This brief provides an overview of net billing mechanisms, a market design feature that incentivises prosumers (*i.e.* actors that both consume and produce electricity) to better interact with the grid. This works by introducing a method to calculate the compensation of excess renewable energy injected into the grid by distributed renewable generation assets. Net billing is an alternative mechanism addressing the limitations of net metering schemes (or net energy metering) and feed-in tariff compensation mechanisms, which are largely applicable to prosumers. Further, this brief describes the key benefits of the net billing mechanism for integrating distributed generation into the grid and increasing system flexibility.

The brief is structured as follows:

I Description

II Contribution to power sector transformation

III Key factors to enable deployment

IV Current status and examples of ongoing initiatives

V Implementation requirements: Checklist

I. DESCRIPTION

The installed capacity of distributed renewable generation, especially from rooftop solar photovoltaic (PV) power plants, has increased at a rapid pace thanks to a significant decline in the cost of solar power technology over the past few years. Further, many countries across the globe have introduced schemes, such as net energy metering (NEM) and feed-in tariff (FiT) schemes, to compensate consumers for injecting excess renewable electricity into the grid, leading to a significant growth in rooftop solar capacity additions.

Under the NEM mechanism, the consumer is charged for the net electricity consumption from the grid after netting off the electricity injected by the consumer into the grid. This bidirectional flow of energy is measured through bidirectional meters, also called net meters, which keep account of the net flow of electricity. Since electricity consumption is set off against the electricity injected into the grid, prosumers typically get compensated for the injected electricity at the retail electricity tariff. In contrast, under FiT schemes, electricity generation and consumption from the grid are separated through the installation of two separate meters and are accounted for differently. While energy consumed from the grid is priced at the retail electricity tariff, the excess energy injected into the grid is compensated at a predetermined tariff notified by the regulator, also called the “feed-in tariff”. FiTs can be higher than retail electricity tariffs so that they incentivise consumers to install distributed renewable generation capacity. For example, FiTs higher than the retail electricity tariffs were witnessed in Germany, which led to increased adoption of rooftop solar PV. Subsequently, the FiTs were gradually decreased.

While these schemes have been widely accepted by prosumers, the compensation mechanisms defined under these schemes are not reflective of the cost of electricity at the moment of injection into the grid and might distort the market if the quantity injected were significant. For example, injection of excess renewable electricity into the grid is more valuable for the system during peak load hours than during off-peak hours. Similarly, oversupply of renewable electricity into the grid during time intervals of low demand could lead to curtailment of the power plant or to the formation of negative electricity prices in wholesale markets. Further, retail tariffs include other costs, such as grid access costs, supply costs and balancing costs, which are not subtracted from the compensation made to consumers under NEM. In addition, NEM mechanism allows prosumers to use the grid as a virtual storage system for free by injecting or drawing electricity at any time for the same price, which reduces consumers’ sensitivity to volatile electricity prices and hence undermines efforts to further develop demand-side response (CEER, 2016) (IRENA/IEA/REN21, 2018).

While NEM and FiTs have helped jump-start the development of distributed generation by providing an economic incentive, they must evolve into more mature compensation mechanisms that capture the true value of renewable electricity at the time of injection into the grid. As such, a compensation at wholesale electricity market price (*e.g.* when trading day-ahead platforms are established and liquid) might reflect more accurately the value of electricity injected into the grid.

Net billing is a market-based compensation mechanism, as prosumer compensation is based on the actual market value of the kilowatt-hours (kWh) consumed or injected into the grid. The invoice issued by the retail supplier to the consumer is based on the value of withdrawn electricity after subtracting the value of the injected energy (Energy Community, 2018). Figure 1 depicts the flow of electricity payments and electricity flow in a net billing scheme, which illustrates that two meters are needed. Table 1 contains different methods used to value the injected energy.

