Existing Tariff Schemes in European Countries and design of Feed in tariffs for promotion of Energy Storage Technologies

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Abstract

Faster market integration of new energy technologies could be achieved by use of proper support mechanisms that will create favourable market conditions for these technologies. The best examples for support mechanisms presented in the last two decades are different schemes for promotion of renewable energy sources (RES). In the EU, the most successful supporting scheme are feed in tariffs which significantly increased utilization of renewable energy sources in Germany, Spain, Portugal, Denmark and many other EU countries. Even though of successful feed in tariffs for RES promotion, in many cases the RES penetration is limited by power system requirements linked to the intermittency of RES sources and technical capabilities of the grids. These problems could be solved by implementation of energy storage technologies like reversible or pumped hydro, hydrogen, batteries or some other technology that will be used for balancing, system stabilization or dump load. In these paper feed in tariffs are discussed with proposal for their application for energy storage technologies. After successful application on islands and outmost regions tariffs for energy storages should be also applied in mainland power systems. Increased use of energy storage could optimize the existing assets in the market.

Keywords: Feed-in tariffs, energy storage, renewable energy sources, intermittency, islands

Introduction

In EU there is strong political, public and economic support for all renewable energy technologies. Political support has been or still is reflected trough European Energy Policy and mostly through its directives as Directive 2001/77/EC for support of generation of electricity from Renewable energy sources (RES-E), new directive on the promotion of the use of energy from renewable sources 2009/28/EC; RES and Climate change package 20-20-20 and many other recommendations and reports. While Directive 2001/77/EC has target to meet 12% of electricity production from RES and new RES directive is setting RES target for 2020 on 20% of final energy consumption, the most recent initiatives are already started process to convert EU Energy supply to 100% RES. On 15th April 2010 RE-thinking 2050 (Zervos et al. 2010) was launched in the European Parliament under the patronage of prof. Maria Da Graça Carvalho Member of European Parliament. The European Renewable Energy

Council (EREC) outlines a pathway towards a 100% renewable energy system for the EU as the only sustainable option in economic, environmental and social terms. RE-thinking 2050 shows how the European Union can switch to a 100% renewable energy supply for electricity, heating and cooling as well as transport, and examining the effects on Europe's energy supply system and on CO2 emissions. RE-thinking 2050 initiative will help to create Post Carbon Society for EU. A post carbon society makes possible to reframe the energy and climate change challenges as opportunities, not just to foster a wealthier society, but also a more equitable and sustainable one.

The four pillars of a Post Carbon Society (Carvalho et al. 2009):

- Renewable Energy
- Building as Positive Power Plants
- Energy Storage
- Smart grids and Plug-in Vehicles

In order to stimulate the energy production from RES and to meet the targets set by Directive 2001/77/EC a number of economic support systems has been developed and adopted by the EU member states. These schemes can be classified into five groups: feed-in tariffs, green certificates, tendering systems and tax and investment incentives (European Commission 2005).

1. **Feed-in tariff** systems are characterized by a specific price normally set for a period of several years, which must be paid by electricity companies, usually distributors, to domestic producers of green electricity. The additional costs of these schemes are paid by suppliers of conventional energy forms in proportion to their sales volume and are passed through to the power consumers by a way of a premium on the kWh end-user price. A variant of the feed-in tariff scheme is the **fixed premium mechanism**. Under this system the government sets a fixed premium or an environmental bonus, paid above the normal spot electricity price to renewable electricity generators.
2. Under the **green certificate system** RES-E is sold at conventional power-market prices. In order to finance the additional cost of producing green electricity and to ensure that the desired green electricity is generated, all consumers (or in some countries producers) are obliged to purchase a certain number of green certificates from RES-E producers according to a fixed percentage, or quota, of their electricity consumption/production. Penalty payments for non-compliance are transferred either to renewable research development and demonstration fund or to the general government budget.
3. Under a **pure tendering procedure** the state places a series of tenders for the supply of RES-E which is then supplied on a contract basis at the price resulting from the tender. The additional costs generated by the purchase of RES-E are passed on the end consumer of electricity through a specific levy.
4. **Tax incentives** are used as an additional policy tool. Tax incentives may be a tax credit or a cash payment or an exemption from tax obligations or low VAT.
5. **Investment incentives:** A common investment subsidy is a grant for the installation of capacity.

The big challenge for the renewable energy industry has been to make the cost of clean energy competitive with heavily-subsidised conventional energy. Political commitment and other factors including the granting of administrative authorisations are also important as they may cause delays in investments and render RES-E investments unattractive. These means that beside financial there are many other barriers for RES-E installations which has been identified by (Oikonomou et al. 2009; Suarez et al. 2009), they also propose methodologies for overcoming identified barriers for RES-E installations. As presented (Garcia and Menendez 2006) utilities have been accused in the past of using third-party grid access as an obstacle to RES-E deployment, this and similar barriers should be addressed before FIT application for storage development. The Feed-In Tariff (FIT) has proven to be the most effective policy instrument in overcoming these barriers. This simple, low-cost mechanism has turned several European countries into world leaders in the renewables sector (World Future Council 2007). One difference between feed-in tariffs and other policy instruments is that feed-in tariffs can operate almost entirely as a standalone policy alternative, depending on a few social institutions for their effective growth. Feed-in tariffs are successful because when priced right they are a strong incentive and design the electricity market to prioritize increasing the proportion of renewable generators. They also incentivize the project builders and owners themselves, those who make the decisions to site and buy renewable generation technologies. Yet they also put pressure on plant developers to efficiently design, situate and maintain their generators as payment is contingent upon producing electricity.

