Water Consumption in the Energy Sector and Energy Consumption in the Water-Sector in a Danish Municipality

Response to TES Co-editors Article: Inseparability of water and energy, in vol. 10 no. 1, 2011

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Abstract: *This article discusses the relation between the water sector and the energy sector based on the water and energy consumption in the municipality of Aarhus with more than 300,000 inhabitants. Water consumption at the fuel suppliers is not analyzed.*

1. The Municipality

The municipality of Aarhus has 310,800 inhabitants pr. July 2011 (6% of the population in Denmark) and population growth within the municipality is roughly 1% p.a. The area of the municipality is 468 km^2 (roughly 1% of Denmark) with around 290 km^2 of farmland, forest and uncultivated areas. The City of Aarhus has a varied mix of economic branches, food-industries, machinery, IT, financial and harbour activities. The city is a regional center for hospitals and education.

The municipality published Green Accounts from 1997 to 2005, but substituted the publishing with (less) information on the municipality´s homepage. Today the municipality has a target of becoming CO2-neutral in 2030, and the (slow) progress towards achieving this target is bi-yearly documented in a "CO2-account" for the municipality.

The municipality had until the turn of the century a large owner share in the large CHP (Combined Heat and Power) plant, "Studstrupværket" (SSV) located in the northern part of the municipality, but from 2001 the CHP plant was privatised. Until 2008 the main water supply, the sewagewater system and the wastewater treatment plants were owned and run by the municipality. From 2008 all water-utilities was fusioned to an independent company, with the municipality as the stockholder. The privatisation of the utilities has to some extent decreased access to relevant data.

2. The Energy Sector

The CHP plant "Studstrupværket" (SSV) located in the northern part of the municipality and has direct access to Aarhus Bay. It is one of Denmark's 15 centralised power plants delivering electricity to the national electricity grid. There is no direct relation between electricity production on this power plant and the electricity consumption in the municipality. The power plant produced 2,844 GWh (net) in 2008 – or 2,215 GWh in 2005 (DONG Energy 2009). The estimated electricity consumption in the municipality in 2005 accounts for 1,451 GWh (Aarhus Kommune 2006) or 1,603 GWh in 2009 (Aarhus Kommune 2010) – slightly more than half of the electricity generation on the CHP-plant.

Private households consume 31.3% of the total electricity consumption, while public institutions consume 21.3 %, industry consumes 18.8% , and commercial sector consumes 14.3%. Farmers use only 3.1 %. (Aarhus Kommune 2006).

This CHP plant capable of producing much more than the municipality´s electricity demand and the main part of the demand for heat in the municipality uses 318,245 m^3 water (drinking water quality) and 443,085 m^3 water of cleaned water from a waste water treatment plant. The cleaned wastewater is used for the air-filter removing sulphur, and the water from the grid is used primarily for de-ionized water to the boilers and to replace losses in the heat grid (DONG Energy 2009).

The water consumption is 1.7 % of the total water supply and 1.5 % of the cleaned sewage water otherwise discharged to the Aarhus Bay.

It is not possible in a CHP plant to distinguish between water used for electricity production and for water used for heat production. If we suppose that 50% of the water consumption is due to electricity generation, then key-figures are 56 liter drinking water pr MWh and 78 liter cleaned wastewater pr MWh.

When the heat demand in the municipality in the summer is low, or if the demand for electricity exceeds the demand for heat, the power plant circulate saline water from the bay for condensing steam. 615 m^3 was circulated in 2008 (DONG Energy 2009).

3. Heat Supply

The CHP plant SSV delivers electricity to the national electricity grid and heat to the mainly municipality owned Varmeplan Aarhus (VPA) covering 95% of the building heating in the municipality and some minor towns in nearby municipalities. The VPA is also supplied with heat from the municipality owned CHP incineration plant, and heat from several gas-oil fired "peak and reserve load" heat plants in the municipality – and from a minor incineration plant and wood fired plant i a neighbour municipality. Some minor waste-heat sources from industries and a biogas plant is also fed into the heat-grid.

The heat consumption in the municipality delivered through the heat grid is 2,932 GWh. Private households account for 73 % of the total heat consumption, while public institutions consume 13 %, and commercial sector consumes 11%. Industry consumes 2% and farmers consume 1% (Aarhus Kommune 2010).

Supplier of the heat circulated in the heat grid is first and foremost the above mentioned CHP plant with around 70% of the heat (2,100 GWh). Next is the incineration plant with 20% (480 GWh) of the heat. The incineration plant consumed 38,293 m^3 fresh water (0. 2% of the freshwater consumption in the municipality) and 38,167 m^3 reused water. The incineration plant produces 2.2 MWh heat and 0.5 MWh electricity for every ton waste incinerated, and consumes 323 litre water/ton waste (AffaldVarme, Aarhus 2011).

Especially some of the factories use fuels for process heat. This article does not analyse possible water consumption in the stage of mobilizing fuels, and there is normally not water consumption in connection with combustion of fuels. So, it is just mentioned, that other fuels used in the industry accounts for around 600 GWh (Aarhus Kommune, 2010).

The heat grid contains around 90,000 m^3 of water and – as a thumb rule - is renewed once a year due to losses in the grid. This amount of water is delivered from SSV.

The conclusion is that the energy sector in the second largest city in Denmark only consumes a little fragment – around 2% - of water consumption in the municipality.

