P003

Grid Services based on Demand Response and H_2 technologies

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Abstract

Intermittent nature of RES imposes considerable burden on grid balancing capacities. The broad trends of development of the energy production systems are ranging from centralized to decentralized generation and control, in parallel with market liberalization.
A holistic approach for Smart Energy solutions is provided by GOFLEX project, which will deliver a set of technology solutions for distributed flexibilities and automated dynamic pricing market. This will enable regional actors like Generators, Prosumers, Flexible Consumers and demand side operators such as Energy Suppliers, Microgrid Operators and Energy Communities to aggregate and trade flexibilities. GOFLEX technology solutions are being applied in three demonstration sites in Germany, Switzerland and Cyprus where trials, validation, and evaluation through 12 months' demonstration will take place, engaging more than 500 prosumers of different types. The consortium has a clear orientation towards the commercial exploitation of the GOFLEX solutions, supported by the intent to continue demonstration for two years after project.
Large and dynamic MWe size Fuel Cell power plants are one of the key enabling technologies for balancing the grids with high RES capacities installed. GRASSHOPPER project (GRid ASsiSting modular HydrOgen Pem PowER plant) aims to create a next-generation MW-size Fuel Cell Power Plant unit (FCPP), which is cost-effective and flexible in power output, accomplishing an estimated CAPEX below 1500 EUR/ kWe. The FCPP will be characterized by operation flexibility and grid stabilization capability via its fast response, capable of engaging in the automatic trading of energy flexibilities. It will be operated continuously for 8 months in industrially-relevant environment for engaging grid support modulation as part of an established on-site Demand Side Management (DSM) programme. Potential coupling of this type of FCPP with an electrolyser would represent a hydrogen prosumer, i.e. EE generation and consumption system with ability of energy storage.

Introduction

By the year 2020, European Union (EU) member states aim at producing at least 20 % of their total energy using renewable energy sources (RES), as indicated in the Renewable Energy Directive [2009/28/EC]. To achieve these and more ambitious targets of the year 2030, specified in the EU 2030 Framework for climate change, the increased share of electricity production from RES is a key contributor [1].

However, accommodating higher amounts of renewable energy from intermittent RES is challenging and coming at a cost that is not sustainable [2]. Electrical utilities and network operators are being exposed to excessive risks induced by uncertain, irregular and often distributed supply, causing volatility and increase in wholesale electricity prices, demand-supply imbalances, and more frequent occurrences of grid congestions. The pervasive emerging of distributed energy resources is adding additional stress to the existing distribution grid, which was originally designed and implemented for unidirectional flow of electricity – from suppliers to consumers. Furthermore, low power factors of RES require overly-conservative and costly investments for enabling sufficient capacity to support generation at the few hours of peak [3].

To overcome these issues, the key is to take advantage of the increased intelligence and flexibility in terms of available adaptation capacity in the distribution grid. Towards this direction, promising solutions have been proposed in a number of technological areas. The challenges of modernizing the electricity grids in Europe lie in enabling increased flexibility of the European power system, efficiently providing increased transfer capacity and enabling an active participation of users and new market actors. Demand response (DR) enables end users to participate actively in energy markets and profit from optimal price conditions, making the grid more efficient and contributing to the integration of renewable energy sources. Demand Response schemes and infrastructures offer various incentive frameworks and solutions for making a prosumer (i.e. both producing and consuming) active, so it varies its electricity consumption and/or production in response to direct commands or economic rewards, for: offering auxiliary services, e.g. to aggregators, balance responsible parties (BRPs), distribution system operators (DSOs); creation of microgrids and virtual power plants, to exploit flexibility in demand and supply.

The overall objective of the GOFLEX project is to further develop, innovate, integrate and demonstrate an integrated solution that will significantly contribute to the cost effective use of demand response in distribution grids and increase the available flexibility of loads/generation to be included in demand response schemes. This will be done through involvement of different types of prosumers in balancing of electricity demand and supply and optimizing energy consumption and production at the local levels of electricity trading and distribution systems. The key objectives are to introduce dynamic pricing of energy through automatic demand response trading by prosumers; augment demand response through energy storage in processes; integrate optimized and balanced demand response ready energy management system; integrate grid users from the transport – charging/discharging station management system; improve observability and manageability of distribution grid for use of demand response; and provide cloud (SaaS) based data and forecasts provision service platform for energy market and weather forecasts data.