Recent experience from around the world suggests that feed-in tariffs (FITs) are the most effective policy to encourage the rapid and sustained deployment of renewable energy (Couture and Gagnon 2010). Also as explained by (Gonzalez 2008) FIT made Spain and Germany as two of the most successful countries in the public promotion of electricity from renewable energy sources (RES-E). The FIT led to the emergence of a RES-E technoinstitutional complex made up of learning networks between RES-E producers, RES-E equipment suppliers, local communities, policy makers and NGOs (Gonzalez and Gual 2007).

After introduction and description of RES-E intermittency problems and their solving by use of energy storage application, description of FIT has been discussed. The second part of paper presents methodology for design of FIT for pumped hydro as the most mature technology, including results for application of FIT for storage system in the Ios Island case study. Conclusion for FIT and energy storage is given at the end of paper.

RES intermittency problem and energy storage

The intermittency of renewable sources like wind, solar and waves limits their use for power production as in many cases it is very hard to match intermittent production with load that is very often predictable only to certain level. Intermittency problem could be technically solved by introduction of different types of energy storages. Various energy storage options and integration of different energy and resources flows that could help solving intermittency problems in the islands energy systems, have been proposed trough Renewislands methodology (Duić, Krajačić, and Carvalho 2008).

Intermittent nature of renewable energy sources (RES) like wind, solar and waves is one of the limitation factors for their penetration in networks especially autonomous ones. Apart from the progress in forecasting techniques (Giebel 2003) or providing information to end-users regarding management of uncertainty (Tsikalakis et al. 2009), a parameter that can help in managing intermittency is via energy storage applications (Barton and Infield 2004).

The available options for energy storage and integration of different energy and resources flows that could help solving intermittency problems in the islands energy systems, have been proposed trough Renewislands methodology (Duić et al. 2008). Hydrogen is an energy vector that can store all forms of renewable energy, allowing a stable and reliable energy supply is available for power generation and for transport. Case studies and calculations for pumped hydro and hydrogen are proposed in many cases (Duić and Carvalho 2004; Caralis and Zevros 2006; Krajačić et al. 2008) or have been either recently implemented, like in Madeira (EEM 2010) or are under final construction, like in Ikaria Island in Greece (PPC 2010). Experience with use of benefits from batteries management in island power systems have been presented in (Tsikalikis 2004), not only from the economic point of view but also from the improved adequacy level. Hydrogen has also been proposed as a storage means (Lund et al. 2007; Zoulias and Lymberopoulos 2007; Parissis et al. 2009). Some authors found that due to the limited storage capacity of some media, namely batteries and water pumping the hydrogen can be a promising solution. In (Korpas and Greiner 2008) explains how electrolytic H_2 production could be used as a load management method for wind power in weak distribution grids and concludes that H_2 production and storage may become a viable option in areas where reinforcements of existing grids are costly or controversial due to environmental concerns. Similar conclusion that the advantage of the wind–hydrogen system when compared to the wind-only system is that the generation of energy can be managed, bringing it closer to the demand is presented by (Agustin and Lopez 2008).

(Kaldellis et al. 2009) proposed storage systems for islands based on their energy systems size and shown that in those systems storage could even contribute to cost reduction of produced electricity.

As RES penetration gets higher for autonomous or weakly interconnected islands, operators give instructions for disconnection of part of RES production. Similar problems will face big power systems when RES penetration reaches certain levels. Potential use of this excess electricity can be by heat pumps and thermal energy storage proposed for harsh winter climate areas (Lund 2005) or by use of ice banks or other cold energy storage in regions with cooling needs.

The problem of storage systems is that they increase the cost of already expensive distributed and renewable energy sources, making them, in market circumstances, even less economically viable. For the case of hydrogen it has been shown in (Agustin and Lopez 2008; Krajačić, et al. 2009) and that price should be in range of 43 c€/kWh to 171 c€/kWh.

To overcome financial barriers and create favourable market conditions for energy storage technologies support schemes and policies must be developed.

Currently only Greece has policy that supports installation of hybrid systems that include energy storage. Policy is set by Greek law (Hellenic Republic Ministry of Development 2006) and it is currently under revision. Main characteristic is that one tariff is set for electricity of intermittent RES source that directly fed to the grid while another is set for electricity produced by storage units. There is restriction on amount on energy from the grid that can be used for filling of storage. (Solano-Peralta et al. 2009) proposed FIT system for hybrid systems for Ecuador . Use of thermal energy storage in Denmark was indirectly supported trough triple tariffs system for CHP generation as excess capacities in CHP units can be used to relocate the hours of electricity production if thermal energy storage is added to CHP plant (Lund and Andersen 2005).

Design of FIT for both concepts of application of storage system is rather simple and it could be easily performed by Energy Regulatory Agencies or Electricity Market Operators by assistance of experts from TSO and DSO. Calculations necessary for evaluation of FIT design could be done by use o energy planning models described (Lund et al. 2007; Connolly 2009).

Feed in Tariffs

As it was explained in the introduction majority of EU countries have implemented FIT as main instrument for RES support while 6 countries use a quota obligation with TGCs (Figure 1).