Figure 1: Schematic electricity flows and payments in a net billing scheme

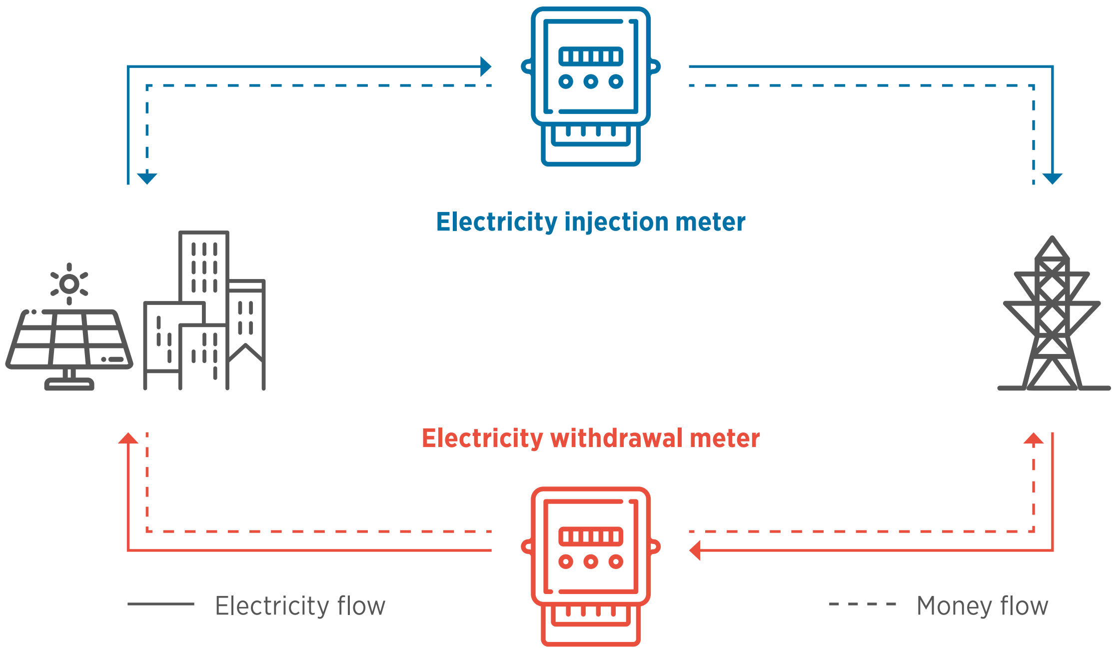


Table 1 Methods for determining the compensation tariff for excess electricity injected under net billing schemes

Method	Description		Example
Time-of-use tariffs	**Static**	Tariffs determined in advance and based on historical power system balance.	Mexico
	Dynamic	Tariffs determined in real time and based on actual power system balance or linked to wholesale market electricity prices .	Finland
Location-varying tariffs	Tariffs based on grid congestion at different nodes, including among other environmental factors.		New York (United States), Mexico
Tariffs based on the avoided cost of electricity	Tariffs based on the marginal cost of electricity procurement that was avoided by retailers/system operators because of the injection of one unit of renewable electricity into the grid		Arizona (United States)