The developed, innovated and tested solutions will be integrated and evaluated in real environment in several use cases in three demonstration sites in Cyprus, Switzerland and Germany.

GRASSHOPPER will focus on FCPP (Fuel Cell Power Plant) technologies as flexibility enabler for prosumers through the use of hydrogen. With the new energy market rules in place all consumers will be able to generate, store and/or sell their own electricity to the market based on retail market conditions and taking into account the costs and benefits for

the system as a whole, what brings additional benefits for implementation of FCPP technologies on the market. By introducing scarcity pricing, the current initiative wants to give due credit to such technology as well. By strengthening the price signal, we are in practice FCPP technologies to take advantage of instantaneous market remuneration, whilst creating a case for longer-term investment in the technology.
The Demand Side Flexibility report [3] estimates that the financial benefits of explicit Demand Side Flexibility in future will vary widely from lower to higher amounts. Lower amounts (€6/kW/yr. to €10/kW/yr. by 2030, or €3bn/yr. to €5bn/yr. for the EU) have been found where substantial other sources of flexibility are assumed to be added to the system. Much higher values (up to €92/kW/yr. by 2050 in Great Britain, which would imply €45bn/yr. if replicated across the EU) have been exhibited where such other sources of flexibility are not increased.
Another scenario estimates the potential savings in the costs of additional transmission capacity needed in the EU by 2030 for renewables integration. This resulted in an estimate of around €10 billion to €15 billion per year (€20/kW/yr. to €30/kW/yr.). Transition requirements can be greatly reduced, if local generation, coupled with demand side management is used. We estimate this number can go up to as much as 20 %, especially in the areas with high RES penetration.

1. GOFLEX

The core of the integrated GOFLEX system is the solution for automatic trading of energy flexibility of prosumers. Flexibilities are extracted from the prosumers' processes managed by their energy management systems (xEMS). Flexibilities are then shaped into the Flex offers by Flex Offer Agent (FOA) – the forms ready to be sold on the market. These are traded by FMAN (by delegated trading via aggregator or by direct trading) on the trading platform (FMAR). Purchasing of the flexibilities would be done by a party which needs them: the aggregator, the BRP or the DSO/TSO – as is the case in the GOFLEX project.

Glossary:

BG	Balance Group
BRP	Balance Responsible Party
DOMS	Distribution Observability Management System at DSO as flexibility buyer
DR	Demand Response
DSM	Demand Side Management
DSO/TSO	Distribution System Operator / Transmission System Operator
xEMS	Energy Management System at any different type of prosumer
FCPP	Fuel Cell Power Plant
FCPP2G	Fuel Cell Power Plant to Grid trading interface
FO	Flex Offer
FOA	Flex Offer Agent
FMAN	Flex Offer Manager (direct trading or delegated trading representatives – aggregators)
FMAR	Flex Offer Market - Trading Platform
MBA	Market Balance Area
MO	Market Operator
MRP /MGR	Microgrid Responsible Party
RES	Renewable Energy Sources
VPS	Virtual Power Plant System

