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Hydropower Policy and Energy Saving Incentives

Pernille Parmer
Department of Economics, Norwegian University of Science and Technology

Department of Economics

Norwegian University of Science and Technology
N-7491 Trondheim, Norway
http://www.ntnu.edu/econ/working-papers

Hydropower Policy and Energy Saving Incentives*

Pernille Parmer†

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Abstract

Many Norwegian local governments are affected by hydropower production. A law passed in 1917 mandates that hydropower plants sell up to 10 percent of their power basis to local governments affected by the production. Historically, this concession power was meant to ensure the small rural local governments supply of electricity, in competition of the larger cities. Today, many local governments resell their concession power when prices are high and generate large revenues. However, the actual transferred concession power is restricted to general electricity consumption in the community. As a result, local governments with a positive gap between potential concession power and general electricity consumption have reduced incentives to save electricity. In other words, the concession power system has adverse effects on incentives for energy efficiency. In this study, a simple two-period model to study energy efficiency is developed, and the model's predictions are supported by empirical findings. The results underline how misspecified and outdated laws can reduce incentives for energy economizing projects.

Keywords: electricity consumption, energy efficiency incentives, public sector, hydropower, laws.

JEL: *D78, H11, H27, H71, Q2, Q4, Q5*

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†Norwegian University of Science and Technology, Department of Economics, Dragvoll, N-7491 Trondheim, Norway; E-mail: parmer@svt.ntnu.no

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1 Introduction

From the early stages of the development of the Norwegian hydropower sector at the beginning of the 20th century, there has been a consensus that the local districts that are affected by hydropower production are entitled to earn a share of the value created by the hydropower production. Thus, local governments earn rents from the hydropower production in the form of taxes and revenues from concession power. The Ministry of Petroleum and Energy (2012, p.70) raises the question as to whether the historically established wealth-distribution arrangements between local governments, developers, and affected districts is suitable for future renewable energy policy goals. With respect to present-day climate challenges, the Ministry of Petroleum and Energy (2012, p.70) also questions how the energy policy in Norway should be framed to maximize the utility of renewable resources and simultaneously consider national efficiency in energy consumption, (Ministry of Petroleum and Energy, 2012, p.49). This paper shows that the current hydropower energy policy may have adverse effects on incentives to reduce energy consumption in some Norwegian local governments. These mechanisms are illustrated in a dynamic model and supported by empirical findings.

According to the Industrial Licensing Act and the Watercourse Regulation Act, hydropower plants are mandated to sell up to 10 percent of their power basis to the local government affected the hydropower production, at a price that is equal to the costs of production. When the law was implemented in 1917, it served as security for the supply of electricity to local communities facing competition from large cities. Today, it serves as a redistribution system for local governments to participate in value creation in the hydropower sector. In addition, under certain restrictions, the local governments can extract the concession power to maximize profits. By extracting and reselling the power when prices are high, local governments can earn substantial profits. The local government's entitlement to concession power is, however, restricted to general electricity consumption in the local government. If the potential concession power is greater than general electricity consumption, the difference is "lost". Hence, the incentives to reduce energy consumption in local governments with a positive gap between potential concession power and general electricity consumption will be damaged. If the local government reduces its energy consumption through energy savings or efficiency, its general electricity consumption will go down. As a result, the difference between potential concession power and general electricity consumption will increase, which will again lead to a "loss" of concession power and the associated future revenues.

In addition, if a local governments has a positive gap between potential concession power and general electricity consumption, it will not be incentivized to lead as an example of energy efficiency, i.e., in reducing energy consumption. The ability to use energy resources efficiently is important for sustainable energy consumption in the long run. Improving efficiency and saving energy can also protect the environment and cut energy bills. However, for households and industry to engage in such measures, they must be informed and motivated. This is a public responsibility, and the national- and local public sector should lead as an example and take the initiative to invest in energy saving and efficiency in the public sector.

For example, Magnussen and Havskjold (2003) show how local government behavior can affect private households with respect to electricity consumption. They investigate how abnormal high electricity prices during the 2002/2003 winter affected electricity consumption in private households in local governments with and without concession power. This was carried out by conducting a case study that compared energy consumption in private households in six local governments in the western parts of Telemark county. The local governments were similar in population composition, but differed in the amount of their hydropower resources. Two of the local governments, Tokke and Vinje, were entitled to concession power, and the other four had no concession power. Concession power can be resold at a reduced price to inhabitants, and private households in Tokke and Vinje were thus offered electricity at a fixed reduced price from the local governments. As expected, they found a relatively small increase in electricity consumption compared to the winter of 2001/2002 over the districts. However, the increase was two percentage points higher in the two local governments with concession power than in the local governments with no concession power. The dataset included in this paper show that both Tokke and Vinje have a positive gap between potential concession power and general electricity consumption in 2012. Thus, by subsidizing households with cheap electricity, total electricity consumption in Tokke and Vinje is not affected by electricity price changes in the same manner (or to the same extent) as other local governments. Although my focus in this paper is on public sector electricity consumption, the Magnussen and Havskjold (2003) study shows that it is important to keep in mind that this subject is also relevant in the private sector.

Gillingham et al. (2009) performed a literature overview for how market failures can lead to inefficiently low levels of investment in energy efficiency. These authors also argue that empirical estimates in the literature indicate that energy utilization demonstrates a substantial degree of responsiveness to changes in energy prices, in addition to demonstrating adoption of – and innovation regarding – energy efficient technologies. Jessoe and Rapson (2014) finds survey evidence that imperfect information about product attributes inhibits efficiency, which can be overcome by providing simple low-cost information. These authors design and implement a framed field experiment by introducing short-term price increases and provision of real-time information to a sample of residential electricity customers in Connecticut. Their results suggest that providing residential electricity customers with real-time information about energy usage increases the price elasticity of their demand. These results thus suggest that information facilitates learning. The results can be generalized and underline the importance for the local public sector to inform (directly and indirectly) and motivate its inhabitants to be energy efficient. In addition, Reiss and White (2008) investigate household-level data from California's energy crisis during 2000 and 2001 and reveal that conservation appeals and informational programs can produce sustained reductions in energy demand. The literature linking gasoline prices, taxes and fuel economy, in general, finds that energy efficiency is modestly, but positively, affected by fuel prices (Klier and Linn, 2010; Li et al., 2009; Bento et al., 2009).

The literature discussed above shows that local governments can indeed influence the electricity consumption patterns of its constituents and of local industry in both directions. By informing and leading as an example with energy-economizing projects, local government investment offers the possibility of substantial positive spillover effects on overall electricity consumption.

The remainder of this paper is structured as follows. Section 2 provides a discussion of energy consumption and local public responsibilities. Hydropower and its roles in the local governments are discussed in Section 3. Section 4 presents the model. The data and the corresponding empirical analysis is presented in Section 5 and 6. The results are presented in Section 7. Section 8 presents robustness tests on the empirical baseline model. Finally, Section 9 offers some concluding remarks.

2 Energy goals and local public responsibilities

The focus on climate change has influenced international and national energy policies. The International Energy Agency (IEA), among others, claims that both producers and consumers in the energy sector must adjust their behavior to mitigate climate change. Politics and laws play an important role in achieving energy saving goals. For example, in 2012, the EU implemented the Energy Efficiency Directive, which aims to contribute to achieving an overall goal of 20 percent energy savings in the EU by 2020. Norwegian energy policies are designed within an international framework and in view of obligations that have previously been undertaken. The responsibility of the public sector to act as an example to society and to show how energy efficiency can be implemented in practice is an important part of the adjustment process. By law, local governments are required to contribute to reducing the greenhouse gas emissions, to improving energy efficiency, and to transitioning to environmentally friendly forms of energy (Ministry of Climate and Environment, 2009). Local government initiatives and instruments to save energy are written into official municipal plans. Local governments are able to implement these measures because they are political and commercial operators, service providers, government practitioners, purchasers, and property owners.

The long-run economic gain that can be achieved by investing in energy efficiency is substantial, although (investment) costs can be high. In 2012, the local public sector spent over NOK 471 billion (USD 78 billion) on energy consumption[1]. It is clear that energy consumption is an important economic and policy area in which to identify and address inefficiencies in the local public sector. In Europe, energy prices are rising and ambitious targets are being set to lead to a low-carbon economy. Thus, investments in energy efficiency and savings should be easy decisions to make, but these changes are not necessarily easy to implement in practice. In general, there are two major barriers to improving energy efficiency: first, lack of information and awareness regarding the opportunity to save energy and second, the lack of an available budget to finance the investments. However, in some Norwegian local governments, there is an additional barrier to investment in reducing energy consumption. If its potential concession power is higher than general electricity consumption, a local government will have reduced incentives to save electricity. This paper aims to put this matter onto the political agenda. This aim is discussed in more detail in Section 3.1.

In the Nordic countries, a large part of the energy consumption results from heating in households and industry, which results in higher energy consumption during the winter. Year-to-year variations in consumption can be explained by weather and temperatures, business cycles and the price of electricity. In the long run, it also depends on economic growth, industry and demographics. In addition, the supply of energy in other European

[1]The energy bill accounts for 1.4 percent of gross operating expenditures in the local public sector. Source: Statistics Norway.

countries, specifically in the Nordic region, will affect electricity demand in Norway by affecting electricity prices.