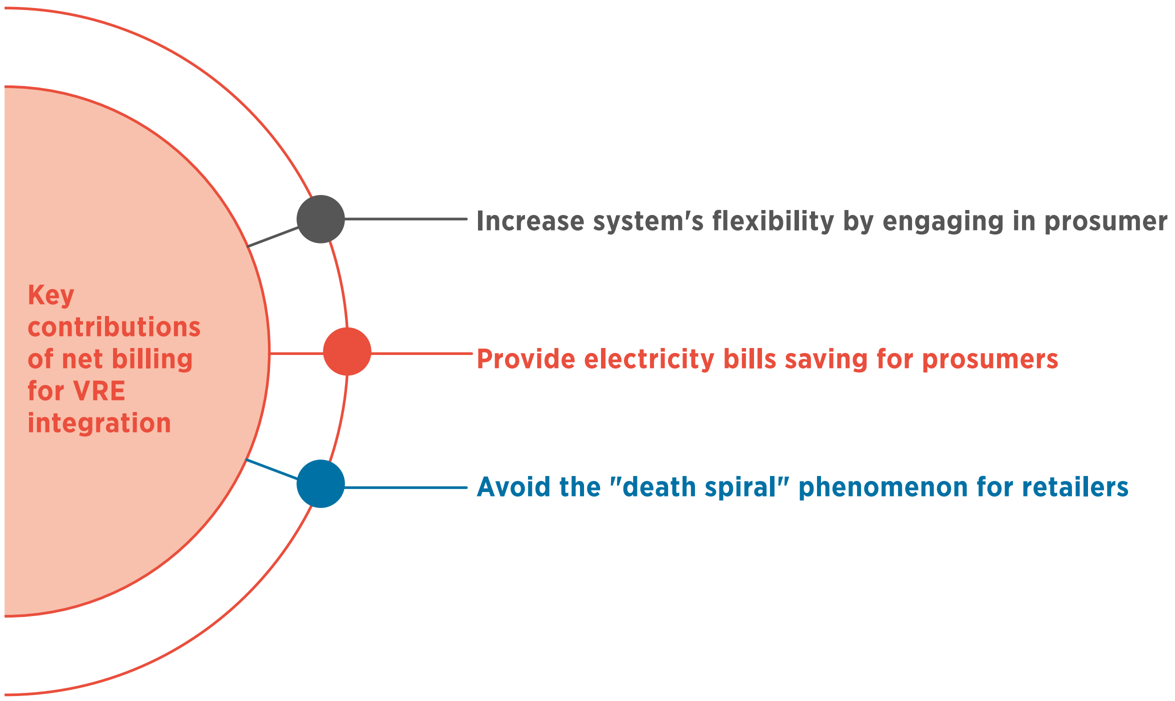
Variants of compensation tariffs for injected renewable electricity under net billing schemes shown in Table 1 can incentivise prosumers to inject energy when the compensation tariffs for injection are higher and to maximise self-consumption or to store electricity when these tariffs are lower. To take full advantage of net billing for the power system, the method for defining the tariffs should be dynamic, so that the prosumers would be able to respond to differentiated rates for the surplus electricity, according to the real-time system conditions.

Another innovative approach to net billing is the net billing advanced arrangement, which would be applicable even if generation and consumption were located in different places (also known as ''virtual net billing''). In addition, net billing could be applied in multi-apartment buildings, where the net credits for production on one site could be split between several consumers, which could facilitate the integration of community-owned generation projects into the system.

II. CONTRIBUTION TO POWER SECTOR TRANSFORMATION

A compensation mechanism that appropriately values the injected distributed renewable energy according to a sound methodology can help maximise the value of such generation for all stakeholders, such as system operators, utilities, distributed renewable energy generation owners and even those who do not own such systems (Zinaman *et al.*, 2017). Under the net billing scheme, if the compensation for the injected renewable electricity is based on time or location-varying tariffs, consumers can – by responding to price signals – help support the grid. Figure 2 below depicts the ways in which the net billing mechanism can contribute to increased flexibility in the system, while maximising self-consumption by the prosumers.

Figure 2: Contribution of net billing schemes to enhanced grid integration of renewable electricity



Increase system's flexibility by engaging the prosumer

Net billing schemes incentivise prosumers to interact with the grid in a way that maximises the benefit of self-consumption and distributed generation the most for the system.

Well-designed net billing schemes can increase the injection of renewable electricity into the grid when the compensation tariffs are high, if such tariffs are reflecting scarcity in the system. In the same way, they can maximise self-consumption or store the generated electricity in behind-the-meter batteries when the compensation tariffs are low, given that the tariffs reflect abundant VRE generation in the system and lower demand. By responding to time-varying compensation tariffs, prosumers can either shift their demand or deploy battery storage systems to maximise their revenue streams from their distributed renewable generation. Such incentives lead to more flexibility in the system, encouraging prosumers to inject electricity in the grid when the system needs it, and consume electricity from the grid when there is abundant renewable generation in the system and low demand. This would further facilitate the integration of distributed renewable generation into the grid. Moreover, when locational signals are incorporated in addition to time-of-use tariffs, prosumers can contribute to reducing network congestion and potentially deferring or minimising network investments (IRENA, 2017) (see Innovation landscape brief: Time-of-use tariffs [IRENA, 2019b]).