There are several different ways to structure a FIT policy, each with its own strengths and weaknesses. (Couture and Gagnon 2010) also present an overview of seven different ways to structure the remuneration of a FIT policy (Figure 2). In general they divided FITs in two broad categories: those in which remuneration is dependent on the electricity price, and those that remain independent from it. Moreover, authors examined the advantages and disadvantages of different FIT models, and made an analysis of design options, with a focus on their implications both for investors and for society.

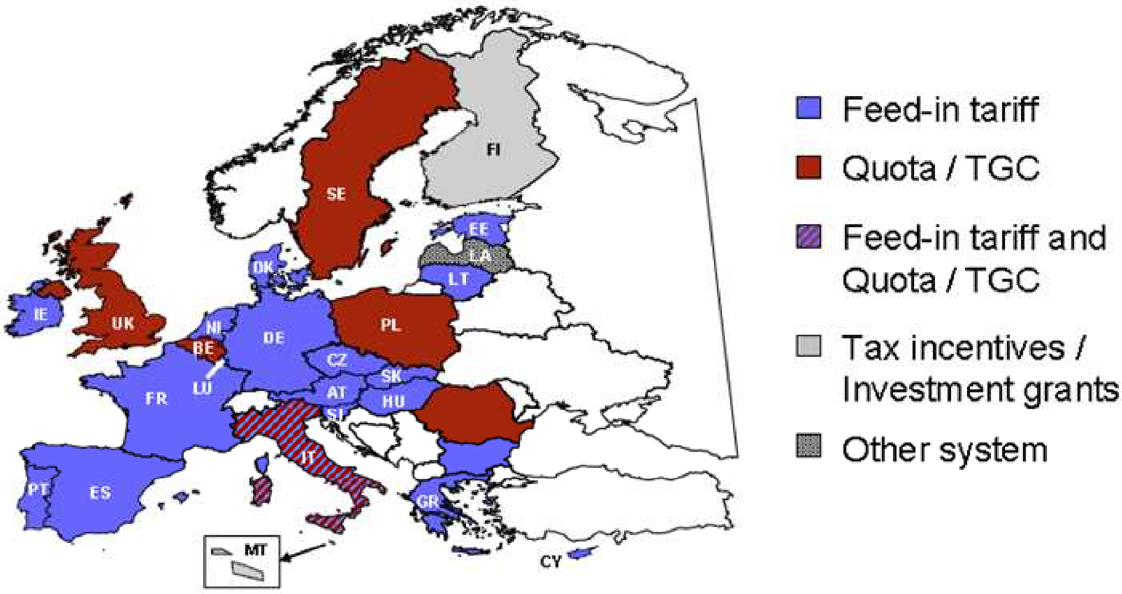


Figure 1. Support schemes for RES in the EU (Ragwitz 2009).

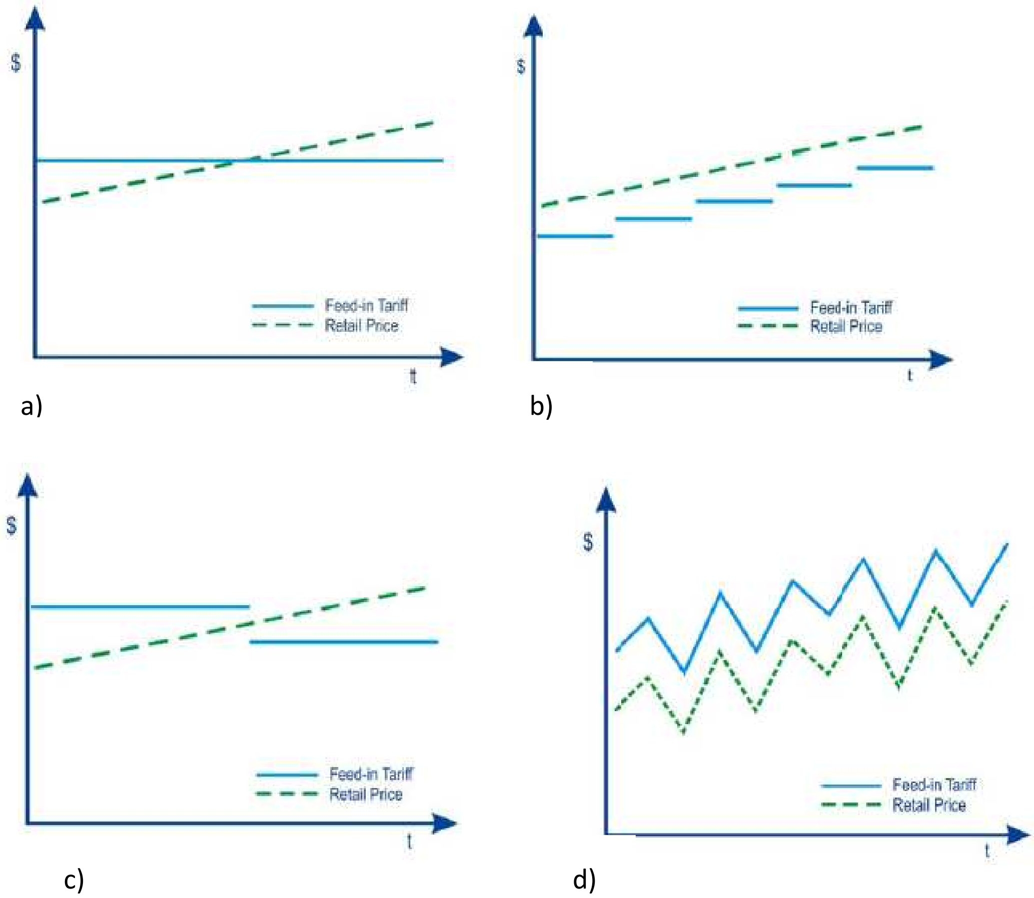
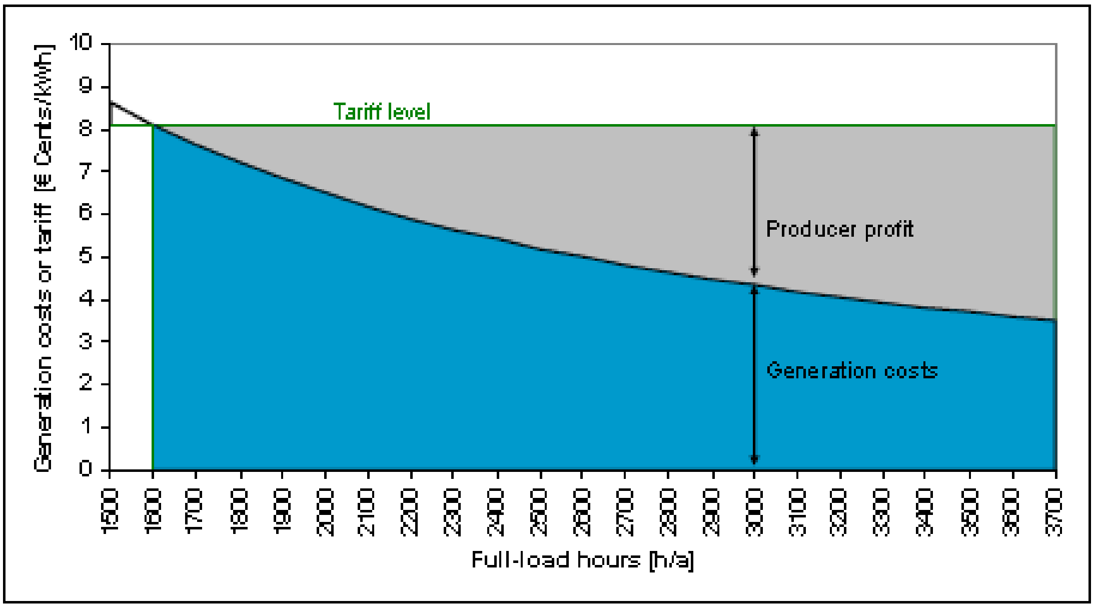