Over 50 percent of the stationary energy consumption in Norway is from buildings (Norwegian Ministry of Petroleum and Energy, 2013), and there is enormous potential for energy savings in public buildings. According to Enova (2008), it is possible to reduce the electricity consumption in public buildings by 10-30 percent by simple actions, such as by lowering the overall temperature, maintaining separate day and night temperatures, reducing ventilation plant hours, reducing inside and outside lighting hours, reducing snow-melting facility hours, and reducing the heated space. Other actions that can increase energy efficiency, albeit with higher installation costs, are; heat pumps, central control system, and to add new and modern insulation.

Financing can be a barrier for public investment in projects aimed at improving energy efficiency. However, several funds and subsidy schemes provide financial support for such projects, in both the private and public sectors. At the national level, Enova provides economic support through targeted programs and support schemes. They support projects that can document energy savings, that convert non-renewable energy use to renewable energy use, and/or that generate renewable energy. Other local funds are based on similar types of schemes.

The distinction between saving energy and improved efficiency is important in understanding the short- versus long-run price elasticity of energy demand. Short-run changes may depend principally on changes in consumption. Long-run changes include greater transformations of the energy efficiency of the equipment stock.

3 Hydropower in Norwegian local governments

Hydropower is production of electricity based on water. Norway is blessed with a topology and climate that favors hydropower production, and it enjoys the highest per capita production of hydropower in the world. In 2012, over 96.7 percent of the electricity production in Norway was related to hydropower[2], and was equal to 142.9 TWh[3]. Figure 3 maps the locations of the nearly 1,400 hydropower plants in Norway in 2012 and illustrates that hydropower plants are situated in all parts of Norway.

There are two main types of hydropower plants developed in Norway, high-head and low-head power stations. High-head power stations are constructed to utilize a high head (total water drop), but smaller volume of water[4]. Many of these plants are reservoir power stations, and store water in a reservoir[5]. Reservoir power stations allow water to be retained in flood periods and to be released in drought periods. Second, low-head power stations are situated in longer water systems that carry large water volume, but

[2]According to International Energy Agency (2014), the corresponding number worldwide was 16.5 percent in 2012.

[3]According to data collected from the Norwegian Water Resources and Energy Directorate, total installed capacity for that year was equal to 26,324 MW.

[4]Common in Western Norway, Nordland county and parts of Troms county. The topology in these areas is typically steep water systems with steep waterfalls.

[5]Water is directed into pressure shafts leading down to the power plant, where it strikes the turbine runner at high pressure. To increase the hydropower production potential, water can be transferred from one part of a river system to another, or some places even between neighboring river systems.

Figure 1: Developed hydropower plants in Norway, 2012.
Data source: the Norwegian Water Resources and Energy Directorate (plant coordinates).

with smaller heads[6]. Most low-head stations are run-of-river power stations. Regulation of the water flow is difficult, and as a result the water production varies with the incoming water given by nature. For both high and low-head power stations there are often several stations in the same river system. See Norwegian Ministry of Petroleum and Energy (2013) for more details about the Norwegian hydropower sector.

Acquisition of ownership rights of the waterfall, by anyone other than the State, requires a license in accordance with the Industrial Licensing Act. If water in a regulation reservoir is used for power generation, a separate permit from the Watercourse Regulation Act is required[7]. The Acts was passed in 1917, and safeguarded the State's and the general public's interests. Development of hydropower plants has an impact on the local environment. It may have negative effects on fish, plants, insects, bird life, and on the landscape connected to the river system. It may also conflict with various industry, tourism and recreational interests, particularly at the local level.

As a compensation for environmental damages and other consequences of hydropower

[6]Common in Eastern Norway, Trøndelag region and Finnmark county.

[7]Smaller new installations are given a permit according to the Water Resource Act. This Act does not give right to concession power. See Norwegian Ministry of Petroleum and Energy (2013) for more information about the information about the water resource administration.

production in the local community, the Industrial Licensing Act and the Watercourse Regulation Act require mandatory sales of electricity to the local governments that are affected by the hydropower production[8]. The concession power agreement is discussed in Section 3.1. Also other compensation schemes ensure the local governments a share of the value creation. A natural resource tax is imposed on the produces. The natural resource tax equals NOK 0.011/kWh. The local governments are also free to impose property tax on the power plants. This may generate large revenues. In total, the generated hydropower revenues have been important to generate local support for projects that are profitable for the society at large.

3.1 Concession power to the local governments

According to the Industrial Licensing Act §2(12) and the Watercourse Regulation Act §12(15), hydropower plants are required to sell up to 10 percent of their power basis to the local government affected by the hydropower production. When this law was implemented in 1917, it served to guarantee the supply of electricity to local communities, that were competing with large cities in purchasing power. Today, the institution of concession power serves as a redistribution system for local governments to participate in the value creation generated by the hydropower sector. Modern technology in the electricity transportation system, ensures an equal supply of electricity across local communities. In addition, there are few regulations in the electricity market, which makes the supply of electricity equal across local communities.

The potential concession power to the local government is calculated on a theoretical/hydrological basis[9]. Hence, it is fixed over time and is independent of actual power produced from year to year. The concessionaire must sell up to 10 percent of the power basis to the applicable local governments. However, the entitlement to concession power is restricted to general electricity consumption by the local government. If the potential concession power is greater than such general electricity consumption, the actual transferred concession power is equal to general electricity consumption[10]. Thus, the concession power actually transferred to the local government can vary with general electricity consumption from year to year. In the dataset, 44 local governments have a positive gap between potential concession power and general electricity consumption in 2012, which is henceforth referred to as "a GAP" and is discussed further in the Section 3.1.1.

General electricity consumption is the total electricity consumed in the local community and includes both private and public consumption, but excludes electricity consumption in energy-intensive industries[11]. General electricity includes electricity consumed in the public and private sectors and by inhabitants. At the end of each year, local governments must submit a forecast of general electricity consumption for the next year to the

[8]Some minor revenues are also generated by an annual concession fee, development funds, and revenues from reversions of power plants.

[9]The concession power level is calculated by the Norwegian Water Resources and Energy Directorate and applies over the entire license period.

[10]The difference accrues to the county council

[11]These industries include production of chemical raw material, iron, steel, ferro-alloy, primary aluminum, lead, zinc, tin, copper and other non-iron-bearing metals. In addition, wood processing (such as pulp, paper and cardboard) is defined as an energy-intensive industry.

applicable concessionaire. This forecast is based on the temperature-corrected electricity consumption from the previous year and on expected changes in consumption.

For most licensees, the price of concession power is calculated as a yearly fixed price by the Ministry of Petroleum and Energy and reflects the general cost of production[12]. In 2012, the concession power price was 0.11 NOK/kWh (0.018 USD/kWh). In comparison, the average electricity market spot price was 0.23 NOK/kWh (0.038 USD/kWh). The concession power price has been lower than the market price since 2001. See Appendix A for a descriptive table of electricity prices.

In 2012, 255 out of 429 local governments were entitled to concession power. Table 1 shows that potential concession power varies greatly among local governments. In 2012, potential concession power accounted for approximately six percent of total hydropower production[13]. Concession power can be consumed in the public sector, resold on the market, or sold to inhabitants. The value added by concession power varies from year to year; it varies with the difference between the concession power price and the market price, and how the local government chooses to manage the electricity resource. Local governments can – under certain restrictions – extract the concession power to maximize profits. By extracting and reselling the power when prices are high, local governments can earn substantial profits. In 2009, the total value of concession power was estimated at NOK 1.8 billion (USD 0.3 billion) (Ministry of Petroleum and Energy, 2012).

3.1.1 GAP

As discussed above, if the potential concession power is greater than general electricity consumption, the actual transferred concession power to the local government will vary with general electricity consumption from year to year, which is the GAP. To simplify, the GAP is equal to:

$$GAP = \begin{cases} 1 & \text{if} \quad \text{Potential concession power} > \text{General electricity consumption} \\ \\ 0 & \text{if} \quad \text{Potential concession power} \leq \text{General electricity consumption} \end{cases}$$

In the dataset, 44 out of the 255 local governments with concession power had a GAP in 2012. Table 1 shows that they are typically small in population size. The map in Appendix B maps the locations of the local governments with a GAP.

Table 1: Concession power and GAP in the local governments, 2012.

Group of governments	**Concession power (MWh)** *Mean*	*Min.*	*Max.*	**Population** (mean)	**Number of governments**
All	20257	0	350819	11623	429
Concession power>0	34079	0.10	350819	8413	255
GAP = 1	118849	27009	350819	2340	44

[12]For licenses given before the 10th of April 1959, the price is based on the production costs of the individual power plant.

[13]Total produced hydropower = 142.9 TWh. Total theoretical concession power = 8.7 TWh. Source: Norwegian Water Resources and Energy Directorate.

A closer look at the data, shows that the size (in MWh) of the GAP varies considerably. Table 2 illustrates this variation. The table presents the size of the GAP as a share of potential concession power and as a share of general electricity consumption. On average, the size of the GAP is substantial and accounts for 51 percent of the concession power. Therefore, on average, those local governments with a GAP are only entitled to about half of the potential concession power.

Table 2: GAP share of concession power and general electricity consumption, 2012.

Share of	**Mean**	**Median**	**St.dev.**	**Min.**	**Max.**
Potential concession power	51%	56%	24%	4.8%	88%
General electricity consumption	170%	126%	165%	5.1%	752%

The GAP situation is illustrated in Figure 2. Three scenarios are presented, depending on the level of potential concession power. Assume that local governments 1, 2 and 3 have the same general electricity consumption as one another, which is equal to X. The local governments differ in their hydropower resource abundance, and the potential concession power is equal to $\overline{K}_j$. Local governments 1 and 2 do not have a GAP because $X \geq \overline{K}_j$. Local government 3 has a positive GAP, because $X < \overline{K}_3$. Hence, local government 3 is only entitled to concession power equal to X.