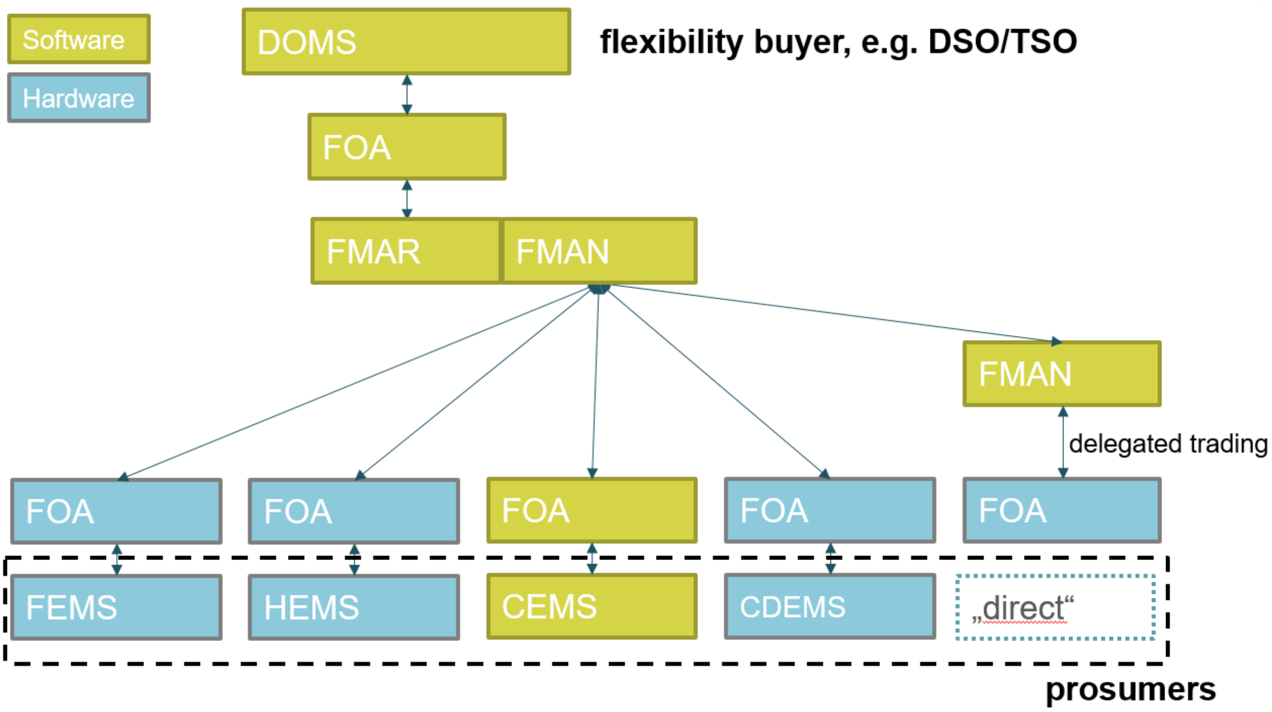

Fig.1: Architecture of the GOFLEX flexibility trading system [4].

The system is designed to accept any type of prosumers with an xEMS by linking them to FOA, which standardizes their available flexibility into Flex Offers (FO). A special group of consumers are no-EMS consumers, which can participate by delegating the FO trading function to the aggregator (subordinated FMAN).
The DSO's buying offer is based on the operating state of the local grid using powerful short term forecasting techniques. Trading type is either the two-sided or one-sided pool trading. The default trading interval is 15 minutes and can be adapted to the actual case.
Typical configuration of the demonstration project is depicted on the schematic in Fig.2. The schematic shows the case where the energy flexibilities are supplied by a number of different types of prosumers, including hydrogen FCPP as a type to be demonstrated in the GRASHOPPER project. The buyer is the responsible DSO, who purchases the flexibilities for balancing the local grid or for avoiding congestion.
The GOFLEX project defined a number of Use cases – market situations for implementation of GOFLEX integrated solutions.
The GOFLEX project focus is local, with the DSO as the dominant user of energy flexibility for avoiding congestion and local balancing of the grid. Thus there are two basic use cases that will be demonstrated within the project in the three demonstration sites:
1. VPS (Virtual Power Plant System) for congestion management in distribution grid;
2. VPS based on DSM for optimization of operation of a microgrid.

