8TH CONFERENCE ON APPLIED INFRASTRUCTURE RESEARCH (INFRADAY)

9-10 OCTOBER 2009

TU BERLIN, GERMANY

Coherence between institutions and technologies - The case of mini hydropower in Switzerland

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Abstract

Switzerland, with the forecasted electricity gap between domestic production and demand, aims to significantly increase renewable energy sources including hydropower. Mini hydropower (<1MW) currently has considerable unused technical potential. As a renewable energy source (RES) it can contribute to climate change mitigation. CO_2-taxes or emission trading systems (ETS) for planned thermal power plants could help facilitate mini hydropower (MHP). The technology is mature, but requires adequate frameworks (e.g. regulation, streamlining of procedures, adequate financial mechanisms) to maximize its remaining potential under economically viable conditions. This paper analyzes the coherence between institutions and technologies in the case of MHP in Switzerland. It takes into account the current liberalization of the electricity market, the government's goal to increase the weight of RES and the post-Kyoto context. The analysis aims to increase the degree of coherence between the institutions and the technology. As a result the economical performance of MHP will increase. The paper contains a dynamic perspective on the infrastructure and a conclusion with recommendations for further research on the development of adequate policy shaping institutional and financial mechanisms to facilitate MHP in Switzerland – mechanisms that could be adapted to other countries.

Keywords: mini hydropower, institutional framework, regulation, financial mechanisms

JEL-code: Q25, Q48

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1. Introduction

Climate change and sustainable development are top priorities worldwide today. In Switzerland, alongside neighbouring countries, there will be an electricity gap between the domestic production and demand in the near future[1]. The Swiss government aims to increase the total amount of electricity produced by renewable energy sources (RES) between 2010 and 2020 from 16 to 24%[2]. One of the seven measures of this initiative is the facilitation of hydropower, including mini (0.1-1 MW) and small (1-10 MW) hydropower[3]. As mini and small hydropower technology is well established this research provides an interesting case of institutions having to evolve and innovate in a coherent way with technology.

The European electricity sector is presently undergoing a liberalisation process. The sector is supposed to function based on market-mechanisms but in the current economic crisis institutional and regulatory interventions may become more important again. In addition, new investments are required within the sector and governments want to promote more RES infrastructure ("green new deal"). In Switzerland, there is large heterogeneity among the electricity production firms, most of them still belonging to public entities, such as communes and cantons. As the cantons and communes decide on the institutional framework as well, they are shareholders and institutional decision maker at the same time.

Hydropower throughout the world provides 17 % of the electricity from an installed capacity of some 720 GW, making hydropower by far the most important renewable energy source for electrical power production. In the EU-15, hydropower accounts for around 84 % of electricity generated from renewable energy sources in 2006[4].

The depletion of oil and natural gas deposits will lead to higher generation costs for thermal plants, as well as CO_2-taxes or cap and trade schemes. By offsetting thermal generation, mini and small hydropower can be leading technologies in efforts to reduce greenhouse gases and in climate change mitigation. The growth of the world's population, especially in developing countries, will require the appropriate

[1] SFOE, 2007b; ECG, 2009.
[2] EnergieSchweiz, 2008, p. 6.
[3] SFOE, 2004.
[4] ESHA, 2006, p. 5.

infrastructure for irrigation and water supply. The addition of a hydropower component to such a project is economic and has no major environmental or social impacts but a broad range of benefits through ensuring decentralized energy supplies. In addition, mini hydropower plants in developing countries can benefit from CO_2-compensation mechanisms such as Clean Development Mechanisms (CDM) and Adaptation Funds (or similar mechanisms in a post-Kyoto context).

The main advantages of mini hydropower (MHP) are:

- It does not involve a process of combustion, therefore avoiding CO_2 emissions, acid rains and smog; it is a **clean resource**;
- The fuel is water, which is not consumed in the electricity generation process; it is a **renewable resource**;
- MHP is available within the borders of one country and not subject to disruption by international political events, and because it is a domestic resource, it is not subject to market fluctuation like fuel or natural gas; it is a **secure resource**;
- It can satisfy energy demand with no depletion of the resource and with little impact on the environment; it is an **efficient resource**;
- Usually, it does not require the creation of large lakes, thus avoiding sedimentation problems and the filling of the reservoir; it is a **sustainable resource**.

The aim of this paper is to contribute towards the shaping of institutional frameworks in such a way that facilitates mini hydropower. The unit of analysis is Switzerland which is a country well known by the author, and which has remaining MHP potential. It is also a country with specific institutional perspectives. The conclusions of this paper will also be useful for mini hydropower in other countries.

This paper is structured as follows: Section 2 gives a brief summary on the framework of coherence between institutions and technologies on which this paper is based. Section 3 describes in general terms the MHP technology and the institutions around it within Switzerland. Section 4 analyses the coherence between the technology and institutions in the case of MHP in Switzerland. Section 5 provides concluding thoughts and recommendations for further research.

2. Coherence between institutions and technologies

MHP is part of the electricity network infrastructure. This infrastructure is technically, economically, politically and environmentally complex. As electricity is essential, all actors in the sector must ensure its continuous delivery within specific quality standards (e.g. reliability).

The current liberalisation process of the electricity sector focuses on institutional changes, such as deregulation, reregulation, unbundling, introduction of competition at the production level and other measures related to the market structure. At the same time, governments want to increase the usage of RES for electricity production. In this context MHP can be seen as a mature and therefore very constant technology (see Section 3.2). Consequently the institutions should evolve in such a way that MHP is facilitated as a RES and its overall performance increased.

The conceptual framework for the analysis within this paper is the literature on the co-evolution between institutions and technology in the case of network industries[5]. Figure 1 shows this framework:

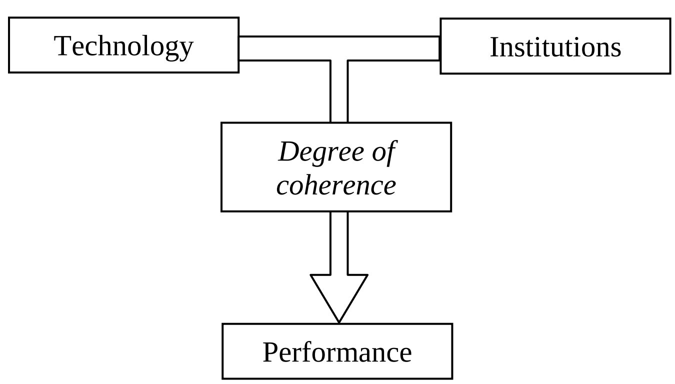

Figure 1: The relationship between technology, institutions, coherence and performance[6]

According to the Oxford dictionary the definition of the term “technology” is the "scientific knowledge used in practical ways in industry”. Within this paper MHP represents the technology.

[5] Finger, Groenewegen et al., 2005; Groenewegen, 2005; Hodgson, 2006; Künneke, 2008; Künneke, Groenewegen et al., 2008; Ménard, 2009.
[6] Finger, Groenewegen et al., 2005.

North defines institutions as “the rules of the game in a society or, more formally, the humanly devised constraints that shape human interaction. In consequence they structure incentives in human exchange, whether political, social, or economic. Institutional change shapes the way societies evolve through time and hence is the key to understanding historical change.”[7]

The coherence between technology and institutions increases if both are aligned on a similar level for example organisational structure, coordination mechanisms et al. This paper will focus on this topic.

The performance in this framework is defined through three parameters: the economic performance, the public value and the technical system integrity[8]. The economic performance concerns the static, dynamic and system efficiency. The public value is defined by the quality, accessibility, affordability and reliability of the service, as well as environmental aspects. Performance criteria of the technical system integrity are resilience and robustness. In the case of this paper, the focus is on the economic performance.

In summary, it can be stated that the technology needs to be supported by suitable institutional frameworks in order to perform satisfactorily.

3. Mini hydropower in Switzerland

Mini hydropower plants combine the advantages of hydropower with those of decentralized power generation. There are no important environmental costs, no costly transport of electricity and no need for expensive maintenance. It is independent of imported fuels and increases the electrical grid stability. Most projects are not cost-efficient and require an adequate institutional framework to be implemented with contributions from the private sector. In developed countries, as well as in developing countries, MHP can be combined with other existing or planned infrastructures.

[7] North, 1990, p.3.
[8] Finger, Groenewegen et al., 2005, Ch. 2.3.