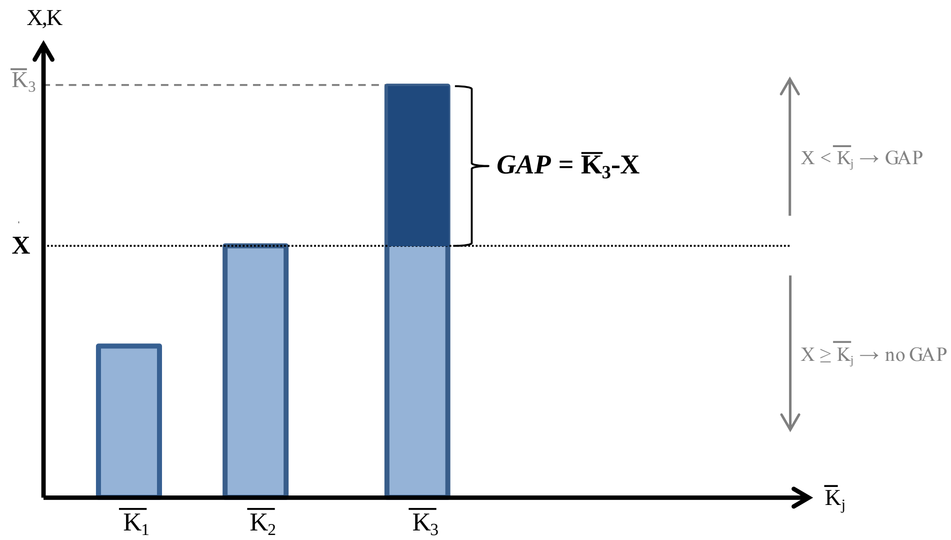

Figure 2: Concession power ($\overline{K}_j$), fixed general electricity consumption (X), and GAP.

3.1.2 Incentives to save energy when GAP=1

As discussed above, the value added by the concession power can be substantial. Thus, the local governments have incentives to maximize – or at least not to reduce – the concession power transfer. As a result, the GAP may have adverse effects on energy saving incentives in the local government for the following reasons: if a local government with a GAP invests in energy savings and efficiency, it will reduce its general electricity consumption, and the corresponding reduction in general electricity consumption will reduce the concession power transferred in the next period. Thus, even if energy costs are reduced, local governments can lose profit in the long run.

The loss of transferred concession power is illustrated in Figure 3. Assume that each of the three local governments discussed above saves electricity equal to S_1. In the next period, both local government 2 and 3 will receive less concession power, equal to $X - S_1$, whereas the amount of concession power in local government 1 is unaffected by the energy savings. The consequences of having a GAP on the incentives of energy saving are discussed in the next section.

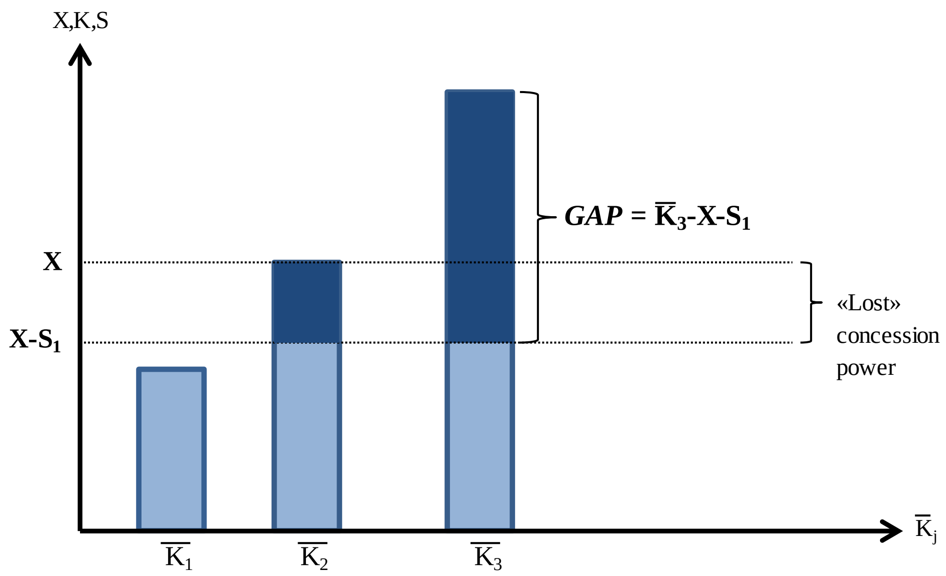

Figure 3: Concession power ($\overline{K}_j$), fixed general electricity consumption (X), energy saving (S_1), and GAP.

How energy-saving incentives are affected by the GAP rule may also depend on other local governments' specific ownership interests and long-term contracts for electricity sales. First, it might be argued that a local government that owns the hydropower plants that are redistributing the concession power will not claim the concession power (they will earn the profit through the ownership of the plant). However, if the local government has a GAP, it will still "lose" future concession power if it invests in saving electricity. If the local government has a GAP, the local county will claim the excess power. Hence, a local government with a GAP will have reduced incentives to save electricity even if they have an ownership interest in the hydropower plant. Second, some local government may have agreed to long-term contracts for electricity sales. Depending on the details of these contracts (fixed price, restricted to concession power, etc.), these types of contracts may affect the incentives that the government has to save electricity, whether there is a GAP or not.

4 Model

The model provides a simple dynamic framework to discuss how the transfer of concession power to local governments and the GAP rule affect incentives for energy saving and investments in energy efficiency in the public sector. The intertemporal decision for local governments to invest in energy saving depends on the investment tradeoff today and in the future. Therefore, the model is a two-period model. Period 1 represents the current period, and period 2 represents the future. The model shows that a positive GAP between potential concession power and general electricity consumption has a negative effect on energy savings and/or energy efficiency. As explained in Section 2, it is common that energy saving and energy efficiency differ. The model shows that the outcome of the GAP rule is the same for both scenarios. The model focuses on energy saving in Subsection 4.1 and energy efficiency in Subsection 4.2.

In the model, all local governments are assumed to have identical preferences and to be profit-maximizing. The only good explicitly modeled is electricity. The municipalities will maximize total profit in periods 1 and 2, implying that government funds can be put to uses other than energy consumption or investment in energy saving. Profit in period t is given by R_t. The local governments receives a fixed government transfer equal to T.

All local communities are assumed to have a total general electricity consumption equal to X in both periods. This model focuses on electricity consumption and electricity savings in the public sector. Therefore, total electricity consumption is split in two; local government electricity (X_L) and private electricity consumption (X_p). Both variables are exogenous in the model, but electricity saving in the public sector is exogenous, as will be discussed below.

Electricity can be bought at the electricity market at price $p_{m,t}$. The market price is assumed to be exogenous. Local governments with hydropower endowments are also entitled to purchase concession power. Potential concession power is equal to $\overline{K}$. Hydropower recourses are given by nature; hence, $\overline{K}$ is exogenous in the model but varies across local governments. The actual concession power transferred in period 1 depends on $\overline{K}$ and X. As discussed in Section 3.1.1, the actual concession power transferred will not exceed general electricity consumption in the local government. The concession power is bought at price $p_{c,t}$ and is fixed, having been set at the central level. It is assumed that $p_{c,t} < p_{m,t}$[14]. The local government can either consume the concession power at a cost equal to $p_{c,t}$ or resell it in the electricity market at price $p_{m,t}$. It is assumed that households and industry can only buy electricity at the market price.

The actual concession power transferred in period 2 is endogenous in the model, which depends on accumulated electricity consumption from period 1. In other words, the level of concession power depends on general electricity consumption and the energy saving and/or energy efficiency improvements in period 1. The mechanisms are, however, a bit different for energy saving and energy efficiency, as will be shown in the next two subsections.

[14]The concession power price has been lower than the yearly mean spot price since 2001. See Appendix A for historic data regarding electricity prices.

4.1 Model with energy saving

Local government electricity saving is endogenous in the model, and is given by S_t. All local governments are assumed to face the same cost function, *C(S_t)*, which is assumed to be increasing and concave in S_t. Investments in energy saving in period 1 do not affect energy savings at time 2[15]. However, energy saving in period 1 can influence the concession power at time 2. If a local government with potential concession power equal to $\overline{K}$ also has $\overline{K} > X$ (GAP=1), it will receive less concession power in period 2 if it engages in energy saving in period 1. This is because the energy saving in period 1 reduces general electricity consumption, which will reduce the concession power transferred in period 2. This is illustrated graphically in Figure 3. The example described above is equal to local government 3 in the figure. In addition, local government 2 will receive less concession power in period 2, even though $\overline{K}_2 = X$. The concession power transferred to local government 1 is not affected in period 2.

In general, the concession power transferred in period 2 can be expressed by[16]:

$$K_2 = \begin{cases} \overline{K} & \text{if} \quad X \geq \overline{K} \quad \text{and} \quad X - \overline{K} - S_1 > 0 \\ \\ X - S_1 & \text{if} \quad X < \overline{K} \end{cases}$$

4.1.1 The maximization problem when saving energy

Local governments will maximize total discounted profit in periods 1 and 2:

$$\max_{S_1, S_2} \quad R_1 + \beta R_2 \qquad , 0 < \beta \leq 1$$

Whether the discounted profit function is maximized with respect to energy savings in periods 1 and 2, S_t depends on the local government's profit in period 1 and 2. β is the discount factor, which is assumed to be between zero and one. The profit function per period equals:

$$R_t = T - p_{c,t} K_t - p_{m,t}[X_L - K_t - S_t] - C(S_t)$$

Inserting the profit functions into the maximization problem yields:

$$\begin{aligned} \max_{S_1, S_2} \quad & T - p_{c1} K_1 - p_{m1}[X_L - K_1 - S_1] - C(S_1) \\ & + \beta[T - p_{c2} K_2 - p_{m2}[X_L - K_2 - S_2] - C(S_2)] \end{aligned} \tag{1}$$

The general first order condition (FOC) with respect to S_1, is given by:

[15] Investments to improve energy efficiency will save energy in periods 1 and 2. See the corresponding model for energy efficiency in Section 4.2.