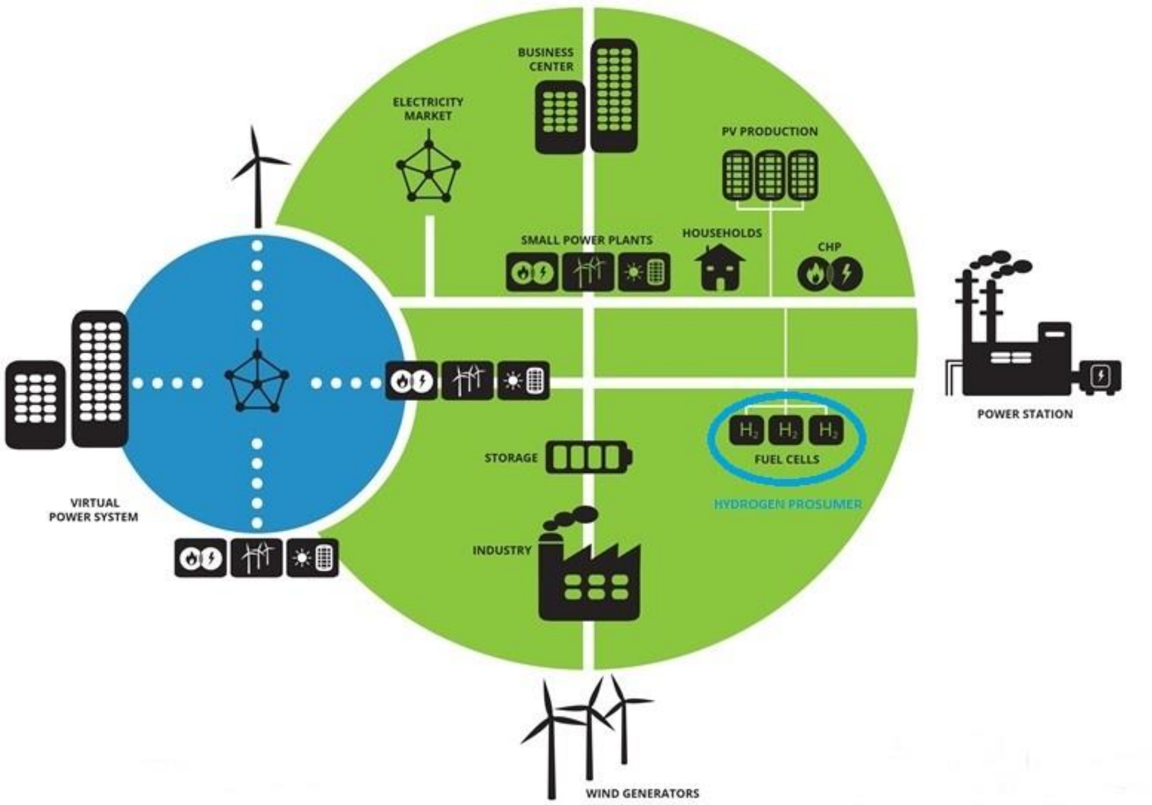

Fig.2: KIBERnet flexibility trading platform developed by INEA. [5]

Use Case UC1: VPS for congestion management in distribution grid

Active roles and trading relations between them are depicted in red.

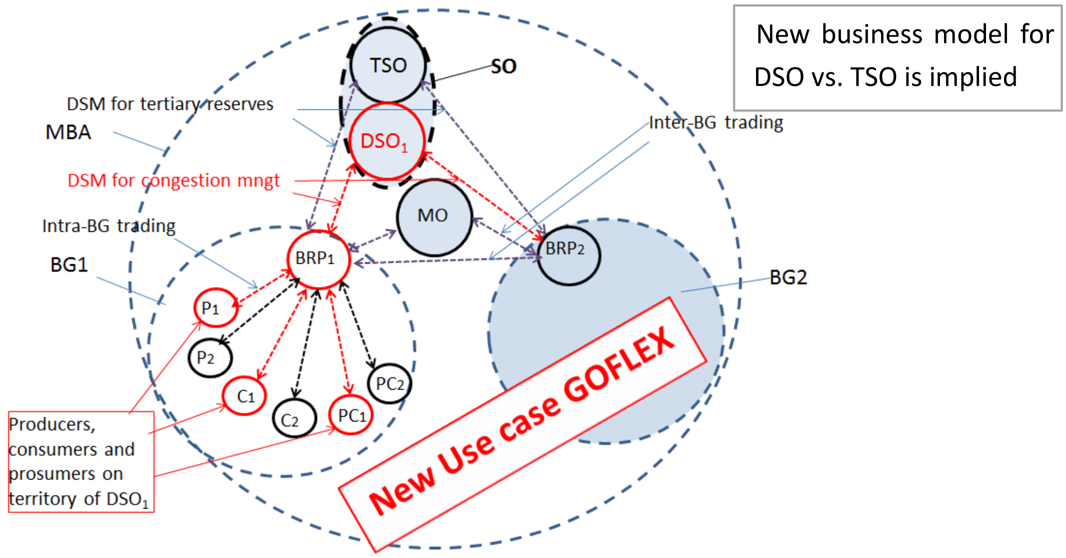

Fig.3: Schematic representation of Use case 1 with players, roles, processes and relations [4].