3.1 Definition and history

The definitions used in this paper correspond with International Energy Agency[9] and World Bank definitions[10], as well as with most of the Swiss and European regulations:

- Mini hydropower (MHP): 100 – 1’000 kW or 0.1 – 1 MW
- Small hydropower (SHP): 1 – 10 MW

As SHP has similar issues around its coherence between the technology (it is a bigger scale of MHP) and institutions (which are similar to MHP), SHP is mentioned occasionally within this paper. Certain RES facilitation mechanisms concern MHP and SHP together.

MHP and SHP have a long history. First hydraulic machines in China and the Mediterranean basin date from 200 B.C[11]. The first hydroelectric scheme was installed in Wisconsin, USA in September 1882 only three years after Thomas Edison invented the light bulb[12]. In the early 20th century, there were nearly 7’000 MHP and SHP plants in Switzerland of which more than 90% were rated below 300 kW and consisted of water wheels and mini turbines[13]. Table 1 highlights figures during the 20th century when the number of operated MHP plants below 300 kW strongly decreased. History shows that MHP and SHP are mature technologies and received a lot of technical R&D in Switzerland during the past decades through government facilitation programs (PACER, DIANE) and research laboratories (e.g. MHyLab, EPFL-LCH). In 2008, MHP represented 2.2% of the Swiss hydropower production and 1.2% of the total electricity production (Table 1).

[9] IEA, 2003, p. 31.
[10] www.worldbank.org/re
[11] Andaroodi, Schleiss et al., 2005, p. 20.
[12] http://practicalaction.org/?id=smallscale_hydro
[13] Leutwiler, 2006

Installed electrical capacity (kW)	1947		1973		2008				
	Plants	MW	Plants	MW	Plants	MW	GWh / year	Total electricity production from hydro-power	Total electricity production
Below 300	~5'700	85	~1'900	50	700	56	250	0.7%	0.4%
301 - 1'000	116	68	126	72	171	97	510	1.5%	0.8%
1'001 - 10'000	102	407	139	518	172	641	2'725	7.7%	4.2%
Above 10'000	65	2'300	163	10'040	167	12'538	31'744	90.1%	48.8%
Total till 10'000	~5'920	560	~2'165	640	1'043	794	3'485	9.9%	5.4%
Total hydropower	~6'000	2'860	~2'330	10'680	1'210	13'332	35'229	100.0%	54.2%

Table 1: MHP and SHP in Switzerland during the 20th century[14]

3.2 Technology

Hydro-turbines convert water pressure into mechanical power, which can be used to drive an electricity generator, or other machinery. The power available is proportional to the product of head and flow rate. The simplified formula for hydro system power output is:

$$\text{Power (kW)} = 8 \times Q \times H$$

Where:

- 8 takes into account the gravity acceleration g (9.81 m/s^2) and the overall efficiency of the system (in average 82%)
- Q is the volume flow rate passing through the turbine (m^3/s),
- H is the effective pressure head of water across the turbine (m).

There are no different technological paradigms. The potential energy of water is transformed into electrical energy. There are, however, different MHP systems. Two main classifications are used. The first one is the connection to a network. MHP plants can be off-grid, mini-grid or grid connected. In the case of off-grid, electricity is produced for one, or a limited number of users. In a mini-grid (e.g. local grid) and grid-connected case the electricity is provided to numerous users.

[14] Leutwiler and Dasen, 2008.

The second classification uses the head. High head MHP has a head of 100 m or more. Figure 2 shows the main components of such a plant.

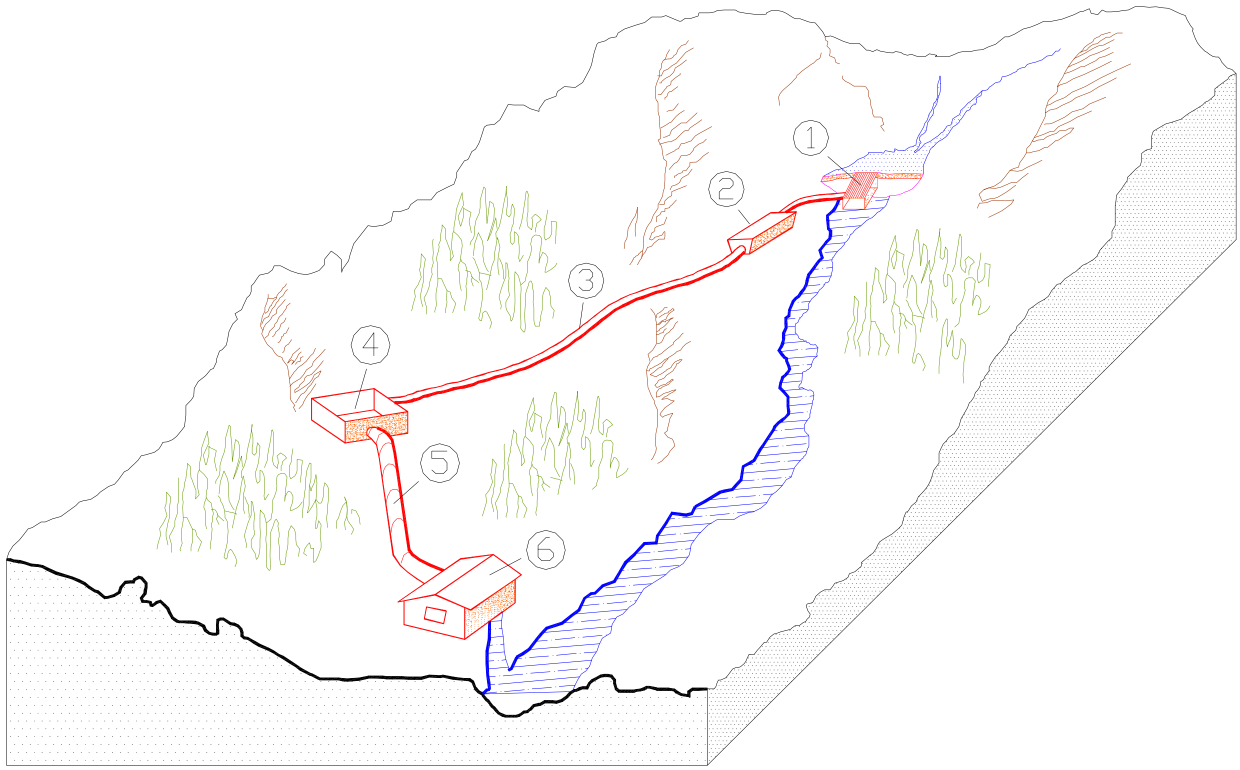

Figure 2: Main component of a high-head MHP plant[15]

The water is diverted through a water intake in the river bank or bed (1). A settling basin (2) is placed after the intake structure to remove sand particles from the flowing water. Then a headrace canal (3) follows the contour of the hillside to provide the required head for energy production. After that the water enters a forebay (4) and passes into a closed pipe known as a penstock (5). This last structure is connected at a lower elevation to a turbine located in the power house (6). At the outlet of the turbine, the water is discharged to the river, via the tailrace. Medium head MHP are between 30 m and 100 m head. Low head MHP are below 30 m. They are typically built in a wide and flat river valley.

In developed countries, as well as in developing countries, MHP can be combined with other existing or planned infrastructures[16]. These can be potable, runoff, irrigation and waste-water networks and

[15] Andaroodi, Schleiss et al., 2005, p. 22.
[16] Crettenand, 2006.

installations using the residual flow at bigger hydropower plants (so called “Dotierkraftwerke” in German). The advantages of this are:

- Use of existing or planned network infrastructure. No new networks needed.
- No additional negative impacts on the environment.
- Limited investment for a MHP setting.
- Simple administrative procedures.

MHP has a high energy payback ratio. For each power generation system, the “energy payback” is the ratio of energy produced during its normal life span, divided by the energy required to build, maintain and fuel the generation equipment. If a system has a low payback ratio, much energy is required to build and maintain it and this energy is likely to produce major environmental impacts. Run-of-river hydropower has an energy payback ratio of 30 to 267; biomass 3-27; wind power 5-39; solar photovoltaic 1-14[17]. The payback ratios do vary significantly for renewable energies. This is due to variable site conditions (e.g. topography in the case of hydropower, quality of the wind in case of wind power, intensity of solar radiation for solar power).

Compared to other RES, MHP has lower production costs (including financial costs) at 10-25 cts/kWh. Wind power has costs of 20 cts/kWh, biomass of 28-42 cts/kWh and solar of above 60 cts/kWh[18]. Hydropower projects have a high initial investment followed by low operational costs.

For plants with an installed capacity below 300 kW, standardized construction and standardized electromechanical equipment are possible. Plants above 300 kW require individual design specific to the geographical site.

