Sustainable Energy Technologies and Assessments 26 (2018) 6–16

Contents lists available at ScienceDirect

Sustainable Energy Technologies and Assessments

journal homepage: www.elsevier.com/locate/seta

Original article

Evaluation and recommendation of a subsidy instrument for new large hydropower plants, use case of Switzerland

Thomas Gisler[a], Massimiliano Capezzali[b,*], Mélanie Guittet[c], René Burkhard[d], Daniel Favrat[e]

[a] University of Applied Sciences Lucerne (HSLU), Switzerland
[b] Institute for Energy and Electrical Systems, School of Management and Engineering Vaud (HEIG-VD), Switzerland
[c] Centre de Recherche Energétiques et Municipales (CREM), Martigny, Switzerland
[d] Pronovo AG, Switzerland
[e] Energy Center, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

ARTICLE INFO

Keywords:
Subsidies
Hydropower
Switzerland
Systems Engineering

ABSTRACT

Hydropower is the central pillar of the current Swiss electricity mix. The Swiss energy transition will profoundly change the electricity mix by transitioning a third of electricity generation from nuclear towards renewable energy sources mainly. This backbone role of hydropower is hindered by the current Europe-wide sluggish economic situation, characterized by subsidized new renewables energies which distort electricity prices, a partially liberalized market and power production overcapacity. In this difficult context, a strong and comprehensive political support through long-term policy will be of utmost importance to accompany hydropower across this transformation. This article explores various subsidy instruments, before using the general framework of "System Engineering" to base a precise recommendation for Swiss hydropower. The recommended mixture of investment contribution with discount reclamation appears the most appropriate instrument. Also, the short time horizon means that the subsidization can be quickly terminated if necessary. In parallel, it is a mature instrument since it is already used for other new renewable energies. The discount model allows reclaiming subsidies in case of an excess profitability. The strength of this study is its robust, comprehensive and all-encompassing methodology which can be replicated to other cases (for instance, other technologies or energy sources) and other countries.

Introduction

Worldwide, electricity production from hydro power could double by 2050 to reach 7000 TWh, and the main part of this growth will be coming from large hydropower plants (HPP) in emerging economies and developing countries [1,2]. In Switzerland, hydro power contributes to 60% of the total power generation [3], with an average of 36 TWh of produced electricity per year [4]. In the context of the new "Energy Strategy 2050" targets (thereafter called Swiss energy policy) and the intended nuclear power phase-out, around 40% of the electricity supply will have to be compensated by other energy means. Along with other renewable energies, hydropower represents a crucial pillar of both the current and future Swiss energy mix [5,37]. The actual sluggish electricity market makes it however questionable whether hydropower will be able to fulfill this role, since both an increase in capacity and a lot of investments in existing assets (for retrofitting and refurbishment) are necessary [6].

The envisioned extended role of renewables in electricity generation has been promoted through various government subsidies since 2008, notably with the introduction of feed-in remuneration at cost encouraging investments in renewables, including photovoltaic solar energy, hydraulic energy and small hydro, biomass energy or geothermal energy [7]. Despite this first step, the growing distortions in the market and the declining value of renewables on electricity trading markets have sparkled many debates around the subsidization of hydropower [8].

The paper is organized along three axes. It first explores and compare the existing subsidy instruments, and how they apply to hydropower in Switzerland. On this basis, this article then explains how the general methodology "Systems Engineering" can be used to assess the performance of those instruments, and how this methodology could be replicated either to other countries or to other technologies. Finally, through this detailed process, validated guidelines and recommendations are provided for a subsidy instrument to support the envisioned expansion of new hydro power capacities in Switzerland, along with other renewable energies, considered as pillars of the future Swiss

* Corresponding author.
E-mail address: massimiliano.capezzali@heig-vd.ch (M. Capezzali).

https://doi.org/10.1016/j.seta.2017.12.004
Received 4 November 2016; Received in revised form 30 September 2017; Accepted 19 December 2017

Table 1
Overview of subsidy instruments.

Focus on	Subsidy instruments		
	Direct		Indirect
	Price-driven	Quantity-driven	
Investment [currency]	- Investment contribution - Credit discount	- Investment based tender process	- Eco-taxes - Green certificates
Production [currency/MWh]	- Feed-in tariff/ premium payment - Bonus model	- Production based tender process - Quota regulation (with certificate market)	

energy transition. It is important to highlight that the methodology developed can be replicated to other countries, Switzerland's situation being used as a study case, thus underpinning the significance of this paper.

Comparison between existing subsidy instruments

Existing subsidy instruments

Existing subsidy instruments and support schemes are listed in Table 1 and discussed in the following paragraphs [7,9–13]. Their specific relevant to the hydropower situation in Switzerland is highlighted in each case.