The Use case 1 is the basic case for local balancing of energy imbalance on the distribution grid, using the local resources closest to the point of imbalance. The congestion management is thus done by reducing the energy flows rather than by increasing the energy flow from TSO and providing increased capacity of the grid. This is a new use case that is made possible by introducing a cellular (self-similar) structure in the electricity grid system. To carry it out, a new business model for DSO vs. TSO is implied.
Business Cases of the Use case 1 are based on avoided costs of balancing the local grid by local balancing as opposed to balancing regionally by TSO. The business case driver is the DSO as the primary user of energy flexibilities.

Use case UC2: VPS based on DSM for optimization of operation of a microgrid

The active roles and trading relations between them are depicted in red.

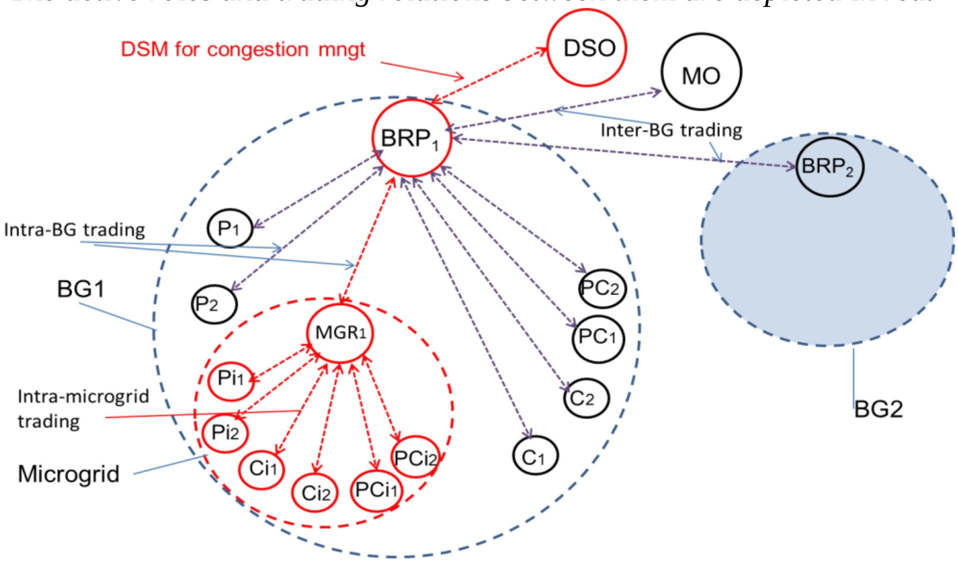

Fig.4: Schematic representation of Use case 2 with players, roles, processes and relations [4].

The use case 2 is one of the new GOFLEX use cases and implies further structuring of the Harmonized Electricity market model and cellular structuring of the electricity grid system. Therefore, the Use case 2 system structure is similar to the structure of its parental Use case 1 system. The local community microgrid is a balance group (BG) subsystem on the geographical territory of a sub-DSO (or DSO). The territory has to fulfil the requirement of easy separation from the parental distribution grid.
The basic business case is a scaled down business case of the parental system. The microgrid responsible party (MRP) has a driving role and is the user of flexibilities. Additional business cases stem from coupling it with the previous use case (congestion management): energy flexibilities for DSO vs. incremental investment into distribution network grid capacity. The driving role and the user of flexibilities in these cases is DSO.

2. GRASSHOPPER

The Fuel Cell Power Plant (FCPP), which will be developed by GRASSHOPPER consortium represents an example of the electrical power generator with ability to participate in the automated flexibility trading market.