The last in-depth study of MHP potential in Switzerland was completed in 1987[19]. The technical potential of MHP and SHP combined in Switzerland was evaluated at around 9‘000 GWh/a, when approximately 3‘000 GWh/a were used. In November 2008, the Swiss government initiated a new study on the

[17] ESHA, 2006, p. 6.
[18] SFOE, 2007a, Fig. 3.2-3.
[19] Desserich and Funk, 1987.

evaluation of the remaining technical potential of MHP and SHP in Switzerland. The final results will be available in 2012. MHP still has considerable unused technical and ecological potential[20].

Newly designed MHP plants are well integrated environmentally and respect issues of the water intake, minimum instream flow (downstream of the water intake) and fish passes. The equipment is readily available and construction procedures are well known. On a worldwide level, MHP is one way to enable people to have electricity to reach the Millennium Development Goals and to protect the environment whilst using a RES.

3.3 Institutions

A reason why most MHP projects are not economic profitable under the current framework conditions is that the external costs of energy production (e.g. pollution such as GHG emissions) are not internalised. MHP costs tend to be significantly higher than those of conventional sources of energy. The result is that electricity generated with renewable energy sources cannot compete on a free market with conventional generation and therefore some form of market incentive or support is required to develop the technology. Consequently, MHP electricity requires two essential elements for positive development: (i) a stable regulatory framework to reduce uncertainty and attract investors, (ii) a price support mechanism that enables renewable producers to enter the market and make a reasonable profit. The latter will be described as financial mechanisms hereafter.

Financial mechanisms

The following main existing financial mechanisms have been identified:

[20] The definitions of different potentials are defined by the Swiss Federal Office for Energy (Piot 2006). See Appendix 2.

Mechanism	**Explanation**
Feed-in tariff	The Swiss feed-in tariff was introduced on the 01.01.2009. It is a cost-effective net metering (Energy Law, 2009, Art. 7a). Before it was introduced MHP benefited from a guaranteed tariff of 15 cts/kWh. Now the tariff depends on the installed capacity, head and a bonus linked to the hydraulic construction. It varies between 5 - 39.5 cts/kWh. The tariff is guaranteed for 25 years and there are no ecological constraints to it. It cannot be combined with the green electricity market. The pool to fund the feed-in tariff is limited and its income is provided by 0.4-0.6 cts per consumed kWh. It is a consumer based mechanism and not a state subsidy. The pool has been quickly emptied resulting in a lack of financing for new MHP plants. The huge demand is a sign of the reality of the remaining MHP potential in Switzerland.
Water rental	This is a tax of 80 CHF/kW. It applies to SHP and ranges from 0 to 80 CHF/kW. MHP is exempt. (Plaz and Hanser, 2008, p. 52)
Labelling	The sole existing label for MHP in Switzerland is "Naturemade" (http://www.naturemade.org). It is a Swiss label for green energy and recognized by ProNatura, WWF and Greenpeace, and can be used at a European level. A certified MHP plant can sell the ecological value of its electricity at an increased price. The price for the ecological value changes between 0.03 cts/kWh to 0.17 cts/kWh (www.topten.ch May 2009). The labelling costs for a new project are around CHF 10'000. For projects using older infrastructures or existing projects which want to be certified the costs will be higher due to the need to improve the environmental integration of the plant. These costs are very high in relative terms for MHP projects. Hydropower projects which seek the label must fulfil the greenhydro standards (Bratrich and Truffer, 2001).
Government subsidies	Federal contributions to the pre-feasibility and feasibility studies for MHP range from 60% (5kW) to 30% (1MW) of the study costs. www.smallhydro.ch.
Mechanisms at canton level	Some cantons support MHP development independently. The canton of Bern supports plants with an installed capacity below 300 kW in the form of loans without interest and reductions of financial charges (Art 9 Loi sur l'aménagement des eaux, LAE, 1989).

Table 2: Existing financial mechanisms related to MHP in Switzerland

With these mechanisms there are three main revenue options for a MHP plant:

A. Feed-in tariff

B. Free market price + Labelling

C. Free market price

Regulatory framework and other mechanisms

Firstly, there is **technical regulation** such as the minimum instream flow which needs to be guaranteed downstream of the water intake. This regulation is a national state level. Secondly, as mentioned above, the **regulatory framework** varies between cantons. Project phases are different, procedures with the authorities are different, and there are even differences between communes[21]. Promoters of MHP projects are unable to standardise their procedures between cantons and have to build up their network and local knowledge for each new area they work in. This increases their transaction costs. The costs for the pre-feasibility study, feasibility study, project design and partnership building are higher for MHP than for larger hydropower in relation to the whole investment.

Since 1991 the Swiss government has had ongoing **facilitation programs** for RES from which MHP has benefited (PACER, DIANE[22][23]). These will continue until 2020. The most recent is "EnergieSchweiz nach 2010"[24].

At a national institutional level, **quota** for RES could be introduced (as prepared in the Energy Law[25]). This will be the case if the other mechanisms (e.g. feed-in tariff) are not enough to reach the governmental goals on RES facilitation and climate change.

Furthermore, in the post-Kyoto context, MHP could generate **CO_2-credits** and become part of the Swiss Emission Trading System (ETS). The increase of electricity production from RES will not fill the coming electricity gap in Switzerland and electricity producers, alongside better energy efficiency and frugalness,

[21] SFOE, 2004.
[22] Chenal, Vuillerat et al., 1995.
[23] Hintermann, 1994.
[24] EnergieSchweiz, 2008.
[25] Energy Law 2009, Art. 7b.

will need to increase their production through the increased use of large power plants, including combined cycle gas thermal plants[26]. These plants are only politically and economically feasible if adequate ecological provisions, such as CO_2-compensation, are taken into account.

3.4 Strengths and weaknesses

The main strengths of MHP in Switzerland are:

- MHP is a mature technology with a very high efficiency (82-90%);
- MHP is a renewable energy (no fossil fuel, no CO_2-emissions);
- the environmental impact is limited;
- MHP can be integrated in multipurpose infrastructure.

Whereas the main weaknesses of MHP in Switzerland are:

- the electricity production significantly dependents on hydrology;
- there are higher production costs (compared to conventional generation of electricity with thermal plants);
- there is still considerable environmental opposition.

Feed-in tariffs, labelling and CO_2-credits could prove beneficial to MHP and the changes within the liberalisation of the electricity sector could also be an opportunity for MHP. However, there are also threats from climate change (disrupting water supply and modifying hydrology) as well as the attention (financial and political) given to other renewable energies such as solar and wind power.

[26] ECG, 2009.

4. Analysis of the coherence between the institutions and the technology

4.1 Liberalisation process within the electricity sector and economic performance

The aim behind the liberalisation process is to increase the economic and systemic efficiency as well as the quality of the service. Due to this process, the institutional framework has changed from a public utility-oriented system towards a market-oriented system even though electricity is still seen as a public service. The technological side however has changed much less. In order to make the facilitation of RES within the liberalisation a success, some further institutional changes might be necessary.

In the electricity sector the introduced competition is at the production, access and sale levels. Transport and distribution remain monopolies and are strictly regulated. MHP as RES has to compete at the production level with the other energy sources. The liberalisation process is pointing in the direction of the development of decentralized and small-scale power production, which requires less investment and is perceived as being less risky[27]. MHP is one technology to assure such production.

From an institutional perspective liberalisation leads to the unbundling of the vertically integrated electricity sector. The changes occur within level 2 and 3 of the four level model of Williamson (Figure 3). On the technological side, changes must happen on corresponding levels of Künneke's model (Figure 4) to ensure the coherence in the electricity sector. MHP as a decentralized production alternative is aligned with the aim of increasing the degree of coherence and the overall performance of the electricity sector within the institutional changes of the liberalisation.

Williamson's model is based on different approaches in the field of social science[28]. It distinguishes four levels of analysis of institutions and is based on two main criteria: first, the level of analysis and second, the frequencies and purpose of change of institutions. Both of these criteria are qualitative and aim to highlight only some general differences.

[27] Künneke, 2008, p. 235.
[28] Williamson, 1998.

Künnecke developed a similar model from a technological perspective[29]. Technological paradigms are long-term waves of technological practices (e.g. currently ICT and biotechnology). Technological trajectories deal with the understanding of the features of specific technical systems that serve certain needs[30]. According to Nelson and Sampat the notion of "routine" refers to "*a collection of procedures which, taken together, result in a predictable and specifiable outcome*"[31]. The "routines" deal with the optimization of scale and scope of a given technology. The last level of the model refers to the day-to-day management of systems components.