Provide electricity bill savings for prosumers

Prosumers can save on energy charges in the final electricity bill. Self-consumption of locally generated renewable electricity replaces costlier electricity withdrawn from the grid, thus resulting in savings on energy-related charges payable to electricity retailers in the final electricity bill.

Demand charges are generally based on the highest electricity usage requirement (peak demand in terms of kilowatts [kW]) for the consumer within a specified period (usually ranging from 15 minutes to 3 months), depending on the applicable tariff designs. When the demand charges are based on peak demand, the savings can be significant for commercial and industrial consumers, but limited for household consumers. Locally generated renewable electricity can serve some of the consumer's peak loads, thus helping reduce peak demand and, consequently, the demand charges. If the consumer's consumption pattern and renewable generation do not match well, either consumption can be shifted to coincide with the hours when renewable generation is the highest or battery storage technologies may be deployed to add flexibility.

Avoid the "death spiral" phenomenon for retailers

Under schemes such as NEM and FiT, prosumers are incentivised to produce electricity at a level that may not be optimal for the electricity system overall, sometimes being overcompensated for the renewable electricity fed into the grid. This may lead to oversupply of distributed renewable electricity into the grid, based on distorted price signals, further leading to grid integration challenges, while resulting in revenue losses for retailers and utilities. As a consequence, to maintain their revenue base, retailers may increase tariffs, which results in increased self-consumption and exacerbates the situation further. Higher rates also increase the economic incentives to become a self-consumer, creating a vicious circle (IRENA, 2017). In other words, the oversupply of distributed generation injected into the grid may increase retail tariffs, which consequently makes the grid more expensive for consumers who depend exclusively on the grid for their consumption, while making self-generation of electricity economically attractive for more consumers. The interdependence of such factors is often referred to as the "death spiral" or "death valley" for retailers.

The risk for "death spiral" to occur is lower when net billing mechanism is in place, preventing distributed renewable generation being unduly overcompensated. For instance, in the United States, rapid growth in rooftop solar installations under the NEM framework has led some utilities to modify their NEM policies and move towards net-billing-based mechanisms. Some of the examples from Nevada, Arizona, and New York are explained in the following sections.

III. KEY FACTORS TO ENABLE DEPLOYMENT

To enable the adoption of net billing schemes, a method must be developed to send the right price signals to prosumers. Appropriate mechanisms to recover network costs need to be in place. Enabling infrastructure, such as advanced metering, is required to accelerate the adoption and functioning of net billing schemes, as is consumer awareness, empowerment and engagement.

Method for valuing the electricity supplied by distributed generation according to system needs

The concept of net billing is based on assigning a high value to electricity injection from distributed renewable sources into the grid when this is most needed, while keeping the system in balance. Such valuation can therefore vary with time, location, grid characteristics or supply and demand situation, among other factors. In addition to benefitting the individual consumer, the method needs to maximise the benefits of distributed generation for the system.

For example, the New York Public Service Commission approved the first phase of the Value of Distributed Energy Resources Order, which contains a transparent method that values the injection of renewable energy from distributed renewable installations owned by commercial, industrial, non-profit and governmental entities, and is based on:

- **Locational marginal price** – the price for adding 1 kWh of electricity from a distributed energy resource (DER) into the grid, including the wholesale price of electricity, transmission congestion charges and line losses.

- **Avoided distribution infrastructure costs** – the price payable to distributed renewable generators for meeting demand and reducing stress on the distribution grid.

- **External value** – a price element corresponding to the positive externality of the environmental and health costs avoided through the replacement of polluting generation sources with renewable sources (Roselund, 2017).

California's Distributed Energy Resources Roadmap and Texas utility ERCOT's Distributed Resource Energy and Ancillary Markets Task Force include or consider locational marginal prices as part of the net billing methodology.

Appropriate mechanisms to recover network costs

Volumetric tariffs are charged on the consumption of every additional unit of electricity, whereas capacity tariffs are linked to either the installed capacity or the peak load. In many countries, fixed network costs are primarily recovered through volumetric tariffs. This is, for example, the case in most European countries (European Commission, 2015). However, increased self-consumption leads to lower revenues for distribution system operators, which may not be sufficient to recover their fixed network costs, especially when the number of self-consumption points is significant.