Figure 2. Examples of different ways to structure the remuneration of a FIT policy (Couture and Gagnon 2010). a) Fixed price model for FIT policy design, b) Fixed price model with full or partial inflation adjustment, c) Front-end loaded tariff model, d) Premium price model.

(Haas et al. 2004; Gonzalez 2008) concludes that the specific design elements of support schemes and not so much the type of support scheme being chosen are a major factor for their success. By providing different support levels per technology, FITs are more likely to promote different types of technologies than other instruments, which prioritise the cheapest technologies (Gonzalez and Gual 2007). This is important characteristic for FIT if it will be applied for energy storage technologies as there are many storage options on the market in various development stages.

A stepped FIT is characterised by a lower tariff for technologies, locations and plant sizes with a greater efficiency (Gonzalez 2008). Stepped FITs are a tool to reduce the producer surplus and, consequently, the societal burden (Huber et al., 2004), (Figure 3).



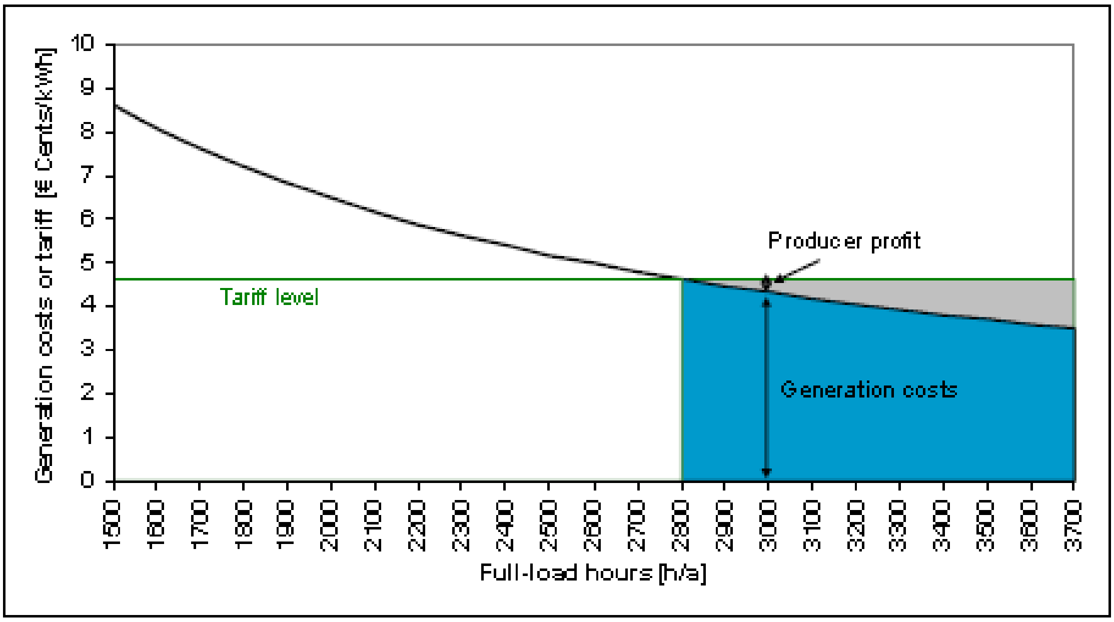


Figure 3. Design of a stepped FIT (Klein et al. 2008).