[29] Künneke, 2008.
[30] Dosi, 1982.
[31] 2001, p. 42.

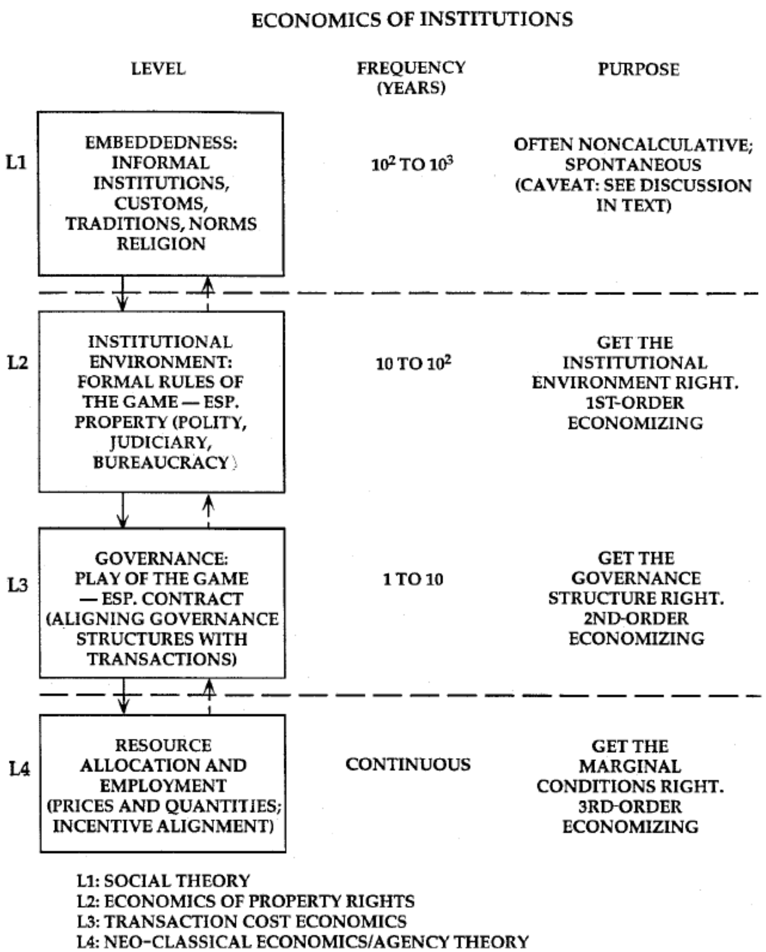

Figure 3: The four level model of Williamson (1998)

Level	Economics of technological practice	Frequency of change (years)	Purpose
1	*Technological paradigm*	> 100	Often non-calculative and spontaneous
2	*Technological trajectory*	10–100	First-order economizing: development of coherent and efficient technological systems
3	*Routines*	1–10	Second-order economizing: Optimization[25] of individual technical components
4	*Operation and management*	Continuous	Actual operational management

Figure 4: The four level model of Künnecke (2008)

In the case of MHP, it is not the technology which has to adapt so much but the institutions (again on level 2 and 3 of Williamson's and Künneke's models). This in turn will increase the economic potential and thus the economic performance of MHP (Section 2). The economic, enlarged economic and "socio-acceptance" potential of MHP is represented on the following figure.

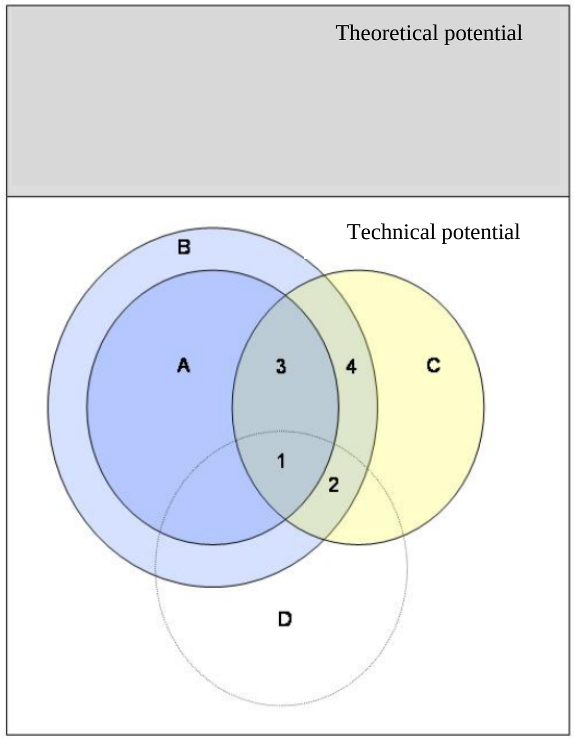

Figure 5: The different potentials[32]

The theoretical potential of a given technology (in our case MHP) is represented by the main rectangle. Part of the theoretical potential is technically feasible, therefore leading to the technical potential (white rectangle). Within the technical potential 4 further potentials emerge. Circle A represents the economic potential in a given context. B is the enlarged economic potential (e.g. economic potential created by specific measures to facilitate the chosen technology). C is the ecological potential (e.g. what is ecological acceptable) and D is the "socio-acceptance" potential which is a more fluid concept. The overlapping of these 4 potentials within the technical potential lead to the usable potential (1, 2, 3 and 4) and finally to the expected potential (1 and 2). To increase the economic performance the aim is to increase potential A and B, as well as D. D includes institutional and political aspects, whereas A includes only economic mechanisms (e.g. CO_2-tax for fossil energy which would increase the economic potential of MHP as RES). The increase of B includes specific economic mechanisms linked to MHP such as the feed-in tariff for RES. (See Appendix 2 for more details on the potential's definition.)

The conceptual framework of section 2 will lead to align changes between the technology and the institutions and thus increase the potential A, B and D. Therefore the overall performance of MHP will be increased.

4.2 Increasing the degree of coherence by changing institutions

Increasing the degree of coherence between institutions and technology in the case of MHP, and therefore increasing the MHP performance, leads to a closer look at the following mechanisms. The innovation aspect currently focuses more on institutions, even though the technology can develop further (e.g. increase the environmental integration, increase lifetime of turbine, better part-flow / variable speed turbines, …). The institutional framework must evolve further to facilitate the mature MHP technology. Overall, a more coherent approach from the institutional perspective is required (interlinking mechanisms, streamlining of facilitation, balance between hydropower and ecology, etc.).

Feed-in tariff

The Swiss government wants to significantly increase the amount of RES within electricity production (see Section 1). In 2009 a feed-in tariff for renewable energies was introduced as a step towards the facilitation of RES. It has certain provisions lacking in the case of MHP[33]. It is not well adapted to either low head schemes or continually maintained and rehabilitated plants. In addition, the administrative procedure costs, especially around the required certification, are, in relative terms, significant for MHP projects as they are small-scale projects. There is no longer any funding available for these feed-in tariffs (see Table 2) and new ways of financing it are required. It is also worth noting that if a MHP plant receives the feed-in tariff, it cannot receive additional revenue through labelling (see below).

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[32] Piot, 2006.
[33] Leutwiler, 2008.

Solution statements:

- **Financing**: The regulation of feed-in tariffs enables an increase in income of up to 0.6 cts per consumed kWh (currently 0.45 cts/kWh). Instead of increasing this amount, the feed-in tariff could also be funded through a CO_2-tax perceived on fossil energy for electricity generation (e.g. planned gas plant in Switzerland) or fossil fuel. This would favour the introduction of more hybrids and electrical cars. The CO_2-tax would encourage a move away from fossil fuel and facilitate RES for the electricity production required for these cars.

- **Adapt the feed-in tariff for well maintained and rehabilitated MHP plants and low-head schemes**: The rehabilitation of existing plants should be encouraged even if the plants were only just financially viable before the introduction of the feed-in tariff. Further optimisation of these plants is favourable because the CO_2-emissions and the grey energy consumption (all the energy to produce a good - production, transport, storage) are significantly reduced. Low head MHP schemes represent most of the remaining potential and their facilitation must be part of the design of the feed-in tariff.

- **Application quality**: Many projects allocated to receive the feed-in tariff will never be built for ecological and local reasons. It is therefore important to allocate their tariff to feasible projects as soon as possible. A Swiss engineering office is currently developing a tool to help decision-makers to assess a project before granting it the feed-in tariff.

- **Application procedure**: Procedural costs should be decreased in the case of MHP and other small-scale projects. This point is discussed below.