[16] The special case, in which $X \geq \overline{K}$ and $X - \overline{K} - S_{1,j} < 0$ (local government 2 in Figure 3), yields the same solution as a local government with $X < \overline{K}$. See Appendix C.

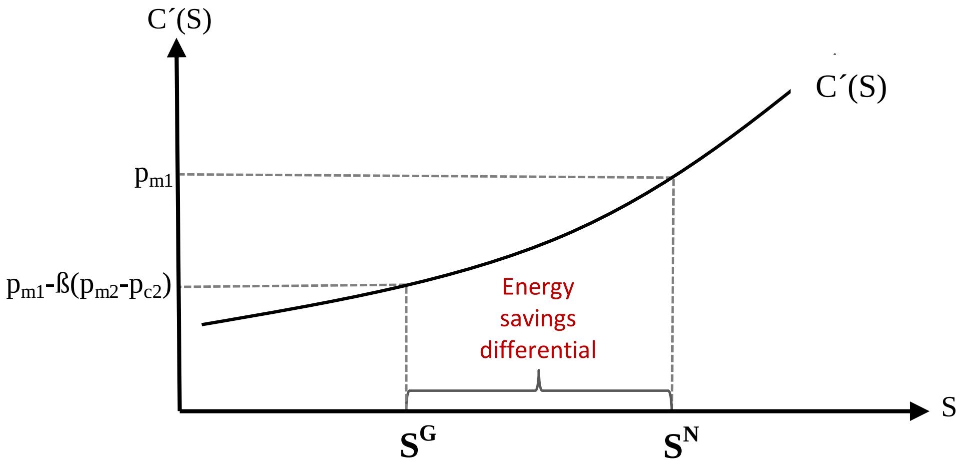

Figure 4: Energy savings differential between local governments with and without a GAP.

$$C'(S_1) = p_{m1} + \beta(p_{m2} - p_{c2})\frac{\partial K_2}{\partial S_1}$$

Solving the first order condition with respect to $\frac{\partial K_2}{\partial S_1}$ gives:

$$\begin{aligned} &\text{If} \quad X \geq \overline{K}: \qquad C'(S_1^N) = p_{m1} \\ &\text{If} \quad X < \overline{K}: \qquad C'(S_1^G) = p_{m1} - \beta(p_{m2} - p_{c2}) \end{aligned} \tag{2}$$

Here, $C'(S_1^N)$ is the marginal cost earned by saving an additional unit of electricity for a local government with no GAP. $C'(S_1^G)$ is the corresponding marginal cost for local governments with a GAP. The FOC in equation (2) shows that, in equilibrium, a municipality with a GAP (i.e. $X < \overline{K}$) will invest less in energy saving than a local government with no GAP. Given that $C'(S_1^G) < C'(S_1^N)$ in equilibrium, the marginal costs are smaller in the local government with a GAP[17]. The different equilibrium solutions, and the corresponding energy saving differential, is illustrated in Figure 4. In equilibrium, the marginal cost for saving one unit of electricity is equal to $C'(S^N)$, if the local government does not have a GAP. The equilibrium level of energy saving is then given by S^N. For a local government with a GAP, the marginal cost of saving one unit of electricity is equal to $C'(G^N)$, and $C'(G^N)$<$C'(S^G)$. Hence, in equilibrium the electricity savings differential between local governments with and without a GAP is equal to S^N-S^G.

The differential in energy saving when $X < \overline{K}$ results from the fact that, at the margin, the local government in period 2 must buy the saved unit of electricity from period 1 at market price p_{m2}. The alternative electricity price for the same unit is equal to p_{c2}. The

[17]The main conclusion is independent of the assumption that it is total discounted revenue – and not the sum of per period discounted utility – that is maximized. In the case of maximized utility functions, the maximization problem yields $\max_{S_1,S_2} \quad U(R_1) + \beta \cdot U(R_2)$. The corresponding general FOC then equals $C'(S_1) = p_{m1} - \beta\frac{U'(R_2)}{U'(R_1)}(p_{m2} - p_{c2})\frac{\partial K_2}{\partial S_1}$. Thus, the same result holds.

quantitative effect also depends on the discounting factor. The higher the weight that is placed on the future, the less incentive there is for energy saving today.

The model shows that the GAP act has adverse effects on energy saving incentives in period 1. It is also notable that the energy saving rate at the margin in period 1 is not directly dependent on the size of the concession power; instead, it depends only on the difference between the potential concession power level and general electricity consumption.

The savings rate in period 2 will not be affected by either the concession power or a potential GAP. With respect to S_2, the FOC yields $C'(S_2) = p_{m2}$. In the real world, with infinite periods, future periods will also have less incentive to engage in energy savings.

4.2 Model with energy efficiency investments

It is straightforward to extend the model to study investments in energy efficiency. Investments in energy efficiency, in contrast to investments in energy saving, improves energy savings in both periods 1 and 2. Thus, in this two-period model, the investment is complete in period 1, but the investment saves energy in both periods 1 and 2. To simplify the model there is no energy efficiency investment in period 2, but this does not alter the findings.

Assume that energy efficiency improvements are given by E and are the same in periods 1 and 2. The cost function is given by *C(E)*. Given the same model framework as the model with energy savings, the profit functions are now given by:

$$
\begin{aligned}
R_1 &= T - p_{c,1}K_1 - p_{m,1}[X - K_1 - E] - C(E) \\
R_2 &= T - p_{c,2}K_2 - p_{m,2}[X_L - K_2 - E]
\end{aligned}
$$

4.2.1 The maximization problem when investing in energy efficiency

The corresponding maximization problem is:

$$
\begin{aligned}
\max_{E} \quad & T - p_{c1}K_1 - p_{m1}[X_L - K_1 - E] - C(E) \\
& + \beta[T - p_{c2}K_2 - p_{m2}[X_L - K_2 - E]]
\end{aligned}
$$

The general FOC with respect to E becomes:

$$C'(E) = p_{m1} + \beta[(p_{m2} - p_{c2})\frac{\partial K_2}{\partial E} + p_{m2}]$$

Inserting for $\frac{\partial K_2}{\partial E}$ gives:

$$
\begin{aligned}
&\text{If} \quad X \geq \overline{K}: \qquad C'(E)_N = p_{m1} + \beta p_{m2} \\
&\text{If} \quad X < \overline{K}: \qquad C'(E)_G = p_{m1} + \beta p_{c2}
\end{aligned}
$$

The presented FOC condition is comparable with equation (2). A local government with a GAP has less incentive to invest in energy efficiency. The intuition for this is that, at the margin, a local government with a GAP has less payoff by the energy efficiency in period 2 than a local government without a GAP[18]. In equilibrium, $C'(E^N) > C'(E^G)$, because $p_{m2} > p_{c2}$.

5 Data

To empirically test the predications of the model, comparable data on electricity consumption at the local level must be utilized. A panel dataset on electricity consumption per square meter in public sector buildings from 2012 and 2013 allows me to do so. The data are presented in the next subsections. A table with descriptions of the variables and corresponding descriptive statistics is given in Appendix D.

5.1 Electricity consumption per square meter

The dependent variable in the analysis is electricity consumption per square meter in public sector administrative buildings and school buildings. Only buildings that are owned by local government are included in the statistics. The consumption is given in MWh per square meter and denoted as $ELm2_{Admin,jt}$ and $ELm2_{School,jt}$. Both building categories are used for the same propose across local governments. The data is collected from Statistics Norway. Reported observations on electricity consumption for the administrative buildings were 305 in 2012, and 345 in 2013. For the school buildings, the corresponding numbers are 322 and 368. The local governments that have not reported their electricity consumption are relatively small in population size, on average. However, the omitted local governments do not seem to differ from the observed local governments with respect to the other explanatory variables included in the analysis.

5.2 General electricity consumption

General electricity consumption is equal to all electricity consumed in the local community, with the exception of the energy-intensive industries. See Section 3.1 for more details. Data on electricity transfers to local governments from electricity companies in 2012, is collected from the Norwegian Water Resources and Energy Directorate. General electricity consumption is equal to the sum of total electricity consumption minus electricity consumption in the energy-intensive industries, which include the following industries: production of ferro-alloys, production of iron and steel, production of chemical raw materials, production of primary aluminum, production of other non-iron metals, and production of pulp, paper and cardboard[19].

[18] The special case where $X > K$ and $X - \overline{K} - S_1 < 0$ do not alter the results, which can be illustrated by an approach similar to that shown in Appendix C

[19] In practice, some businesses are not as easily defined as being in an energy-intensive industry (or not). In those cases, the definition is defined between the local government and the state. Thus, the general electricity consumption variable is not always accurate.

5.3 Potential Concession power

Data on potential concession power is also collected from the Norwegian Water Resources and Energy Directorate. The data includes potential concession power obliged to go the local governments in 2013. As explained in Section 3.1, the potential concession power from each individual plant is fixed over time[20]. As a result, the potential concession power to the local governments is stable over time; for most local governments, it is the same in 2012 and 2013. The variable is given by $ConcessionPower_j$, and is measured in MWh. In the regression, concession power is given in per capita terms.