Indirect subsidy instruments (eco-taxes, green certificates)

Indirect instruments such as certificate systems and incentive taxes charge caused external costs such as the costs of environmental pollution, by setting a price on the polluting activity. Thus, all (ecological) costs of the energy source are included within the electricity price ("polluter pays principle") [14]. Assuming that electricity from renewable energies is associated with low external costs, indirect instruments promote the development of renewable energies by indirectly changing the relative electricity prices.

Eco-taxes are a fiscal policy which tax environmentally-impactful energy sources [12]. While this measure has been established in Switzerland for heavy vehicles, it is not yet implemented for energy production [15]. **Green certificates** are an advanced version of tradable quotas [14,16], and they have recently gained a huge momentum in many European countries. It obliges producers, consumers or distributors to have a certain share of their electricity consumption or production that is deemed "green" (i.e. coming from a renewable energy source), through a state-controlled certification mechanism. This also allows a separation between the "physical" market where the electricity is sold at standard market prices (and competing with cheaper energy sources), and the certificate market (or eco-services market) which allows the producer to make up for this loss by selling the green certificates [17].

Difficulties in implementing this type of measures lie in the effective definition of the internalization charges as well as in the determination of potential quotas for the production of various energy sources. Additionally, these indirect promoting instruments need an appropriate legal basis. In Switzerland, this basis has not yet been fixed.

Investment contribution

Investment contributions are a one-time direct payment granted either in the form of a percentage of the total costs of the investment, or in the form of a predefined amount per installed MW [7,9,18]. The level of the investment is normally defined on a technology-specific basis; for hydropower, it is between 40% and 60%. The investments are paid to all providers of renewable energy that meet some predefined factual conditions.

This instrument suffers from two main drawbacks: first, the total spent cannot be determined beforehand, and second, the amount of electricity supplied by the plants supported through this mechanism cannot be foreseen. A subsidy price variable over time may compensate these weaknesses.

The Swiss Federal Office of Energy will apply this incentive scheme to support small hydropower (< 10 MW) rehabilitation and extension [19]. The new Energy Act, which has been accepted by popular vote in May 2017 and is also referred to as "Energy Strategy 2050", expresses that in the case a future excessive profitability of new large hydro plants, paid subsidies may be reclaimed [19]. The **contract reclamation** is an inverted version of the investment contribution. As soon as contractually agreed criteria are met, the repayment of the predefined amount is due.

Credit discount

Credit discount is a way of financing provided in return for a debt or repayment obligation, usually with advantages such as lower interest rates or with lower security requirements [20]. Credit discounts have a similar effect to that of investment contributions. This instrument is independent with respect to the funding level.

A disadvantage of this discount is that it is based on the size of the loan and not on the capacity installed. Given the same plant capacity, expensive investments get higher promotions compared to cheaper projects. In contrast to investment contribution, credit subsidies promote more expensive (and possibly less efficient) investments. Nevertheless, this type of subsidy is often used as a complementary tool.

Feed-in tariff

The feed-in tariff (FIT) guarantees a fixed compensation rate per unit of electricity produced from renewable energies, for a defined time period, and covers the difference between the production cost and the market price [21]. Producers have the guarantee that at least their production costs are covered and that they are not exposed to fluctuations of the electricity price, thus increasing the security of new projects. This rate is above the market price of electricity, otherwise the promotion would not be efficient [22]. This rate may also be corrected over time (through a process called dynamic adjustment), thus the quantity produced can be easily influenced (see Fig. 1). Additionally, it guarantees supplies with priority access and dispatch [23].

Since power supply companies are obliged to first buy the electricity produced from renewable energies (priority dispatch), the producers neither bear the costs for the marketing of their electricity nor the associated financial risks. Since the remuneration is higher than the market price and the power purchase is guaranteed regardless of the market demand, this instrument is not very close to the market [14,21,24]. The bearer of the costs is either the tax payer or the electricity consumer through a supplement on the electricity price.

Since 2008, the expansion of renewable energies has been promoted

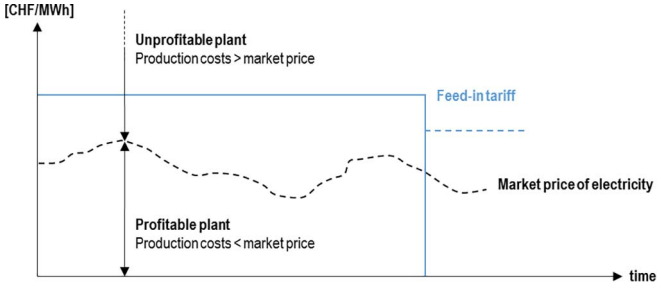

Fig. 1. Feed-in tariff, above the market price of electricity for a limited amount of time (blue line). Its value can be adapted (dashed blue line) to better influence the quantity produced. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)