An additional idea is introducing a **modular tariff**. This is a type of feed-in tariff which allocates a high financial value to the first kWh followed by decreasing financial values to the kWh produced afterwards. This offers more financial security due to the ability to better take into account the hydrological uncertainty of the overall production.

Further, the feed-in tariff could be adapted to promote production during **peak hours**. The government wants to guarantee the supply in electricity, even during peak demand periods. Hydropower can adapt very quickly and easily to an increase in electricity demand. The feed-in tariff could offer more remuneration for kWh produced during peak hours. This would enable additional investment in the design and construction of the plant to add the storage capacity and, if technical and ecological feasible, the pump capacity as well.

Green electricity market

Another mechanism to facilitate RES is the creation of a green electricity market which is not linked to the labelling mentioned below. If the feed-in tariff is unable to fund all remaining technical and ecological feasible projects, other mechanisms need to be implemented. A green electricity market could be at a national level and linked with other European countries. It would also contribute to high ecological standards.

Solution statements:

> A green certificate actually represents the “greenness” of a unit of RES production. This divides the unit into two parts: the physical electricity and its associated “greenness”. These can be traded in two different markets: the conventional physical electricity markets and a market for the Tradable Green Certificates (TGC)[34]. Generated TGC with MHP could contribute to facilitate the technology. TGC could be traded with companies in countries where there is a required quota of RES production and when such companies do not fulfil their quota target.

Labelling and greening

A key issue around MHP is the balance between water protection and hydropower. Politically, the government and the cantons want to increase hydropower, but the ecological aspects need to be taken into consideration as well. Ecological NGO’s and environmental offices within administration take care of the latter.

Solution statements:

> One solution statement is labelling. MHP plants only get an ecological label if they fulfil ecological standards. The existing label “Naturemade” for hydropower is unfortunately linked

with very high transaction costs. In addition, the ecological standards might have to be slightly adapted for MHP plants as they are not simply a reduction in scale of large hydropower plants. If that is not possible, a new label could be introduced (maybe a quality label as described below). Labelling could be combined with greening of existing rivers. The revitalisation and renaturalisation of the river (up- or downstream) could balance out the benefit-damage assessment of a MHP plant. The additional revenue through selling labelled electricity to customers who want specifically hydropower or renewable energy would finance that process.

"maxEnergy"

Today's incentive mechanisms have an upper limit concerning the installed capacity (e.g. 1 or 10 MW). This can lead to the design of smaller plants which receive incentives instead of designing one or several bigger plants which are technical and ecological the optimal solution for a given site.

Solution statements:

Introduce a quality label such as minEnergy for buildings[35]. Called maxEnergy, it would be given to the plant with the optimal technical and ecological solution that uses the maximum available energy for a given head and flow, while respecting environmental constrains. It would be an incentive for the optimal environmental integration and in favour of a high load-factor. maxEnergy could be linked with feed-in tariffs or other financial mechanisms.

Such as label could be used as a label for local production as well. Decentralized and local electricity generation increases the grid stability and decreases energy lost on transport of the energy.

CO_2-credits

As stated in Section 3.3 it is very likely that combined gas thermal plants will be built in Switzerland to cover electricity demand. These plants will require adequate ecological provisions, such as CO_2-compensation.

---

[34] Mitchell and Anderson, 2000.
[35] http://www.minergie.ch/

The current compensation scheme does not allow use of RES, except biomass, for CO_2-compensation[36]. But CO_2-credits generated by other RES would make these RES technologies financially more interesting and contribute to increase the electricity amount from renewable and sustainable sources. New MHP and SHP plants could compensate 100% of a 400 MW gas thermal plant.

Solution statements:

> As no thermal plant will be operational before 2013, it is important to wait for the Copenhagen conference in December 2009 to know more about the post-Kyoto framework.
>
> MHP and other RES could be facilitated by generating CO_2-credits which could be traded on the national Emission Trading Scheme (ETS) or, if Switzerland joins the EU ETS, on the European trading scheme. This would contribute to a technological shift from fossil fuel to RES. One of the four main discussion points in Copenhagen is the technology transfer. MHP as a technology for developing countries could be facilitated by generating CO_2-credits (currently under the Clean Development Mechanisms). Here again, transaction costs, mainly procedures costs, should be reduced by streamlining procedures.
>
> Instead of ETS, a CO_2-tax on fossil fuel could be implemented. With its revenue, feed-in tariffs or other financial mechanisms could be financed.

Water rental to tax resource

The water rental is a tax on the installed capacity of a hydropower plant and not a tax on the actual amount of water used.

Solution statements:

> If the government wants to tax the use of water for producing electricity, it should put a tax on the water use and therefore the produced kWh[37]. Currently, the Swiss water rental is for plants with a capacity above 1 MW. To reflect real costs this should be applied to any hydropower plant (including an opposite pollution factor for thermal plants).

[36] FOEN, 2008.

Subsidies

Certain external costs like GHG emissions are currently not taken into account in the electricity generation. If the involved institutions want to reflect the real price of electricity generation, additional mechanisms internalizing external costs need to be implemented such as a specific subsidy for RES.

Solution statements:

> An overall cost-benefit analysis should be done taking into account the parameters of pollution, the grey energy and social impact such as local employment. This would show that MHP is competitive with other energy sources and based on this analysis the amount of required subsidy could be defined. The funding of the subsidy could come from a tax on pollution factors and grey energy factors (a standard method to correct for an externality is to impose a (linear) tax at the rate of marginal external damages on the use of the entity responsible for the externality.).

"No-use revenue"

The environmental organisations are an important social power. They would like to maintain rivers in the natural state. At the same time, electricity production has to increase. More "in-between solutions" need to be found.

Solution statements:

> The following ideas aim to give incentives to MHP to not-use or partly use the water resource in a technically feasible site.
>
> Firstly, design the MHP plant in a way that does not use the water resource in a technically optimal way allowing more water to be released downstream of the water intake than required by law. A bigger instream flow should receive an ecological label and therefore increase the revenue from labelled electricity. This would then compensate for the reduced production of kWh.

---

[37] Plaz and Hanser, 2008, Ch. 4.4.

The second idea is the no-use of a site. Instead of building a MHP plant at a technically feasible site, the river remains the same. The no-use of a site could be financed by the greening requirement of another site (see above). It should be integrated in a spatial planning approach of a region. For example, a valley keeps its river in a natural shape which is more attractive to tourists and can generate other revenues; the other valley uses its river to the fullest for hydropower production. Both valleys agree on a common partnership. This idea is based on the Swiss "landscape cents"[38]. The tourists would have a valley with a natural river and could consume RES electricity from the MHP plant in the neighbouring valley.

Quota

The Swiss energy law contains the possibility of the introduction of a quota for RES within electricity production (see Section 3.3). If other mechanisms do not lead to the set policy goals, such quota could be introduced from 2016.

Solution statements:

Introduce quota as complimentary to the other financial mechanisms.

Investment pool

In line with the facilitation of MHP and "green new deal" ideas, the access to capital has to be facilitated. Most Swiss banks are not currently interested in MHP projects as interest rates are too low. The facilitation of MHP does not only require mechanisms to generate enough revenue, but also the investment capital to fund it.

Solution statements:

The aim must be to increase the confidence of investors. This can be done by guaranteeing a stable institutional framework for MHP (see "streamlining of procedures") and a stable situation over many years for the generation of the revenue (see points above). Once this is given, the facilitation of investment could be reached by creating an investment pool for MHP projects based on micro-credits principles – just with bigger amounts. The government could

[38] http://www.parlament.ch/D/Suche/Seiten/geschaefte.aspx?gesch_id=20083699

play the role of a facilitator by starting to invest in such a pool. If possible, such a pool could even try to become part of the national stock exchange. To a certain extent, local capital should also contribute to finance MHP projects increasing the local ownership.

Standardisation and streamlining of procedures

As mentioned above, the facilitation of MHP requires stable mechanisms in time and space. The time scale is provided by a stable institutional framework in the case of Switzerland. However, the stability from a space perspective is not provided as each canton has different laws, regulation, concession rights, financial incentives, offices, et al. concerning MHP. There can even be differences between communes within a canton. This makes the national facilitation of MHP and RES in general more complicated and is typical for a federal state such as Switzerland.

<u>Solution statements:</u>

A greater level of standardisation and streamlining of procedures would reduce transaction costs. This involves, for example, a harmonisation between canton regulations and project phases (e.g. merge application for concession and construction). It would reduce the procedural costs which are, in relative terms, significant for small-scale projects. The regulatory framework would therefore become more coherent nationwide.