5.4 GAP

The model, in Section 4 shows that it is not the size of the GAP that affects the incentive to save energy; instead, it is whether the local government has a GAP or not. In the empirical analysis, the GAP variable is defined as a dummy variable that equals 1 if there is a positive difference between the potential concession power and the general electricity consumption.

$$GAP_j = \begin{cases} 1 & \text{if} \quad ConcessionPower_j > Generalelectricityconsumption \\ 0 & \text{if} \quad ConcessionPower_j \leq Generalelectricityconsumption \end{cases}$$

5.5 Degree-sum

The climate in Norway varies substantially across local governments. Some districts have long winters, whereas others have shorter winters. To capture the variation in energy required for home heating, I include a variable called degree-sum. Degree-sum is defined as the degree sum below 17°C. Mathematically, this variable can be expressed as (Tveito et al., 2001):

$$T_D = \sum_{i=1}^{365} 17 - T_i \qquad if \quad T_i \leq 17$$

where T_D is the degree-sum and T_i is the daily temperature. The degree-sum is an indication of energy needed for home heating. Gridded data on degree-sum are collected from the Norwegian Meteorological Institute. The gridded data is adapted to the local government level by calculations in ArcGIS 10.2[21]. Figure E.1 in Appendix E illustrates how the degree-sum varies across local governments in Norway.

5.6 Local government revenues

The local government revenue level might affect electricity consumption in the local governments. Rich local governments have fewer economic constraints and might invest more

[20] This calculation assumes that there is no upgraded capacity at the plant.

[21] ArcGIS is a geographic information system (GIS) for working with maps and geographic information.

in energy efficiency. Conversely, it is also possible that rich local governments care less about the energy bill. The revenue effect on energy consumption per square meter is therefore uncertain.

The revenue is split in two. Concession power revenue is first, $ConcessionRevenue_{jt}$. This variable represents the revenue that local governments earn by reselling concession power. Second, the other revenues are given by $OtherRevenue_{jt}$, and equal the sum of block grants, wealth and income tax, property tax, and natural resource tax. Both variables are measured in NOK 1,000 per capita, "deflated" to take into account the regional differentiation in the payroll tax, and adjusted by CPI.

5.7 Other control variables

Population size is included in all the regressions to control for possible differences due to local government size. To control for other heating and lighting sources in the buildings, distinct variables for consumption of heating, oil, gas, and bioenergy are included. However, there is some uncertainty regarding the data for the alternatives to electricity. Given that there is observable electricity consumption in the local government, it is assumed that all missing values for the alternatives are set to zero.

6 Empirical specification

The empirical specification will be as follows:

$$\begin{aligned} ELm2_{b,jt} = \alpha_t + \beta GAP_j + \delta_1 ConcessionPower_j + \delta_2 ConcessionPower_j^2 \\ + \gamma Z_{jt} + \varphi X_{b,jt} + \epsilon_{b,jt} \end{aligned}$$

where $ELm2_{b,jt}$ is the electricity consumption per square meter in building type b, in local government j, at time t. GAP_j is equal to 1 if local government j has a GAP. The model predicts that the concession power level will not affect the energy economizing incentives. To test this prediction, the per capita concession power level is included by $ConcessionPower_j$. The variable is also included in a squared form to allow for a nonlinear effect. The other local government specific variables are included by the vector of variables, Z_{jt}. Z_{jt} includes degree-sum, population size and the revenue variables. The vector of controls $X_{b,jt}$ includes the alternative energy sources for heating in the buildings. Time fixed effects are given by α_t, and the error term is given by $\epsilon_{b,jt}$.

Due to data limitations, the inference is mainly based on cross-sectional variation; therefore, the results may be sensitive to unobservable characteristics. Empirical challenges are further discussed and tested in Section 8.

7 Results

The results are given in Table 3 and Table 4. As predicted by the model in Section 4, the local governments with a GAP seem to be less energy efficient.

7.1 Results from school buildings

First, the regressions in Table 3 report that a GAP has a positive and significant effect on electricity consumption per square meter in school buildings. In other words, local governments with a positive GAP between potential concession power and general electricity consumption seem to consume more electricity per square meter than other local governments. Column 1 only includes the GAP variable. Bearing in mind that the functional form is given by a lin-log relationship, a shift in the GAP variable from zero to one, is associated with a six percent increase in electricity consumption per square meter[22]. However, the coefficient is not statistically significant at a 10 percent level.

Table 3: Results: School buildings

ln EL/m^2 school	(1)	(2)	(3)	(4)
GAP	0.060	0.135	0.261**	0.299***
	(0.124)	(0.139)	(0.121)	(0.110)
Concession/pop		-0.002	-0.005	-0.007**
		(0.003)	(0.003)	(0.003)
(Concession/pop)^2		0.000	0.000	0.000**
		(8.52e-6)	(9.79e-6)	(9.62e-6)
Degree days			0.046*	0.075***
			(0.025)	(0.025)
Population			-0.002***	-0.001***
			(0.000)	(0.000)
OtherRevenue			0.005	0.004
			(0.004)	(0.004)
ConcessionRevenue			-0.044	-0.043
			(0.029)	(0.027)
Distinct heating				-0.005***
				(0.001)
Oil				-0.001
				(0.001)
Gas				0.002
				(0.004)
Bio				-0.002**
				(0.001)
Year=2013	0.027	0.027	0.025	0.026
	(0.035)	(0.036)	(0.035)	(0.036)
Constant	4.861***	4.864***	4.481***	4.450***
	(0.030)	(0.029)	(0.160)	(0.156)
R-squared	-0.001	-0.003	0.036	0.078
N	693	693	688	688

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All regressions are clustered at the local government level.

The per capita level of potential concession power is included in column 2, and, as predicted in the theoretical model, it does not seem to have adverse effects on the incen-

[22] Following Wooldridge (2006), given a lin-log functional form, the accurate percentage change for the predicted left hand side variable is given by: $\%\hat{\Delta}ELm2_b = 100 \cdot [exp(\hat{\beta}\Delta GAP) - 1]$. In other words, the effect of a GAP on electricity consumption per square meeter in this analysis is slightly higher than reported in the tables. For example, if the coefficient is equal to 0.299, the accurate percentage change is equal to 34.9 percent.

tives for energy economizing. The concession power level coefficient is close to zero and statistically insignificant. When including the rest of the control variables, the concession power level is statistically significant at the 10 percent level. However, the sign of the effect is negative, nonlinear, and small in absolute value.

Column 3 contains more explanatory variables. The additional explanatory variables lead to an increase in the GAP coefficient. If the GAP variable shifts from zero to one, the expected increase in electricity consumption per square meter in school buildings is 26.1 percent. The degree-sum variable is positive and significant, as expected. This indicates that increased warming needs due to colder weather, has a positive effect on electricity consumption per square meter in school buildings. A one standard deviation increase in degree-sum is associated with a 5.0 percent increase in electricity consumption per square meter. The population variable is also significant in column 3. The effect is small and negative: an increase of 1,000 inhabitants is associated with a reduction of 0.2 percent in electricity consumption per square meeter. The included revenue variable is not statistically significant, indicating that energy economizing in public sector buildings is not determined by revenue resources.

Column 4 presents alternative energy sources as explanatory variables. The GAP coefficient increases by 3.8 percentage points. These results should be interpreted with caution. As explained in Section 5.7, the data quality of these variables is uncertain. In addition, the variables can be argued to be so called "bad" controls (Angrist and Pischke, 2009), i.e., variables that could themselves be outcomes. However, including additional control variables does not largely change the regression results from column 3 to column 4. In addition, rerunning the regressions with distinct heating, oil, gas, and bio as dependent variables shows that the GAP variable does not have a significant effect on these alternatives. Therefore, it appears that it is not the lack of investment in other energy sources that drives the results but rather the lack of investment in electricity savings and efficiency.

7.2 Results from administrative buildings

The results for the administrative buildings are similar to those presented for school buildings. The results are reported in Table 4. In total, the regressions indicate that a GAP has a positive effect on electricity consumption per square meter in the administrative buildings. Compared with the results from school buildings, the effect is somewhat smaller. In column 4, if the GAP variable changes from 0 to 1, the associated increase in electricity consumption is 24.5 percent. The effect is statistically significant at the 10 percent significance level. Notably, the results in columns 3 and 4 indicate that other revenue has a small positive significant effect on electricity consumption. A one standard deviation increase in other revenue is associated with a 1.1 percent increase in electricity per square meter in administrative buildings. As will be shown in Section 8, the GAP variable is statistically significant when outliers are excluded.

Table 4: Results: administrative buildings

ln EL/m^2 admin.	(1)	(2)	(3)	(4)
GAP	0.134	0.178	0.250*	0.245*
	(0.120)	(0.120)	(0.138)	(0.138)
Concession/pop		-0.002	-0.004	-0.004
		(0.003)	(0.003)	(0.003)
(Concession/pop)^2		0.000	0.000	0.000
		(7.95e-6)	(9.53e-6)	(9.55e-6)
Degree days			-0.027	-0.020
			(0.030)	(0.030)
Population			-0.000	-0.000
			(0.001)	(0.001)
OtherRevenue			0.008**	0.008**
			(0.004)	(0.004)
ConcessionRevenue			-0.024	-0.022
			(0.028)	(0.028)
Distinct heating				-0.000
				(0.001)
Oil				0.002***
				(0.001)
Gas				0.002
				(0.004)
Bio				-0.003*
				(0.002)
Year=2013	0.017	0.017	-0.006	0.001
	(0.040)	(0.041)	(0.039)	(0.040)
Constant	5.006***	5.009***	4.788***	4.716***
	(0.041)	(0.040)	(0.211)	(0.189)
R-squared	0.001	-0.000	0.012	0.068
N	671	671	666	666

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All regressions are clustered at the local government level.