The GRASSHOPPER (GRid ASsiSting modular HydrOgen Pem PowER plant) project will create a next-generation MW-size Fuel Cell Power Plant unit (FCPP), which will be more cost-effective and flexible in power output, accomplishing an estimated CAPEX below 1500 EUR/ kWe at a yearly production rate of 25 MWe. This level is required enter the markets as a competitive player.
The power plant will be demonstrated in the field as 100 kW sub-module pilot plant, implementing newly developed stacks with improved, MEAs and BoP system components, combining benefits of coherent design integration. The flexible demand driven operation will be demonstrated with a set point range between 20 to 100 kW and a ramp-up rate delivering 50 kW within 20 seconds and delivering 100 kW within 60 seconds.
This unit will be operated continuously for 8 months in industrially-relevant environment in Delfzijl, the Netherlands for engaging grid support modulation as part of an established on-site Demand Side Management (DSM) programme. There is the intention of the consortium to keep the FCPP operating for 5 years after the project end. This will help to showcase the technology for interested parties, demonstrate the viability of the technology on medium term and serve as experimental validation of the operational costs for the system.
Dynamic operating capability will be a new feature necessary for economical participation in renewable energy markets. The feature of flexibility and grid support functionality will be introduced by using a smart grid integration.
INEA will develop a prototype software interface to be used as a tool for aggregating and trading flexibility for offering services to the grid and will particularly enable integration of flexible FCPP into the Demand Side Management portfolio. FCPP2G (Fuel Cell Power Plant to Grid) interface will be a tool for aggregators or Grid Operators that will enable them to use FCPP operation flexibility for ancillary services.
FCPP2G interface will enable integration of flexible FCPP into the Demand Response (DR) programmes for offering services to the grid, such as GOFLEX integrated system. Key objective will be to provide automatic DR for integration of FCPP as electricity generator with dynamic pricing functionality. The interface will be communicating with internal FCPP control system. FCPP2G integration interface will be founded on INEA's existing KIBERnet platform (Fig. 2) for managing flexibilities of prosumers for electrical loads and generators and relevant results and experiences from MIRABEL (FP7) and GOFLEX (H2020, LCE-02) projects. FCPP2G integration interface will be validated in selected industrially relevant environment.
The tool will further be used to test and evaluate the new business models for designing competitive demand response programs for relevant new energy market stakeholders such as FCPP users, grid operators, aggregators and utility companies.

Hydrogen prosumer and required policy changes

The coupling of an electrolysis plant with its respective hydrogen storage (which is outside of the project scope) and the FCPP will represent a hydrogen prosumer. Already today, low-cost renewable electricity that has to be curtailed is available in various locations across Europe [6]. During periods of energy excess, electricity prices can be low or even zero, depending on local grid bottlenecks and RES curtailment. The electrical energy would be converted by the electrolyser and stored in form of hydrogen. In the period of high energy demands and high electricity prices, the electrical energy would be generated from hydrogen via fuel cells and supplied to the grid.
Such systems can generate profit from two sources: 1. from buying/selling price difference, and 2. from providing system services by power reserves and smoothing the power consumption peaks.

At current grid balancing remunerations, it is questionable whether the FCPP can provide competitive balancing services. Several policy changes need to be implemented in steps towards the decarbonizing the electrical energy production for the viability of the hydrogen-based renewables services.

Phasing out thermal generation will create a demand for new providers of grid balancing services, be it FCPPs, electrolysers, batteries or flexible demand. The most cost effective solution will emerge, if a level playing field is provided. EU framework guidelines for electricity grid services should be developed, focusing on:

- Asymmetry: separate procurement of upward + downward regulation
- Neutrality between load & generation [6].

A separate procurement enables easier participation of different players to help balancing the grid locally and therefore avoid grid congestions. Overall, this will increase system efficiency and thus benefit all electricity consumers.

An important requirement to be implemented is the balancing responsibility for all producers, including renewable energy power generators on the efficient intraday [7] and emerging balancing markets. Hydrogen prosumer can efficiently complement other production and consumption facilities on all levels of the electricity grid, leading to more balanced and reliable energy supply in the conditions of growing share of inflexible renewable sources on the grid.

3. Conclusions

GOFLEX project will deliver a set of technology solutions to establish market of distributed flexibilities and automated dynamic pricing. Prosumers and communities will be empowered to actively participate in the electricity market and generate their own electricity, consume it or sell it back to the market while taking into account the costs and benefits for the system as a whole. Every prosumer, producer and active consumer will be able to offer energy flexibility and to receive remuneration, directly or through aggregators. Dynamic electricity price contracts based on the local condition on the grid and reflecting the changing prices on the spot or day-ahead markets will allow prosumers to respond to price signals and actively manage their consumption and/or production.

GRASSHOPPER project will develop a Fuel Cell Power Plant (FCPP) characterized by operation flexibility and grid stabilization capability. It will represent an example of the hydrogen-based electrical power generator with ability to participate in the automated flexibility trading market and to receive remuneration for providing ancillary services. While decarbonizing the electrical power generation, efforts should be put to the policy changes required to create a friendly economic environment for the novel technologies to become competitive market players.

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