Reducing the support as the initial investment is paid back can also be justified in order to reduce windfall profits for investors. In contrast, support was not adjusted according to the RES-E potentials of different locations, which is another positive element of a stepped FIT (Ragwitz et al., 2007). Reductions in support levels for new plants are linked to cost reductions due to economies of scale and learning effects (Gonzalez 2008). Similar reduction of over profit for producers due FIT application could be de-escalation of FIT over time. The de-escalating of the feed-in tariff alleviates the burden on the consumers who have to provide the funds for the subsidy through a specially designed RES-E tax. However, if the technological progress envisaged in the policy design is not as quick as expected, the penetration of RES might abruptly cease when the feed-in tariffs fall below the technology's levelised cost (Danchev et al. 2010).

In (Lesser and Su 2008) explained that difficulty with the development of FIT compared with other schemes is requirement of policymakers to define administratively FIT attributes, specifically payments amounts for individual technologies (e.g., wind, solar, geothermal), payment structures (e.g., fixed or declining), and payment duration. All three attributes can require significant „guesswork" on the part of policymakers as to future market conditions and rates of technological improvements. On the other hand (Lipp 2007) concludes that the advantage of the FIT, is that it recognises and distinguishes between RE technologies that are at different stages of development and have different generation costs. Moreover, the FIT does not squash competition, because, in the interest of keeping construction costs low, developers try to buy the cheapest and best technologies and thus have driven the cost of technology down (Lipp 2007). Than it could be concluded that FITs for storage technologies (hydrogen and batteries) will help them to "move up" on learning curves. As presented by (Lipp 2007) in some countries FIT have long history and adequate administration to deal with its procedures. In these countries application of FITs for storage systems could be easily accepted and will not create big disturbance in the market.

(Lipp 2007) also explains specific benefits that countries wish to attain through FIT application as most countries support the development of RES for the following reasons:

- Ensuring security of supply (reducing dependence on fossil fuels and creating diversity of supply).
- Reducing greenhouse gas emissions (and other environmental effects of the energy sector).
- Fostering innovation and broadening industrial capabilities (e.g. to improve export potential, skills and enhance competitiveness).
- Increasing local and regional benefits (e.g. through job creation, manufacturing, economic development).

It is desirable to meet these objectives in the most cost-effective manner and that is main reason for conducting of detailed cost benefit analysis before application of storage systems (Parissis et al. 2009).

As showed by (Saenz de Miera et al. 2008) Widespread public support for electricity from renewable energy sources (RES-E) has been justified according to environmental and socioeconomic reasons, it also resulted in decreasing of total electricity price by RES-E. (Rathmann 2007) shows that the additional amount of RES-E supported by the German RES-E policy (EEG) reduced the wholesale price of electricity in 2005–2007 by 6.4 €/MWh, while increasing the RES-E fee by 3.8 €/MWh. Thus, (Saenz de Miera et al. 2008) concludes that without the RES-E support, the retail price of electricity would have been 2.6 €/MWh higher than it actually has been .

Feed in Tariffs for Energy Storages

In general there are two basic installations of storage systems. Storage installed as separate unit Figure 4 or as part of hybrid system Figure 5. Installation in hybrid system does not necessary mean that producing RES units (wind or photovoltaic or any other power plant) are physically installed at the same location as storage unit it could be just conceptual combination of these two plants where each unit has its own grid connection but they are operated as one hybrid system.

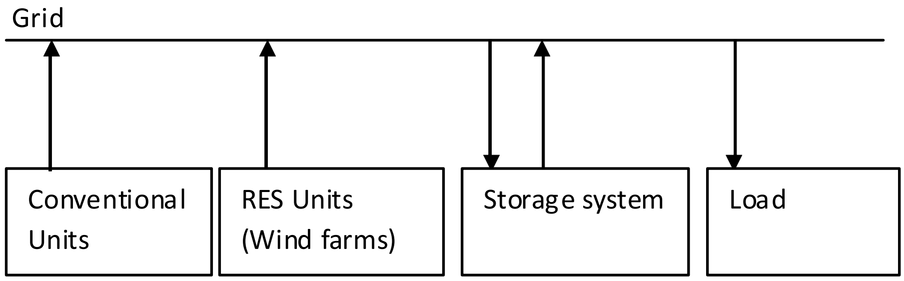


Figure 4. Storage system as separate unit.

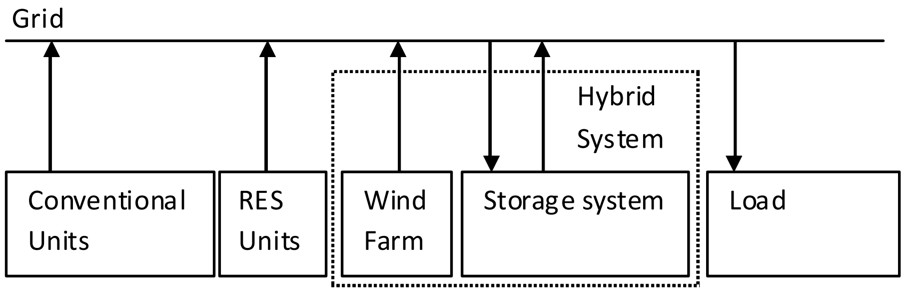


Figure 5. Storage system as part of hybrid system.