8 Robustness

8.1 Extreme values in the dataset

The standard deviations in the dependent variables are large. One concern is that the outliers in the dataset result from measurement errors. To test whether the results are affected by outliers, they are excluded from the sample by restricting the dataset to include data only between the 5th and the 95th percentiles. The regression results are reported in Table 5. Indeed, the GAP coefficients in the main regressions are affected by the outliers, but the results still remain positive and robust. The GAP variable does decrease by a couple of percentage points. However, the results do not appear to be driven by outliers. After excluding the outliers in the dataset, the coefficients reappear more robust for the administrative buildings.

Table 5: Results: Excluding extreme values

	Schools		Administrative	
ln EL/m^2	(1)	(2)	(3)	(4)
GAP	0.203**	0.247***	0.209**	0.192**
	(0.079)	(0.074)	(0.084)	(0.083)
Concession/pop	-0.003**	-0.005***	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)
(Concession/pop)^2	0.000*	0.000***	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Degree days	0.040***	0.060***	0.016	0.026
	(0.013)	(0.013)	(0.020)	(0.019)
Population	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.001)	(0.001)
OtherRevenue	0.004**	0.004**	0.002	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
ConcessionRevenue	-0.005	-0.006	-0.003	-0.003
	(0.007)	(0.007)	(0.009)	(0.008)
Distinct heating		-0.003***		-0.002*
		(0.001)		(0.001)
Oil		-0.001**		-0.001***
		(0.001)		(0.000)
Gas		0.001		-0.002
		(0.002)		(0.001)
Bio		-0.002***		-0.003
		(0.001)		(0.002)
Year=2013	0.000	-0.003	-0.015	-0.017
	(0.015)	(0.015)	(0.020)	(0.021)
Constant	4.519***	4.497***	4.855***	4.878***
	(0.095)	(0.096)	(0.126)	(0.127)
R-squared	0.082	0.165	0.041	0.071
N	619	619	598	598

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

All regressions are clustered at the local government level.

8.2 IV-regressions

All regressions are run by OLS. There are, however, certain empirical challenges in the analysis. First, it might be a problem related to omitted variables, even after including the full set of observable characteristics. For instance, there are no data on the age of the buildings or other technical and building-specific information, which might cause a bias in the results. On average, local governments with a GAP are rich on a per capita basis. Thus, these local governments are likely to have better, and newer, public buildings than local governments without a GAP, which might result to an underestimation of the GAP effect. Conversely, local governments with a GAP are typically small in population size. In general, smaller local governments have relatively little population growth compared with larger local governments. Hence, larger local governments must invest in new buildings to meet their obligations to their growing population. This scenario points in the direction that small local governments (including the GAP local governments) might have buildings that are not as modern and less energy efficient. As a result, the GAP effect may be overestimated. The total direction of a possible bias that is due to omitted variables is not clear. The main variable of interest, GAP_j, is time invariant, making it impossible to run local government fixed effects. However, the results are robust to county fixed effects, as will be shown in Section 8.3.

Second, there is a likelihood of reverse causality between the GAP variable and the left hand side variables, but it can be argued that this likelihood is small. If the difference between the potential concession power and the general electricity consumption is small for both positive and negative differences, a change in the left hand side variable can affect the GAP variable. If electricity consumption in school buildings increases, in theory, a local governments with a small positive GAP can go from GAP to no GAP. However, although the electricity consumption in school buildings and administrative buildings affects the general electricity consumption, the share of the total electricity consumption is small. The mean share of electricity consumption in administrative buildings of total general electricity consumption is 0.7 percent. For the school buildings, the corresponding number is 2.3 percent. Table 2 shows that the average size of the GAP is 170 percent of the general electricity consumption. Thus, it is unlikely that changes in electricity consumption in administrative and school buildings have directly affected the GAP variable.

To address the empirical challenges with omitted variables and possible endogeneity, an instrumental variable approach is implemented. The GAP dummy variable is instrumented by a modified version of the instrument developed by Borge, Parmer and Torvik (2014), which predicts the potential for hydropower production in the local governments by topological characteristics. It utilizes the length and steepness of rivers, in addition to including normal water volume flow. To capture the hydropower potential per capita, it is divided by population size. See Appendix F for details of the instrument. The instrument can be assumed to be strongly exogenous, and to be correlated with the GAP variable. The variable to instrument is however a dummy variable and is difficult to predict. In addition to hydropower production, the GAP variable is also dependent on general electricity consumption, and the instrument does not capture this variation. The instrument might therefore be weak. Nevertheless, the instrumental variable approach is included as a robustness test for the main OLS results. The first stage regression in the instrumental variable approach is run by a probit model. The fitted probabilities are used as instruments in the second stage OLS regressions.

In addition to the instrumental variable approach, the results are also supported by several other robustness tests in Section 8.

8.2.1 Results from the IV regressions

A short summary of the results are presented in Table 6. The GAP coefficients in the IV regressions in columns 2 and 4 are similar in size to the OLS regressions in columns 1 and 3. The IV coefficient in column 2 is significant at a 5 percent significance level. Assuming that the instrument is valid, the endogeneity of the GAP dummy can be tested using a Durbin-Wu-Hausman test. The IV coefficients pass the endogeneity test, which tests the null hypothesis that the variable is endogenous. The p-values are equal to 0.76 and 0.83. Hence, the IV regressions suggest that the cost of relying on the OLS results should be small.

However, the GAP variable is weakly identified by the instrument in the first stage regressions. For the school buildings, the F-value for the GAP variable is equal to 7.42.

For the school buildings, the F-value is equal to 5.19. Therefore, the instrument does not pass the Staiger and Stock (1997) rule of thumb of a strong instrument, which indicates that the regression results should therefore be interpreted with caution.

Table 6: Results: IV regressions

ln EL/m^2	*Schools*		*Administrative*	
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
GAP	0.299***	0.272**	0.245*	0.213
	(0.110)	(0.129)	(0.138)	(0.177)
First stage[a]				
Instrument		2.667***		1.447**
		(0.979)		(0.635)
R-squared	0.078	0.076	0.068	0.066
N	688	688	666	666
Testing exogeneity				
Durbin-Wu-Hausman,p-value		0.763		0.833

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All regressions are clustered at the local government level.
All regressions includes full set of explanatory variables.
a) Probit estimation

8.3 Other robustness tests

To further test the robustness of the simple OLS regressions presented in Section 7, five robustness tests are presented in Table G.1 and G.2 in Appendix G.

First, the theoretical model predicts that the size of the GAP does not matter for energy economizing incentives. To test for this, the GAP size in per capita terms is included in column 1. The size of the GAP is not statistically significant in the regressions, and is also small in absolute value.

Second, a large share of the local governments with a GAP appears to be located in the southwestern part of Norway. See the illustrative map in Appendix B.1. To test whether there are common regional patterns in electricity consumption in public sector buildings, county fixed effects are included in column 2. Including county fixed effects might also control for some variation in electricity price zones[23]. The county fixed effects do not appear to alter the findings from the main regressions. The regressions are fairly robust to the change of specification.

Third, the local governments with a GAP typically represent small populations. Although the population size is included in the regressions, it is of interest to check whether the results hold when applying the regression to a more homogeneous sample. In column 3, the sample is restricted to local governments with population less than the median

[23]Electricity prices in Norway are divided into five price zones. The zones are not defined in accordance local government borders. Thus, it is not possible to control for the price zone at the local government level. However, the price differences are not large in comparison with price differences in other regions in Europe.

population size, which is 4,620 inhabitants. The results hold when regressing the model on the restricted sample. The GAP coefficient for school buildings increases by a couple of percentage points. The GAP coefficient for the administrative buildings decreases by a couple of percentage points.

Fourth, the sample is restricted to include only local governments that are entitled to concession power. In this manner, the sample is more homogeneous with respect to resource abundance, and the change of sample does not seem to affect the GAP coefficients.

Fifth, as discussed in Section 8.2, there is little probability that the GAP dummy variable changes as a result of changes in the electricity consumption per square meter in administrative buildings or school buildings. This check for robustness is also addressed in the IV regressions. Nonetheless, it remains of interest to see whether the main results hold by excluding local governments that are close to a GAP, which is undertaken by excluding local governments that are entitled to concession power that is not more than 95 percent and less than 105 percent of the general electricity consumption. Column 5 in the tables reports the results. The coefficients are robust to the change of sample.

9 Concluding Remarks

The hydropower energy policy in Norway today does not appear to be optimal with respect to incentivizing energy savings in the Norwegian local public sector. If a local government is entitled to more concession power than its own general electricity consumption, the incentives to save energy are reduced. Local governments with a positive gap between potential concession power and the general electricity consumption, will lose future concession power if they choose to reduce electricity consumption, which has adverse effects on the energy economizing incentives. This is shown by a simple two-period model and supported by empirical findings.

The cost of these reduced incentives on electricity saving is difficult to predict. It relies on electricity prices, future consumption behavior, and how local governments choose to allocate their concession power. In addition, the public sector may have an impact on the electricity consumption behavior for its inhabitants, and this effect is difficult to predict.

To ensure optimal energy efficiency in the future, and for local governments to have incentives to lead by example, the right of concession power, and the corresponding GAP rule, should be amended and modernized. The act should ensure that there are no adverse effects on energy saving incentives.