The number of actors and organisations for a MHP project should be as low as possible. The smaller the number of actors and organisations, the smaller are the transaction costs and potential communication misunderstandings.

A further option to reduce transaction costs is to deal only with group projects (e.g. within the same riverine zone) and not with single projects. This would increase the regional grid stability as a certain minimum electricity generation could be guaranteed from a group of projects. If required, certain projects could include storage facilities to be able to contribute to the balancing energy for the network.

Another idea is to complete all administrative procedures in an online E-project with a single web interface. This could contain different sections including feed-in tariff application (State level), subsidies provided by public authorities (federal level), concession rights (cantonal and commune level), etc. Each canton could have its own website whilst still using the same user interface as the other cantons. The different institutions in each canton could be assigned to the corresponding sections and the website used for monitoring and controlling as well. Lastly, the certification procedure for TGC, labels or CO_2-credits could be included within this E-project. As a result, MHP procedure would be unified and transaction costs significantly reduced.

Minimum instream flow

The law requires a minimum instream flow downstream of the water intake for environmental reasons[39]. At present it is a constant value, but could be adapted to increase electricity production revenue and still be environmentally sensitive.

Solution statements:

Use a dynamic minimum instream flow with fluctuation on a daily and / or seasonal basis.

A seasonal dynamic would take into account certain periods of the year when more water should be released into the stream, and during other months this water could be used for power generation.

Daily dynamic could be linked with producing energy for peak demand periods. More water would be released into the river to compensate for more electricity production during peak hours which results in generating the same revenue (less kWh produced, but sold for a higher price).

The above mechanisms are often interlinked. Therefore a multi-criteria approach is required between the economic, political, institutional, environmental and technical aspects. The institutional actors behind each mechanism are the following.

[39] Gewässerschutzgesetz, 1991, Art 31

Institutional actor	**Mechanisms**
State (national government and parliament)	- Feed-in tariff - Tradable green certificates - CO_2-credits - Subsidies - Quota - Standardisation and streamlining of procedures - Minimum instream flow
Cantons (cantonal government and parliament)	- Subsidies - Standardisation and streamlining of procedures
Communes	- Standardisation and streamlining of procedures
Private sector at national level	- Labelling - “maxEnergy” label - “no-use” revenue - Investment pool

Table 3: Institutional actors behind the mechanisms

The next table summarises the mechanisms that exclude each other or that can be interlinked. The most likely mechanisms to change or to be adapted are: feed-in tariff, labelling / “maxEnergy” label, CO_2-credits, subsidies, and standardisation and streamlining of procedures. The overall aim is to develop a more coherent overall approach towards these mechanisms to facilitate MHP from an institutional perspective.

	Feed-in tariff	Tradable Green Certificates	Labelling (ecological)	"maxEnergy" label	CO_2-credits	Water rental	Subsidies	"no-use" revenue	Quota	Investment pool	Standardisation and streamlining of procedures	Minimum instream flow
Feed-in tariff	(black)	(red)	(red)	(yellow)	(red)			(red)				
Tradable Green Certificates	(red)	(black)	(red)	(yellow)				(red)				
Labelling (ecological)	(red)	(red)	(black)	(red)				(red)				(yellow)
"maxEnergy" label	(yellow)	(yellow)	(red)	(black)			(yellow)	(red)				(yellow)
CO_2-credits	(red)				(black)			(red)				
Water rental						(black)		(red)				
Subsidies				(yellow)			(black)					(yellow)
"no-use" revenue	(red)	(red)	(red)	(red)	(red)	(red)		(black)				
Quota									(black)			
Investment pool										(black)		
Standardisation and streamlining of procedures											(black)	
Minimum instream flow			(yellow)	(yellow)			(yellow)					(black)

Table 4: Overview of mechanisms in Switzerland: mechanisms excluding each other (red) and interlinked mechanisms (yellow)

4.3 Infrastructure dynamics and regulation

This paper has discussed a current view of the coherence between institutions and technology in the case of MHP. It has been shown that changes and innovation have to occur mainly at the institutional level. A dynamic view includes discussions on the maintenance and increase of the degree of coherence over time.

The implicit objective of regulatory economics (i.e. static efficiency, consumer protection) conflicts often with other objectives such as dynamic systemic efficiency, social and political objectives (public service, security of supply), and technical objectives (resilience, robustness)[40]. It is therefore important to have a multi-criteria approach, not only economic, to the different mechanisms and institutional changes.

From an economic regulation perspective, the markets need to be sustained and not simply created (e.g. market for RES in the case of MHP). The political regulation must deal with the universal service regulation (consumer protection) and the security of supply. In the case of MHP the whole electricity regulation must guarantee that the domestic electricity demand can be covered either by domestic production or imported electricity. The technical regulation concerns the aspects of interoperability, interconnection, safety, capacity management and system management[41]. In the case of MHP the two latter are of importance. MHP has to contribute to the required domestic production and contribute to the grid stability which is the case as decentralized production units. The infrastructure dynamic within the electricity sector could lead to even more decentralized production wherever technically and ecologically feasible, leading to many independent plants, or to a more centralized approach where several plants are bundled together to form a group (sometimes refer as “virtual plant”). The group interacts then with the network.

Using the following model of Finger[42], the infrastructure dynamic of the electricity sector from a technology perspective went from an integrated system through the unbundling to a distributed system. MHP is an example of distributed and decentralized production. The question arises if for coherence matters the institutions have to move even more into the direction of governance and decentralized decision-making in the MHP case (move in the same direction as technology), or if certain institutional mechanisms need to be at a centralized and governmental level (move in the opposite direction). The latter would lead to a decrease in the coherence within the framework of Figure 1. There may be cases where more incoherence actually increases the performance of the system. This will be subject of further research.

[40] Finger, 2009.
[41] ditto
[42] ditto

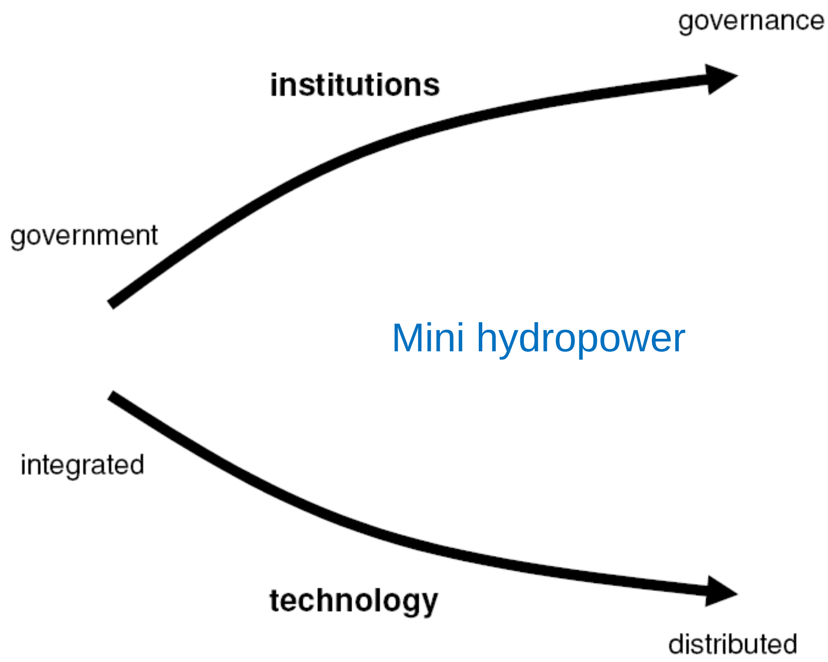

Figure 6: Conceptualizing infrastructure dynamics (Finger, 2009): mini hydropower

5. Conclusion and recommendations for further research

The MHP technology is small-scale, decentralized and mature, and requires adequate institutional frameworks to maximize its remaining potential under economically viable conditions. Taking into account the current liberalisation of the electricity market, the government's goal to increase the weight of renewable energy sources and the post-Kyoto context, further evolution of the institutions is required. This can lead to adapted or new institutional mechanisms as described in Section 4.2. The degree of coherence between institutions and the technology has to increase and as a result the economical performance of MHP will increase.

MHP still has considerable unused technical potential. The current key issues around its facilitation are focused on financing MHP and the right balance between hydropower and environmental protection, as well as reducing the transaction costs linked to procedures, which are, in relative terms, significant for small scale projects. This involves, for example, a harmonisation between cantons and project phases in the Swiss case. The environmental considerations can be linked to the greening of rivers combined with MHP development. CO_2-compensation for planned thermal power plants, in the form of CO_2-taxes or emission trading systems (ETS), could become a mechanism to partly finance MHP. Compared to other RES, MHP should be developed at least as long as the production costs are lower than other RES. MHP has a higher energy payback ratio than other RES (see Section 3.2) and should therefore be pushed even more within the facilitation of RES.