Each of presented concepts has its own advantages and field of application. Storage systems as separate units are mostly used in big systems with large number of producing units so usually size of storage units will be bigger and best representatives of these installations are large pumped hydro power plants currently operated worldwide. Hybrid systems are more common on the islands and in standalone applications.

Feed in Tariffs for Pumped Hydro Storage - PHS

Pumped or reversible hydro power stations –PHS, that are not installed as hybrid system, will use energy from grid, that may come from all power plants, for pumping of water to upper reservoir . This kind of units should be supported only in systems with establish certification of the renewable origin of electricity ("guarantees of origin") in order to avoid use of power from conventional stations for pumping. As it is mentioned in introduction, FIT should be different according project size, application, location or resource intensity and the same role should be applied for support of PHS.

$FIT_{PHS_{WGO}}$ represents FIT that is paid for electricity produced by PHS which amount is equal to electricity used for pumping, decreased for the total efficiency of the PHS system. This means that electricity produced by PHS could also get amount of guarantees of origin for RES electricity decreased by system's efficiency. Or illustrated by equation

$$PHS_{GO} = \eta_{PHS} \cdot W_{GO} \quad (eq. 1.)$$

Where PHS_{GO} are guarantees of origin given to electricity produced by PHS and W_{GO} are guarantees of origin for wind electricity supplied from network to PHS station. η_{HPS} is total efficiency of PHS calculated by

$$\eta_{PHS} = \eta_T \cdot \eta_p \quad (eq. 2.)$$

where η_T is efficiency of turbines and generators and η_p is efficiency of pumping. η_{PHS} is important factor and it must be determined from technical documentation of proposed PHS or groups of PHS.

In the case that η_{PHS} is 70% and if guarantees of origin are standardized on 1 MWh , than for 1 MWh of $E_{PHS_{WGO}}$ (RES-E coming from PHS with provable renewable origin of electricity) or 1 PHS_{GO} will need 1.4285 MWh of E_{WGO} or 1.4285 W_{GO} (RES-E coming from wind power plants with provable renewable origin of electricity). Complex accounting of GO needs central registry which should be located at energy market system operator and should be supported by power system operators (TSOs or DSOs). Importance of GO is given in (Ragwitz et al. 2009) as most probably EU-wide trade in RES-E is likely to take the form of an exchange in guarantees of origin (GOs).

In the case that PHS is using only electricity with W_{GO} for pumping and turbine has load factor <=20%, FIT which will be paid for electricity with PHS_{GO} should cover total costs of electricity production and it is calculated by formula:

$$FIT_{PHS_{WGO}} = \left(\left(\frac{TIC_{PHS} \cdot R + OMC_{PHS}}{E_{PHS_{WGO}}} \right)_{WGO} + \left(\frac{EPC_{WGO}}{\eta_{PHS}} \right)_{WGO} \right)_{E_{PHS_{WGO}}} \quad (eq.\ 3.)$$

where TIC_{PHS} is total cost of investment in PHS, OMC_{PHS} is yearly operation and maintains costs of PHS, $E_{PHS_{WGO}}$ is total delivered electricity to network by PHS. $EPC_{W_{GO}}$ represents price for RES-E used for pumping. Indexes WGO only indicates to which renewable origin of electricity the terms in brackets are related.

The annuity factor R is defined as:

$$R = \frac{i}{1-(1+i)^{-N}} \quad (eq.\ 4.)$$

where, i is the discount rate and N the payback period of the investment.

Size of Hydro Power Plants and Pumped Hydro Storage plants could vary from few hundred kW to hundreds of MW and there is also big span in installation costs. Another characteristics of PHS is that they could been built by adaptation of existing structures (by adding pump station and pumping penstock to existing hydropower plants which already have both reservoirs or by adding upper or lower reservoir, penstock, reversible turbines or turbines and pumps to existing water reservoir as it is described in case studies of STORIES project Deliverable 2.1. In the same deliverable total costs of WHPS and PHS are given by formulas and are described in (Tsikalakis et al. 2009).

Proposers of FIT for PHS systems should take into account local particularities of possible development of PHS and according to that they should propose one or several levels of FIT_{PHS}. For particular energy system, limit on load factor of turbines in PHS, that will be supported by different level of FIT, should be optimized according to desirable level of excess production from RES units or according the needs of security of supply or of energy autonomy of the system as described by (Kaldellis, Zafirakis, and Kavadias 2009).

If turbines of PHS system have capacity factor bigger than 20%, which means that they are working more than 1750 full load hours, then PHS system should receive one FIT until it fulfils quota of 1750 full load hours (or energy equivalent), another tariff between 1750 and 2750 full load hours, and third one when it works more than 2750 hours. As mentioned before the this limit for stepped tariff design should be determined trough system optimization of following parameters security of energy supply or energy autonomy, reduction of RES-E excess rejection, desirable RES-E targets/penetration levels, system regulation, costs and benefits.