These results cannot be directly generalized to other countries or industries, but they nonetheless show how incentives for energy economizing projects can be diminished by misspecified and outdated laws.

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A Electricity prices

Table A.1: Electricity prices in Norway (NOK/kWh), 1999-2013.

Year	**Mean spot price**[a]	**Concession price**[b]
1999	0.11	0.11
2000	0.10	0.11
2001	0.19	0.12
2002	0.20	0.10
2003	0.29	0.09
2004	0.24	0.09
2005	0.23	0.09
2006	0.40	0.09
2007	0.22	0.09
2008	0.37	0.09
2009	0.30	0.10
2010	0.44	0.10
2011	0.37	0.11
2012	0.23	0.11
2013	0.30	0.11

a) Source: Nord Pool Spot

b) Source: Ministry of Petroleum and Energy

B Local governments with concession power and a GAP

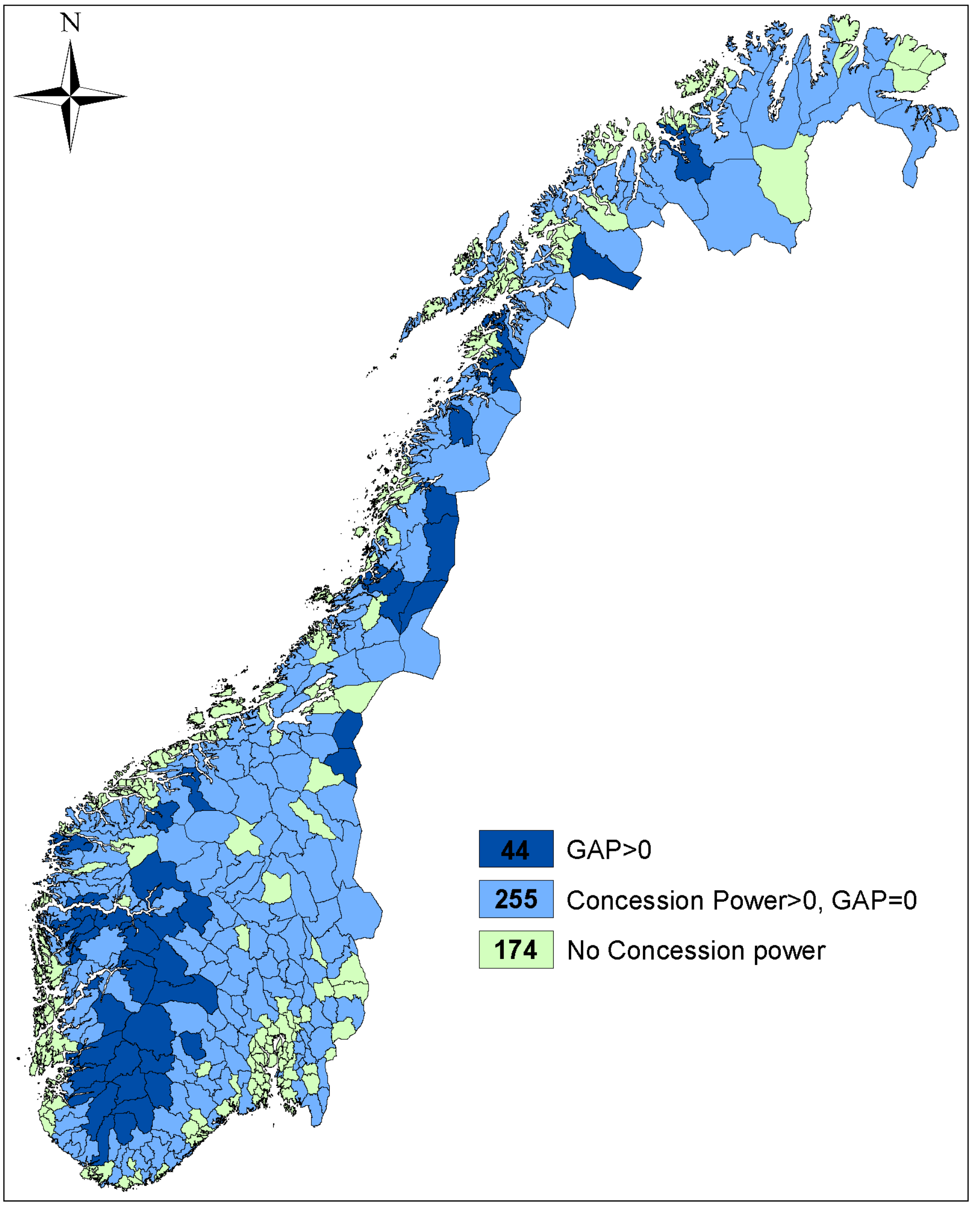

Figure B.1: Local governments with a GAP, 2012.

C Special case

It is possible for a local government to have no GAP in period 1, but a GAP in period 2. The concession power in period 1 in this case is equal to $\overline{K}$ ($X \geq \overline{K}$). The concession power in period 2 differs from period 1 because the local government saved S_1 in period 1. That is: $X - K_1 - S_1 < 0$.

To find the actual concession power in period 2 the saving rate in period 1 can be split in 2 parts.

$$S_1 = S_1^A + S_1^B$$
$$S_1^A = X - \overline{K}$$

The equations implie that the remaining saving S_1^B lead to a GAP in period 2.

$$S_1^B = S_1 - (X - \overline{K}) = S_1 + K_1 - X$$

The concession power in period 2 equals:

$$K_2 = \overline{K_1} - S^B = X - S_1$$

The FOC, to the maximization problem in equation (1), with respect to S_1 is then equal to:

$$C'(S_1)_{NG} = p_{m1} - \beta(p_{m2} - p_{c2})$$

Here $C'(S_1)_{NG}$ is the marginal costs of saving an additional unit of electricity for a local government without a GAP in period 1, but with a GAP in period 2. The FOC is identical to the FOC for a local government with a GAP in equation (2). Thus, also the special case in this model implies that the concession power policy does harm the incentives to invest in energy saving in the case of a GAP.

D Data

Table D.1: Descriptive statistics

Variable	Variable Description	Mean (S.D.)
$ELm2_{School}$	Electricity consumption per square meter in local government owned school buildings (kWh/m^2). *Source: Statistics Norway*	146 (65)
$ELm2_{Admin}$	Electricity consumption per square meter in local government owned administrative buildings (kWhm^2). *Source: Statistics Norway*	198 (315)
Concession Power (MWh)	Potential concession power (MWh). *Source: The Norwegian Water Resources and Energy Directorate*	20346 (47821)
Concession Power (MWh/pop)	Potential concession power (MWh) per capita. *Source: The Norwegian Water Resources and Energy Directorate, Statistics Norway*	8.48 (28.1)
ELgeneral	The general electricity consumption (MWh). *Source: The Norwegian Water Resources and Energy Directorate*	192641 (551877)
GAP	A dummy variable taking the value 1 if the the gap between the potential concession power and the general electricity consumption is positive. *Source: The Norwegian Water Resources and Energy Directorate*	.103
*D*egree-sum	Indication for energy need in houses. The degree sum below 17°C. Normalized by 10^{-3}. *Source of gridded data for Norway: The Norwegian Meteorological Institute*	4.44 (1.08)
*C*oncession Revenue (NOK 1000)	Concession power revenues. Measured in per capita, and adjusted for payroll tax rates and CPI.*Source: The Norwegian Advisory Commission on Local Government Finances*	.756 (2.21)
*O*therRevenue (NOK 1000)	Sum of block grants, wealth and revenue tax, property tax, and the natural resource tax. Measured in per capita, and adjusted for payroll tax rates and CPI. *Source: Statistics Norway*	52.1 (13.9)
*P*opulation	Population size in 1000, the 1'st of January each year. *Source: Statistics Norway*	11.8 (36.5)
*D*istinct heating	Consumption of heating from a central heating plant per square meter (kWh). *Source: Statistics Norway*	
	School buildings	.788 (1.50)
	Administrative buildings	.644 (1.57)
*O*il	Consumption of oil for heating and lightening purposes per square meters (kWh). *Source: Statistics Norway*	
	School buildings	.541 (1.25)
	Administrative buildings	.318 (1.11)

Table D.1: Descriptive statistics (continues)

Variable	Variable Description	Mean (S.D.)
Gas	Consumption of gas for heating and lightening purposes per square meter (kWh). *Source: Statistics Norway*	
	School buildings	.045 (.696)
	Administrative buildings	.041 (.384)
Bio	Consumption of bioenergy for heating and lightening purposes per square meter (kWh). *Source: Statistics Norway*	
	School buildings	.284 (.971)
	Administrative buildings	.042 (.434)