As the electricity sector in its entirety has many complementarities between the technology and economic, political, environmental and societal aspects, the research on the degree of coherence between institutions and the technology must be a multi-criteria approach. Further research will need to focus on the infrastructure dynamics to assess if institutions need to become even more decentralized and on the governance level, or more centralized and on the government level. This includes research on further development of the conceptual framework to make it more quantitative allowing it to be used to measure and compare institutions and technology, and therefore able to quantify the optimal level of coherence. This will lead to recommendations for infrastructure policy around MHP.

Further research will also have to continue to focus on the development of facilitation mechanisms. Such mechanisms can be “command & control” ones (e.g. standards, quotas), marked-based (e.g. feed-in tariff, taxes, tradable permits) or others (e.g. labelling). The mechanisms must be cost-effective, transparent and support the dynamic efficiency. In addition, the regulatory framework needs to be studied more in depth for generating recommendations on the standardization and streamlining of procedures. Based on the outcomes concerning the mechanisms and procedures, recommendations could be given concerning which institutions and concrete organisation need to evolve and innovate.

The aim of further research will be to continue to develop policy shaping institutional mechanisms (including financial mechanism) to facilitate mini hydropower in Switzerland – mechanisms that could be adapted to other countries. The overall objective is to increase the amount of electricity produced by MHP by changing the institutional framework.

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7. Appendix

List:

Appendix 1: MHP statistics 2009

Appendix 2: Potential definitions

7.1 MHP statistics 2008

Datenblatt alle Wasserkraftwerke in der Schweiz

Historische Entwicklung:

(Quelle: Kleinwasserkraftwerke in der Schweiz, Teil III, Bundesamt für Wasserwirtschaft, 1987

Bereich (kW)	1.1.1914 [0)]		1.1.1947 [0)]		1.1.1973 [3)]		1.1.1985 [4)]	
(installierte el. Leistung)	Anzahl	MW [6)]	Anzahl	MW	Anzahl	MW	Anzahl	MW [7)]
bis 300 [1)]	**≈ 6'700**	**85**	**≈ 5'700**	**85**	**≈ 1'900**	**50**	**≈ 700**	**46**
301 bis 1000 [2)]	87	46	116	68	126	72	127	74
1'001 bis 2'000	23	33	37	55	57	86	55	84
2'001 bis 10'000	44	196	65	352	82	432	92	466
TOTAL bis 10'000	6'846	360	5'930	560	2'140	640	980	670
über 10'001 [(3)]	14	290	65	2'300	163	10'040	171	11'780
TOTAL Wasserkraft	≈ 6'860	650	≈ 6'000	2'860	≈ 2'300	10'680	≈ 1'150	12'450

[0)] inkl. nicht Stromproduzierende (mechanische) Anlagen
[2)] 1914 bis 1947: Leistungsbereich 330 bis 500 kW
[4)] ausschliesslich Strom produzierende Anlagen
[6)] 1 MW (Megawatt) = 1000 kW (Kilowatt)
[7)] installierte elektrische Leistung (Die effektive max. mögliche Leistung ab Generator weicht bis +/- 10 % davon ab.)

[1)] 1914 bis 1947: Leistungsbereich bis 330 kW
[3)] teilweise inkl. nichtstromproduzierende Anlagen
[5)] Zentrale als massgebendes Kriterium

Stromproduzierende Anlagen, Stand 1.1.08:

Bereich (kW)	**Anzahl**	**max. mögl. Leistung**	**Mittl. Produkt.-erwartung**	**Energieproduktion in Prozent der**	
	[1]	**MW**	**GWh / Jahr**	**Wasserkraft**	**Stromprodukt.**
bis 300 (Grobschätzung *)	***700***	***56***	***250***	***0.7%***	***0.4%***
301 bis 500	88	34	172	0.5%	0.3%
501 bis 1'000	83	63	338	1.0%	0.5%
1'001 bis 2'000	66	96	466	1.3%	0.7%
2'000 bis 10'000	106	545	2'259	6.4%	3.5%
über 10'001	167	12'538	31'744	90.1%	48.8%
TOTAL KWK bis 10 MW	**1'043**	**794**	**3'485**	**9.9%**	**5.4%**
TOTAL Wasserkraft	**1'210**	**13'332**	**35'229**	**100.0%**	**54.2%**
TOTAL Stromproduktion (Mittelwert)			**65'000**	(nicht mittlere Produktionserwartung)	

[7)] mittlere jährliche Produktionserwartung Jahresproduktion in Gigawattstunden (1 GWh = 1 Million Kilowattstunden)

Quellen: - bis 300 kW: ISKB
- über 300 kW: Bundesamt für Wasser und Geologie (BWG)

***)** Vorbehalt: Die Zahlen bezüglich Kleinst-Kraftwerke unter 300 kW beruhen auf gründlichen Erhebungen des Zuwachses seit 1.1.85 (obere Tabelle) und einer sehr groben der Stillegungen seither, über welche es keine statistischen Angaben gibt. Da in der Mehrzahl nur kleinste Kraftwerke stillgelegt wurden, gilt die Anzahl Kraftwerke nur als Grössenordnung, sind jedoch die Angaben über Leistung und Produktion jedoch etwas genauer.

7.2 Potential definitions

5. Exkurs: Potenzialbegriffe

Michel Piot, Bundesamt für Energie **Oktober 2006**

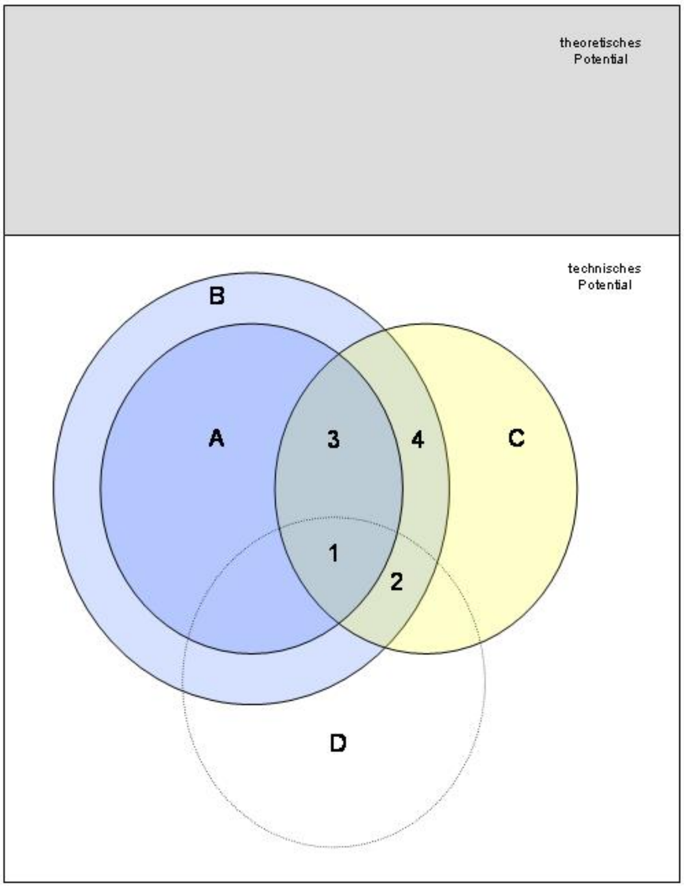
In diesem Exkurs werden Definitionen zu den einzelnen Potenzialen bereitgestellt, um in den nachfolgenden Exkursen eine einheitliche Begriffsverwendung zu garantieren. Der Exkurs ist kurz gehalten. Für weitere Details wird auf [2] verwiesen.

Inhalt

1 Potenzialdefinitionen

Die nachfolgenden Definitionen mit den entsprechenden Buchstaben und Zahlen nehmen Bezug auf Figur 1.

Figur 1: **Potenzialbegriffe in graphischer Darstellung.** Die Grossbuchstaben beziehen sich auf den vollen Kreis, die Zahlen nur auf die entsprechenden Teilflächen. Abkürzungen: A: wirtschaftliches Potenzial (P), B: erweitert wirtschaftliches P., C: ökologisches P., D: soziales Akzeptanz-Potenzial.