Table 1. FIT according to capacity factor

Working hours at full load (or energy equivalent),	FIT
<1750 h	$\mathrm{FIT}_{\mathrm{PHS_{WGO}}}$
1750-2750	$1.055 \cdot \frac{\mathrm{EPC_{WGO}}}{\eta_{\mathrm{PHS}}}$ *(eq. 5.)*

>2750	$1.005 \cdot \frac{EPC_{WGO}}{\eta_{PHS}}$ *(eq. 6.)*

When contracted $FIT_{PHS_{WGO}}$ should last for 12 years and contracting should be allowed for 5 years after FIT is inured (this could give security to investors and system planners), after this 5 years period revision of FIT is recommended.

Including 100% of tariffs in protection from inflation is best way to ensure stability for investors. The amount of the FIT for electricity produced in plants using renewable energy sources during the validity of the contract for the purchase of electricity shall be adjusted annually for the retail price index in the way that the FIT for the previous calendar year is multiplied with the annual retail price index for the previous calendar year, that is

$$FIT_{YPHS} = FIT_{YPHS-1} \cdot IRP_{YPHS-1} \quad \textit{(eq. 7.)}$$

where FIT_{YPHS} is the incentive price for the current calendar year. FIT_{YPHS-1} is the incentive price for the previous calendar year, for the first year it represents the amount of the tariff item FIT_{YPHS} referred to in paragraph 1 of this Tariff System. $IRP_{YPHS-1}$is the annual retail price index according to official data from the Central Bureau of Statistics for the previous calendar year. YPHS is the year index.

(Danchev et al. 2010) describes system where the feed-in tariff schedule is updated each year, taking into consideration the inflation rate. The compensation is not full, however, but amounts only to 25% of inflation. The reason stated is that the less than full compensation provides incentives for constantly improving the efficiency of the subsidised unit through innovation, learning, and so on.

In the case that there is extra inflow of water in the upper reservoir which enables load factor of turbine >=20% (or any other optimum limit), FIT for this production should be calculated according to formula:

$$FIT_{PHS_{TGO}} = \left(\left(\frac{TIC_{TPS} \cdot R + OMC_{TPS}}{E_{PHS_{TGO}}}\right)_{TGO}\right)_{E_{PHS} - E_{PHS_{WGO}} - E_{PHS_{NOGO}}} \quad \textit{(eq. 8.)}$$

$$E_{PHS_{TGO}} = E_{PHS} - E_{PHS_{WGO}} - E_{PHS_{NOGO}} \quad \textit{(eq. 9.)}$$

$$E_{PHS_{WGO}} = \eta_{PHS} \cdot E_{WGO} \quad \textit{(eq. 10.)}$$

$$E_{PHS_{NOGO}} = \eta_{PHS} \cdot E_{NOGO} \quad \textit{(eq. 11.)}$$

Where $E_{PHS_{TGO}}$ is electricity produced by turbinating extra inflow of water, $E_{PHS_{WGO}}$is electricity produced by PHS with GO (by E_{WGO} - energy taken from grid with W_{GO} is used for pumping) and $E_{PHS_{NOGO}}$ electricity produced by PHS without GO (by E_{NOGO} - energy taken from grid without W_{GO} is used for pumping). TIC_{TPS} represents total investment costs for hydro power plant (turbines, generators, penstock and eventually upper reservoir without pumping part). The $FIT_{PHS_{TGO}}$ should cover only cost of PHS when it operates as hydro power plant which means taht TIC_{TPS} should be determined from the ratio $\frac{E_{PHS_{TGO}}}{E_{PHS}}$.

FIT for electricity produced by PHS if there are no guarantees of origin for electricity used for pumping:

$$FIT_{PHS_{NOGO}} = 0 \quad \textit{(eq. 12.)}$$

Which means that PHS is buying electricity and selling back $E_{PHS_{NOGO}}$ according the market prices. This mode of PHS work should be allowed only if there are no scheduled requests for pumping from system operator in order to avoid rejection of RES-E excess production.

If TSO or DSO due some reason ask PHS operator to pump and fill upper storage and if they cannot provide GO, PHS owner should receive compensation for this operation (it is most usually done according to rules for balancing energy and it is prescribed in network operation codes).

Feed in Tariffs for PHS Ios case study

The Ios case study will be used as example to show how proposed formulas for FIT work.

Table 2. Ios case study data

Rated power of the turbine – MW	8.0
Rated power of pumps – MW	6.5
Capacity of the reservoir - m3	120000
Installed power of WT – MW	18.3
Additional installed power of WT - MW	13.5
$\mathrm{EPC_{WGO}}$ - €/MWh	87.42
η_{PHS}	0.696
i	15%
N – payback years	8

Equipment cost TIC_{PHS} is calculated according (Tsikalakis et al. 2009) and it does not take into account cost of lower reservoir as it already exists. Calculated TIC_{PHS} is 6.8 mil. € and $\mathrm{OMC_{PHS}}$is 97.226 €.

Table 3. proposed $\mathrm{FIT_{PHS_{WGO}}}$for PHS on Ios with existing lower reservoir and 20% turbine load factor

Working hours at full load (or energy equivalent)	$\mathrm{FIT_{PHS_{WGO}}}$ [€/MWh]
<1750 h	240
1750-2750	132.5
>2750	126.2

This $\mathrm{FIT_{PHS_{WGO}}}$ should be valid for PHS from 1 MW to 10 MW of installed turbines power for installations that already have installed lower reservoirs, bigger systems and different configurations for installations require additional calculations by using equations 1.-6. and For example if for the system on the Ios island will be necessary to install lower reservoir with the same size as upper the FIT should be at least 263 €/MWh.