E Degree-sum map

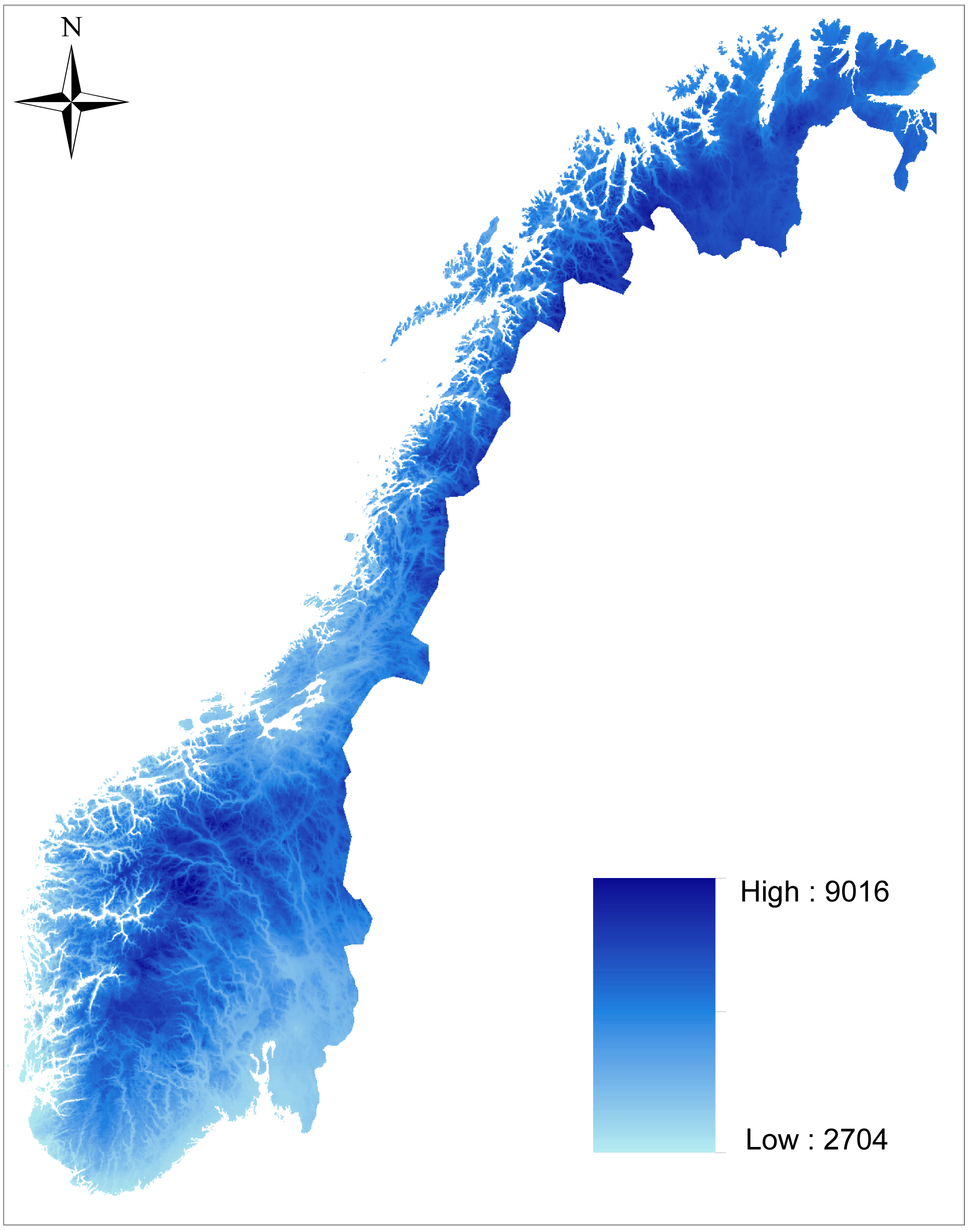

Figure E.1: Degree-sum values in Norway, 2012.

F The instrument

The modified instrument is an modification of the instrument presented in Borge et al. (2013). I refer to our paper for further details about the instrument.

The instrument uses different elements from the hydropower production process to predict potential production in each local government. It utilizes the length, the steepness, and the water volume flow in the river. The production potential of a hydropower plant can be expressed as:

$$N(kW) = g \cdot \eta \cdot Q(m^3/s) \cdot H(m) \tag{3}$$

Here g equals the acceleration of gravity (9.81 m/s^2), η is the total power efficiency of the power plant, Q is the maximal usable water flow (measured in cubic meters per second), and H is the head (the total height of fall).

To construct the instrument, I start out with the formula for hydropower production potential. To capture the Q and the H in equation (3) we use a dataset on water flow volume classes in Norwegian rivers[24] and a dataset on the steepness of the river in any given location. We first calculate how many meters of river in terrain above 4 degrees each local government has within each water flow volume classification[25]. We term this variable $River4_{wj}$. By multiplying $River4_{wj}$ by w, i.e. multiplying the potential water volume with the length of river with water volume equal to w, we get a variable predicting the hydropower production potential within each water volume classification. Now, a river (in terrain above 4 degree) with twice the water volume of another otherwise similar river (same length), has twice the production potential. In order to construct the measure of the total hydropower production potential of each local government, we sum all these multiplicative terms. We then have a variable representing production potential of hydropower in each municipality.

To transform the instrument into hydropower potential per capita, it is divided by population size. The instrument is given by:

$$Instrument_{jt} = \frac{\left[\sum_{w=10}^{w=750} (w \cdot River4_{wj})\right]}{Population_{jt}}$$

To sum up, w is water volume class in the river, $River4_{wj}$ is meter of river with water volume class w in terrain above 4 degrees in local government j, and $Population_{jt}$ is population size.

[24]Classifications (m^3/s): 1-10, 10-50, 50-100, 100-150, 150-200, 200-250, 250-300, 300-400, 400-600, 600-750.

[25]The water flow volume classification, w, allows us to capture the usable water flow in the river. w is equal to the maximum water flow value of each water flow class; $w = \{10, 50, 100, 150, 200, 250, 300, 400, 600, 750\}$

G Robustness results

G.1 Robustness results: School buildings

Table G.1: Robustness: School buildings

ln EL/m^2 school	(1) Gap(MWh)	(2) County fixed eff.	(3) Pop<median	(4) Concession Power>0	(5) Not near GAP
GAP	0.279**	0.247**	0.326**	0.306***	0.305***
	(0.117)	(0.098)	(0.131)	(0.110)	(0.114)
Concession/pop	-0.003	-0.004	-0.006	-0.009***	-0.007**
	(0.007)	(0.004)	(0.004)	(0.003)	(0.003)
(Concession/pop)^2	0.000*	0.000	0.000**	0.000**	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Distinct heating	-0.005***	-0.004***	-0.005***	-0.005***	-0.005***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Oil	-0.001	-0.001	-0.000	-0.002	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gas	0.001	0.000	0.001	-0.003	0.002
	(0.004)	(0.001)	(0.005)	(0.006)	(0.004)
Bio	-0.002**	-0.002*	-0.002	-0.002	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Degree days	0.069**	0.071**	0.067*	0.072***	0.075***
	(0.029)	(0.029)	(0.036)	(0.027)	(0.025)
Population	-0.001***	-0.000	0.012	-0.002*	-0.001***
	(0.000)	(0.001)	(0.054)	(0.001)	(0.000)
OtherRevenue	0.004	0.001	-0.000	0.009**	0.004
	(0.004)	(0.005)	(0.007)	(0.004)	(0.004)
ConcessionRevenue	-0.046	-0.045*	-0.049	-0.046*	-0.044
	(0.031)	(0.025)	(0.030)	(0.028)	(0.028)
Year=2013	0.024	0.028	0.044	0.019	0.024
	(0.035)	(0.034)	(0.066)	(0.048)	(0.036)
GAP(MWh/pop)	-0.004				
	(0.009)				
Constant	4.469***	4.603***	4.735***	4.286***	4.453***
	(0.155)	(0.217)	(0.443)	(0.232)	(0.156)
R-squared	0.077	0.038	0.035	0.079	0.078
N	688	688	319	415	685
County fixed eff.	-	Yes	-	-	-

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All regressions are clustered at the local government level.

G.2 Robustness results: Administrative buildings

Table G.2: Robustness: Administrative buildings

	(1)	(2)	(3)	(4)	(5)
ln EL/m^2 admin.	Gap(MWh)	County fixed eff.	Pop<median	Concession Power>0	Not near GAP
GAP	0.187	0.271*	0.225	0.249*	0.266*
	(0.143)	(0.135)	(0.158)	(0.137)	(0.141)
Concession/pop	0.006	-0.004	-0.008**	-0.005	-0.004
	(0.007)	(0.003)	(0.004)	(0.004)	(0.003)
$(\text{Concession/pop})^2$	0.000	0.000	0.000*	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Distinct heating	0.000	0.000	-0.006***	-0.002	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Oil	0.002***	0.002***	-0.000	0.003	0.002***
	(0.001)	(0.001)	(0.000)	(0.002)	(0.001)
Gas	0.003	0.000	-0.003***	0.007	0.002
	(0.004)	(0.003)	(0.001)	(0.006)	(0.004)
Bio	-0.003*	-0.003**	0.000	-0.002	-0.003*
	(0.002)	(0.001)	(0.004)	(0.002)	(0.002)
Degree days	-0.036	-0.015	0.025	-0.014	-0.022
	(0.032)	(0.037)	(0.033)	(0.038)	(0.030)
Population	-0.000	0.002**	0.119**	0.000	-0.000
	(0.001)	(0.001)	(0.058)	(0.002)	(0.001)
OtherRevenue	0.008**	0.008**	0.020***	0.007	0.008**
	(0.004)	(0.003)	(0.006)	(0.004)	(0.004)
ConcessionRevenue	-0.031	-0.019	-0.016	-0.026	-0.022
	(0.032)	(0.024)	(0.031)	(0.028)	(0.028)
GAP(MWh/pop)	-0.012				
	(0.010)				
Year=2013	-0.004	0.007	-0.020	0.002	0.003
	(0.039)	(0.041)	(0.058)	(0.058)	(0.039)
Constant	4.768***	4.638***	3.572***	4.793***	4.723***
	(0.184)	(0.230)	(0.457)	(0.283)	(0.189)
R-squared	0.070	0.067	0.093	0.014	0.069
N	666	666	309	403	663

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
All regressions are clustered at the local government level.