With a transparent method, fixed costs related to network assets could be recovered through either volumetric tariffs, capacity charges or a combination of both methods. For instance, consumers installing renewable systems may be charged a flat fee based on the installed capacity and other fixed costs incurred by distribution system operators. Such a method was applied in the Flanders region of Belgium in 2015. A grid fee of approximately EUR 70/kW was introduced for solar PV systems for self-consumption with capacity up to 10 peak kilowatts (European Commission, 2015).

Deployment of advanced metering infrastructure

Advanced metering infrastructure (AMI) integrates smart meters, communication networks and data management systems to enable a two-way communication between system operators and consumers.

Net billing requires either two separate meters or one meter with two registers to measure and distinguish the quantity of the electricity injected from the one consumed, which are valued at different rates. In the case of dynamic time-of-use tariffs, AMI is required to enable a two-way communication on prices between retailers, system operators and prosumers. Further, the design of location-varying tariffs requires system operators to monitor and understand the consumption profile at different distribution nodes. To enable this, smart meters that record the consumption on an hourly or sub-hourly basis (*e.g.* half-hourly or quarter-hourly) are required at each of the consumption points.

Prosumer awareness, empowerment and engagement via automation

Consumers installing distributed renewable systems under a net billing regime need appropriate information and supporting technologies, such as energy management systems, to be able to respond to time- or location-varying price signals. Prosumer awareness about their impact on the network, prosumer empowerment to engage with the system and, therefore, their engagement are key challenges that need to be addressed to enable effective implementation of net billing schemes.

Automated inverter control for solar PV systems, along with software applications, may enable consumers to respond appropriately to price signals without the active and manual participation of individual consumers. To achieve this, pilot programmes can be initiated to demonstrate the benefits that consumers can reap if they participate in net billing schemes.

IV. CURRENT STATUS AND EXAMPLES OF ONGOING INITIATIVES

Net billing schemes are being increasingly adopted globally, and some of the regulatory developments are captured in Table 2.

Table 2 Examples of net billing frameworks across the globe

Country	Net billing framework details
Indonesia	As per net metering regulations in Indonesia, electricity injected into the grid by prosumers will be settled at a maximum of 85 % or 100 % of the local generation cost, depending on whether the local generation cost is higher or lower than the national average generation cost (Tongsopit *et al.*, 2017)
Italy	The Italian net billing scheme calculates the value of the excess electricity fed into the grid at wholesale price, and this value can be either used as a credit for subsequent consumption periods or paid back to the consumer (European Commission, 2015).
Mexico	Under the revised net metering regulations in Mexico, renewable energy fed back into the grid will be settled according to hourly time-of-use tariffs (Jimenez, 2016).
Portugal	As per recent Portuguese self-consumption regulations, excess injection of electricity into the grid will be settled at 90 % of the average Iberian spot price; 10 % is deducted to cover the grid integration costs of renewable electricity (European Commission, 2015).
United States (Arizona)	In December 2016, the Arizona Corporation Commission voted to replace net metering with net billing under which the renewable energy injected into the grid would be compensated on the "avoided cost rate", to be calculated by the commission for each utility (DSIRE, 2017).
United States (New York)	In March 2017, the New York Public Service Commission approved the first phase of the Value of Distributed Energy Resources Order, which sets a formula to compensate the injection of renewable electricity from installations owned by commercial, industrial, non-profit and government entities, combining the wholesale price of energy with the distinct elements of DER that benefit the grid: avoided carbon emissions, cost savings to other customers and utilities, and other savings from avoiding expensive capital investments (Roselund, 2017).