Feed in Tariffs for Hybrid Wind Pumped Hydro Storage - WHPS

If the market operator is not possible to ensure GO of origin for electricity taken and delivered from storage units then it is possible to make FIT tariffs according to Greek law (Hellenic Republic; Ministry of Development 2006).

In order to cover costs of electricity production following condition must be always applied

$$FIT_T \geq EPC_T \text{ (eq. 13.)}$$

The contribution of the WHPS, together with economical and reliability indexes, are used to describe the performance of the electrical system after the WHPS integration. The conventional units' EPC EPC_C, the Electrical system's EPC EPC_S and the turbine's EPC EPC_T are used to describe the economic impact of the WHPS to the electrical system. The most critical is the EPC_S, when it is compared with the current cost, the resulting benefit -if any- from the WHPS integration is defined. The EPC_T is important for the private investor, indicating a first estimation of the required price for the turbine's electricity production which provides the feasibility of the investment. Finally, the modification of the EPC_C due to the WHPS integration is critical for the ESO[1] in order to accept this price.

Feed in Tariffs for WHPS Ios Case study

More detailed financial analysis of hybrid system is given in (Papathanassiou et al. 2008). Some of the results for the Ios Case study are showed in (Tsikalakis et al. 2009).

The installation of WHPS contributes to decrease of total EPC of the system and yearly savings are in range of 2.2 mil € with significant amount of avoided emissions. As WHPS is using also electricity from conventional units for pumping, up to 6.3 GWh, which results in 1260t of emitted CO_2 it is desirable to install registry of GO to enable WHPS treatment as RES powerplant.

General Conclusions and Recommendations

In these paper feed in tariffs for various energy storages are discussed with proposal for their application in most suited regions for their application. Although in very small isolated, house-size hybrid systems with RES, storage is essential; in autonomous power systems storage use is not as widespread as expected.

Increased use of energy storage could optimize the existing assets in the market; these facilities (power plants, transmission lines, etc.) will make more money, and hence be worth more.

After successful application on islands and outmost regions tariffs for energy storages should be also applied in mainland power systems.

In 2007 the EU decided on a set of binding renewable energy targets for 2020: an overall 20 percent target (European Commission 2005; European Commission 2005). If adopted by national and regional governments and energy market operators developed financial schemes for storage systems may contribute to EU energy policy 20-20-20. Energy storage is also marked as one of four pillars of EU Post Carbon Society (Carvalho et al. 2009). As EU will strive to reach goals of its energy policy, energy

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[1] The autonomous islands are excluded from the market liberalization and the system operator remains the owner of the local power stations.

storage could make great contribution to that if similar successful mechanisms will be used as they were used for promotion of RES. It will create competitive and fluid environment.

Similar to storage technologies for RES-E that also could receive GO or desalination as dump load that can increase RES-E penetration other similar technologies like thermal energy storage, cold storage, electric vehicles or V2G could be supported by different FITs. This technologies should be supported as in long term they can make more benefits to communities than what will be their costs. This hypotheses has been already proven by FIT for wind energy.

The view among many experts is that wind power would already be competitive in most places if conventional energy had not had the benefit of subsidies. In fact, if the costs of fossil fuels reflected the environmental damage they cause, they would actually be much more expensive. It may not be practical to exploit this in its entirety, but with a support scheme that is already a proven success, and the needs and opportunities there, the only thing lacking is the political will to switch to higher penetration of renewable energy sources.

The combination of a Feed-In Tariff with other subsidy programmes and technical cost breakthroughs will generate increasing and sustained installation of RES and hybrid microgeneration equipment in homes and businesses. Management, sales, advice and other technical support staff will be needed, and the large number of satellite system installers and servicing personnel will have a great opportunity to benefit from this new industry.

Before scheme application it is important to Evaluate domestic conditions in terms of: renewable energy resources, political environment, economic environment, geographical conditions, and technological preconditions; determine the desirable and possible rates of increase in RE in terms of capacity and share in the energy mix; assess the state of the national electricity grid and the level of connection across the country.

It is desirable to start with a comparatively simple regulation for energy storages and improve it over time. Therefore, there should be a monitoring process within the regulation in order to check if the goals and targets are being met. Tariff rates should also be monitored and adjusted in order to control expansion rates and ensure correct payments for each storage technology as it matures. The FIT system means that the pay-back time for hydrogen or other hybrid system is no longer several decades but several years instead. The important thing is that each technology is supported if viable. Some innovative technologies which are still at the demonstration phase of development may require a different type of government support, such as tax incentives or soft loans.

An effective scheme is one that: provides tariffs for all levels, from domestic to large-scale developments takes account of the level of development of each technology guarantees long term investment security is administratively simple is easy to explain in order to ensure public acceptance.

Monitoring of success of financial schemes and RES policies:

- Number of operating installations of each technology
- Amount of RES + storage capacity installed relative to applications for grid connection
- Amount of renewable generation in kWh delivered
- Proportion of RES + storage development owned by and for communities
- Proportion of RES + storage development by homeowners
- Location of development (islands, remote locations, mainland, urban, rural, and so on)

Furthermore it is expected that Regulator makes analysis of financial schemes and according to information received from utility companies (operating costs, base rate, amortization depreciation, investment, taxes and rate of return) gives proposal for new schemes every 4-5.

Identifying comparable conditions in other countries where a finical mechanism for RES hybrid and storage systems (for example Greece) has already been implemented will be helpful.

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