1.1 Theoretisches Potenzial

Definition: Das theoretische Potenzial einer erneuerbaren Energie beschreibt das innerhalb einer gegebenen Region zu einem bestimmten Zeitpunkt beziehungsweise innerhalb eines bestimmten Zeitraumes theoretisch physikalisch nutzbare Energieangebot. Quelle: [1].

Bei erneuerbaren Energien handelt es sich meist um jährlich stark fluktuierende Grössen. Daher bezieht sich das theoretische Potenzial im Allgemeinen auf ein langjähriges Mittel des Energieangebots.

1.2 Technisches Potenzial

Definition: Das technische Potenzial ist der Anteil des theoretischen Potenzials, der unter Berücksichtigung der gegebenen technischen Restriktionen nutzbar ist.

1.3 Ökologisches Potenzial (C)

Definition: Das ökologische Potenzial (C) ist der Anteil des technischen Potenzials, der zu keiner zusätzlichen permanenten (das heisst irreversiblen) Beeinträchtigung des Lebensraumes in Bezug auf Diversität und Wechselwirkungen sowohl zwischen den Lebewesen als auch zwischen Lebewesen und ihrer Umwelt führt. Quelle: [3].

Was „ökologisch“ ist, lässt einen Interpretationsspielraum offen. Aus obiger Definition geht hervor, dass der heutige Zustand als Referenzzustand betrachtet wird. Dies mag auf Anhieb nicht befriedigen, doch handelt es sich bei diesem Zustand um einen willkürlich gewählten Referenzpunkt, der mit entsprechenden gesetzlichen Anforderungen an den Umweltschutz verschoben werden kann. Im weiteren ist es wichtig darauf hinzuweisen, dass Ökologie gemäss obiger Definition a priori keine landschaftsästhetischen Aspekte berücksichtigt.

1.4 Wirtschaftliches (A) und erweitert wirtschaftliches (B) Potenzial

Aus ökonomischer Sicht ist eine Unterscheidung zwischen erweitert wirtschaftlichem und wirtschaftlichem Potenzial sinnvoll. Unter „erweitert wirtschaftlich“ kann auch gesamtwirtschaftlich, und unter „wirtschaftlich“ auch betriebswirtschaftlich – oder einzelwirtschaftlich – verstanden werden. Um diese Unterscheidung zu berücksichtigen werden folgende Definitionen verwendet:

Definition: Das wirtschaftliche Potenzial (A) ist der Anteil des technischen Potenzials, den man erhält, wenn die Gesamtkosten (Investition, Betrieb und Entsorgung einer Anlage) für die Energieumwandlung einer erneuerbaren Energiequelle berechnet und in der gleichen Bandbreite liegen wie die Gesamtkosten konkurrierender Systeme.

Das wirtschaftliche Potenzial berücksichtigt keine Fördermassnahmen für die Energieerzeugung aber solche, die aus anderen Gründen gewährt werden. Eine CO_2-Abgabe auf fossilen Brennstoffen führt zwar zu höheren Gesamtkosten konkurrierender Systeme, hat aber nichts mit einer Fördermassnahme zu tun. Trotzdem wird dadurch aber das wirtschaftliche Potenzial der erneuerbaren Energiequelle vergrössert.

Definition: Das erweitert wirtschaftliche Potenzial (B) ist der Anteil des technischen Potenzials, den man erhält, wenn die Gesamtkosten (Investition, Betrieb und Entsorgung einer Anlage) unter Einbezug möglicher Förderungen für die Energieumwandlung einer erneuerbaren Energiequelle berechnet und in der gleichen Bandbreite liegen wie die Gesamtkosten konkurrierender Systeme.

Gegenüber dem wirtschaftlichen Potenzial ergibt sich dieses Potenzial aus der Konkurrenzfähigkeit der gewinnbaren Energie unter zusätzlichem Einbezug von aus energiepolitischen Gründen vollzogenen Fördermassnahmen. Beispiel solcher Fördermassnahmen sind:

- Beiträge, die unabhängige Produzenten von erneuerbaren Anlagen gemäss Energiegesetz Art. 7 erhalten;
- Anlagen, die eine kostendeckende Einspeisevergütung erhalten;
- Beiträge, die für erneuerbare Energien aus der Vermarktung an Ökostrom-Börsen gelöst werden können.

Die Bestimmung des wirtschaftlichen und erweitert wirtschaftlichen Potenzials ist stark von Annahmen und schwankenden Einflussparametern abhängig. Einerseits spielen Grössen wie Zinssatz, Abschreibungsdauer und prognostizierte Lebensdauer einer Anlage eine wichtige Rolle, andererseits aber auch der Preis für fossile Energieträger.

Nun werden noch einzelne Schnittmengen der Figur 1 definiert.

1.5 Ausschöpfbares Potenzial

Definition: Als ausschöpfbares Potenzial wird die Schnittmenge des ökologischen und erweitert wirtschaftlichen Potenzials definiert, was der Vereinigung der Flächen 1, 2, 3 und 4 entspricht.

In der Regel wird allerdings nicht das ganze ausschöpfbare Potenzial realisiert, da eine weitere, äusserst subjektive Komponente in die Betrachtung einfliesst, die nachfolgend als das soziale Akzeptanz-Potenzial (Figur 1: Kreis D) bezeichnet wird. Was sozial akzeptabel ist, ist ebenfalls interpretationsbedürftig. Dieses Potenzial berücksichtigt unter anderem, dass ein Projekt aus landschaftsästhetischen Gründen nicht realisiert wird, obschon es unter Umständen im ökologischen und wirtschaftlichen Potenzial enthalten wäre.

1.6 Erwartetes Potenzial

Definition: Als erwartetes Potenzial wird die Schnittmenge des ökologischen, des erweitert wirtschaftlichen und des sozialen Akzeptanz-Potenzials definiert, was der Vereinigung der Flächen 1 und 2 entspricht.

Das erwartete Potenzial kann auch als realisierbares Potenzial bezeichnet werden. Auf Anhieb entsteht der Eindruck, dass die Fläche 1, also die Schnittmenge des ökologischen und wirtschaftlichen Potenzials, das auch sozial akzeptiert ist, bereits vollständig verwirklicht sein sollte, da Investoren ein Interesse an der Realisierung der entsprechenden Projekte haben sollten. Dass dem nicht notwendigerweise so ist, kann verschiedene Gründe haben:

- Die Ausschöpfung der Potenziale ist ein träger Vorgang, das heisst, dass potentielle Investoren Strategien haben können, die sich nicht mit dem entsprechenden Ausbau vereinbaren lassen oder sie berücksichtigen Projekte (unter Umständen im Ausland) die einen höheren Return-on-invest generieren, so dass die Prioriätensetzung anders ist.
- Sowohl das wirtschaftliche als auch das soziale Akzeptanz-Potenzial sind zeitabhängig. Da Bauten im Energiesektor mit langen Investitionszyklen verbunden sind, muss eine Investition über lange Zeit wirtschaftlich sein, damit sie auch umgesetzt wird. Ist die Planungs- und damit Investitionssicherheit als Folge von unsicheren politischen Rahmenbedingungen (soziale Akzeptanz, Steuern) und wirtschaftlichen Unsicherheiten (Preisentwicklung der fossilen Brennstoffe, Änderung der Förderungsbeiträge) zu gross, wird möglicherweise auf ein Projekt verzichtet, auch wenn es unter heutigen Bedingungen die Kriterien der Ökologie, Ökonomie und sozialen Aktzeptanz erfüllen würde.
- Das menschliche Verhalten unterliegt gewissen Wertvorstellungen, die unter rationaler Argumentation dem Prinzip der objektiven (systemischen) Nutzenmaximierung nicht notwendigerweise entsprechen müssen.

1.7 Ausbaupotenzial

Alle Potenziale können in bereits realisierte und nicht realisierte Potenziale unterteilt werden. Beim noch nicht realisierten Potenzial wird nachfolgend vom Ausbaupotenzial gesprochen. So ist zum Beispiel das theoretische Ausbaupotenzial die Differenz zwischen dem theoretischen Potenzial und dem bereits realisierten Potenzial und das erwartete Potenzial die Summe des bereits realisierten Potenzials und des erwarteten Ausbaupotenzials.

Definition: Das theoretische (technische, ökologische, wirtschaftliche, ausschöpfbare, erwartete) Ausbaupotenzial ist die Differenz zwischen dem theoretischen (technischen, ökologischen, wirtschaftlichen, ausschöpfbaren, erwarteten) Potenzial und dem bereits realisierten Potenzial

Im Zusammenhang mit der Frage nach den Möglichkeiten eines weiteren Ausbaus der in der Schweiz interessiert somit das Ausbaupotenzial.

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