V. IMPLEMENTATION REQUIREMENTS: CHECKLIST

TECHNICAL REQUIREMENTS	**Hardware:** • AMI, including equipment such as smart meters and smart inverters, which are required for price-based demand management • Behind-the-meter battery systems or vehicle-to-home charging for electric vehicles for added value and increased revenue streams for consumers
	Software: • Communication software for real-time communication between renewable energy generation systems, inverters and batteries • Energy management software for consumer energy cost optimisation, including energy management systems that can respond to electricity price signals and automatically adjust consumption according to the customer's preferences and/or system needs
REGULATORY REQUIREMENTS	**Retail market:** • Supportive regulations encouraging the decentralisation of power systems, liberalisation of retail markets and better utilisation of the existing infrastructure • Appropriate valuation method for renewable electricity injected into the grid that is based on system needs, wholesale prices, location, positive externalities (*e.g.* health and environmental benefits), etc.
	Distribution and transmission system: • Recovery of network costs through suitable network tariff design applicable for prosumers installing distributed generation assets
STAKEHOLDER ROLES AND RESPONSIBILITIES	**Consumers:** • Become prosumers by owning DER assets (*e.g.* behind-the-meter storage, solar PV plants, electric vehicles, etc.) • Take the role of active participants in the market and make informed decisions about reducing system costs and electricity bills, while maximising the revenue streams from DERs
	Policy makers and regulators: • Provide incentive-based policy frameworks for the deployment of AMI • Ensure that consumers are well informed about rights and responsibilities, including impact on the network; empower consumers to take an active role as prosumers and engage with the power system • Encourage pilot programmes demonstrating the benefits of net billing mechanisms for consumers and the system, and disseminate the results publicly

ABBREVIATIONS

AMI	advanced metering infrastructure
CEER	Council of European Energy Regulators
DER	distributed energy resource
FiT	feed-in tariff
kW	kilowatt
kWh	kilowatt-hour
NEM	net energy metering
PV	photovoltaic
VRE	variable renewable energy

BIBLIOGRAPHY

CEER (2016), *CEER Position Paper on Renewable Energy Self-Generation*, Council of European Energy Regulators, Brussels.

DSIRE (2017), "Net billing", NC Clean Energy Technology Center, Database of State Incentives for Renewables & Efficiency, http://programs.dsireusa.org/system/program/detail/3093.

Energy Community (2018), *Policy Guidelines by the Energy Community Secretariat on the Grid Integration of Prosumers, Energy Community*, Vienna, www.euneighbours.eu/sites/default/files/publications/2018-02/PG_01_2018_ECS_RE_grid.pdf.

European Commission (2015), *Best Practices on Renewable Energy Self-consumption*, European Commission, https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_autre_document_travail_service_part1_v6.pdf.

Heidelberger-Energiegenossenschaft (n.d.), www.heidelberger-energiegenossenschaft.de.

IRENA (2019a), *Innovation landscape for a renewable-powered future*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/publications/2019/Feb/Innovation-landscape-for-a-renewable-powered-future.

IRENA (2019b), *Innovation Landscape Brief: Time-of-Use Tariffs*, International Renewable Energy Agency, Abu Dhabi, https://irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Landscape_ToU_tariffs_2019.pdf?la=en&hash=E565514088C268EE9BFE542A6E1E5DB10E508620.

IRENA (2017), *Adapting market design to high shares of variable renewable energy*, International Renewable Energy Agency, Abu Dhabi.

IRENA, IEA, REN21 (2018), *Renewable Energy Policies in a Time of Transition*, International Renewable Energy Agency, Internation Energy Agency, Renewable Energy Policy Network for the 21st century, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_IEA_REN21_Policies_2018.pdf.

Jimenez, M. (2016), "Solar industry prepares as Mexico considers net-billing", Renewable Energy Mexico, www.renewableenergymexico.com/solar-industry-prepares-as-mexico-considers-net-billing.

Roselund, C. (2017), "New York approves formula for valuing distributed solar", PV Magazine, https://pv-magazine-usa.com/2017/03/09/new-york-approves-formula-for-valuing-distributed-solar.

Tongsopit, D. S. *et al.* (2017), *Designing Renewable Energy Incentives and Auctions: Lessons for ASEAN*, US Agency for International Development, Washington D.C., https://pdf.usaid.gov/pdf_docs/PA00SVK9.pdf.

Zinaman, O. *et al.* (2017), *Grid-Connected Distributed Generation: Compensation Mechanism Basics*, National Renewable Energy Laboratory, www.nrel.gov/docs/fy18osti/68469.pdf.

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