4. The Water-Sector

4.1 Drinking Water Supply

"Aarhus Water" is the main supplier of water in the municipality and has published key figures on water use (Aarhus Vand 2008). The utility produces 16 M. M^3 water of "drinking water quality", around 86% of the waters supply in the municipality (Aarhus Kommune, 2006). 32 small private suppliers and several farmers with summer irrigation accounts for around 3 M. cubic meters. The water is delivered from ground water wells out of the city area, and

drinking water quality is achieved with a minimal treatment.

The drinking water pipeline grid accounts for more than 1500 km. On average, 15 km pipes are renovated and the grid is increased with 11 km of new pipes yearly.

The average household consumption of drinking water is 41 m^3/person or slightly more than 100 l/person per day.

The private households consumes 70% of the water while industry and commercial counts only for 17.4 % of the water consumption in the municipality. The loss in the grid accounts for around 8% of the produced water – or more than 1 M. m^3 pr year. This is four times more than the water consumption in the energy sector.

The total electricity consumption (for pumps and treatment etc.) in the drinking water supply in the years 1998-2002 was between 0.491 and 0.518 kWh pr m^3 and the target for future years was maximum 0.5 kWh/m^3 (Aarhus Kommune, 2003). The total electricity consumption in the water supply can therefore be estimated to 9.5 GWh or slightly more than 0.6 % of the electricity consumption in the municipality.

4.2 Waste Water Treatment

All the sewage water in the municipality (exclusive sewage water from relatively few households in the rural area) is treated in 10 advanced waste water treatment plants with removal of phosphor and nitrogen. The total water amount cleaned is 30-35 m. m3 (The difference from the delivered water is due to surface water discharged through a combined surface and sewage sewer grid in older part of the city).

The total electricity consumption in the waste water treatment plants (WWTP) accounted for between 19.5 GWh in 2000 and 20.3 GWh in 2003 and 2004 (Aarhus Kommune, 2005). Water flow in the sewage water pipes is mostly by gravitation, so electricity consumption in the sewage water system is not significant.

The consumption of electricity divided by the load on the WWTPs makes a quite uncertain key-figure, as the load is quite difficult to measure exact. But with reservation, the key-figures are slightly less than 1 kWh/kg COD or roughly 40 kWh per PE (person equivalent). Most of the electricity consumption occurs in the aerobic stage, so the consumption will be very influenced of the efficiency of the mechanical stage.

All in all the water sector in the municipality accounts for roughly 30 GWh/year or 2% of the total electricity consumption in the municipality.

This shows that gas-motors on two large WWTPs driven by biogas from sludge produce roughly a total of 4 GWh per year.

5. Conclusion

The conclusion - on the local level in a Danish City – is that production of energy has limited impact on the water sector, as the water consumption in the sector only accounts for 2% of the water consumption in the municipality.

The water supply and wastewater treatment of water has a minimal impact on the energy sector, as electricity consumption only accounts for 2% of the electricity consumption in the municipality.

The interrelation between the two sectors is therefore insignificant or, at least, limited.

References

AffaldVarme, Aarhus (2011). *Grøn regnskab 2010, Forbrændingsanlægget (Translated title: Environmental Account 2010, Aarhus Watste Incineration).* Aarhus Municipality, AffaldVarme

Aarhus Kommune (2010). *CO2-kortlægning (Translated title: CO2-account) 2009, second edition.* Teknik og Miljø, Aarhus Municipality

Aarhus Kommune (2003). *Grøn regnskab 2002 (Translated title: Environmental account, 2002).* Aarhus: Aarhus Municipality

Aarhus Kommune (2005). *Grønt Regnskab 2004 (Translated title: Environmental account, 2002).* Aarhus: Aarhus Municipality

Aarhus Kommune (2006). *Grønt regnskab 2005 (Translated title: Environmental account, 2002).* Århus: Århus Municipality

Aarhus Vand (2008). *Vandforsyning og spildevandsrensning i Aarhus i ord og billeder (Translated title: Water supply and waste water treatment in Aarhus in words and pictures).* Arhus Vand, Aarhus

DONG Energy (2009). *Studstrupværket Grønt Regnskab 2008 (Translated title: Studstrup Environmental Account 2008).* DONG Energy A/S, Copenhagen

Editors Response:

The response by Uffe Rasmussen shows the current situation with regard to water and energy in Aarhus municipality, and the situation might be similar in the rest of Denmark when an energy account is made. Such data are not common. Looking for the energy costs for pumping and delivery of water for the waterworks, both large and small, they run on average about 0.6 kr/m^3, and represents a total of 5-8% of the total water price (before the environmental tax and wastewater treatment tax is added on). However, it should be noted that administration costs for the delivery of the water represent approximately 80% of the total costs for water in a typical water work, with 12-15% going to the infrastructure development and maintenance (i.e. Marielyst Water Work 2010; Greve Water Works 2010). This means that energy in the water sector take up 30-40% of the non-administrative costs in the water sector. This amount is high enough so that Copenhagen Energy, the water supplier for Copenhagen, Denmark, has been participating in research looking at reducing their groundwater pumping costs (see http://well-field.dhigroup.com/).

The response reflects the current situation, and does not take into account future developments. The impact of the implementation of the EU Water Framework Directive on groundwater abstraction remains uncertain. Copenhagen Energy is anticipating a reduction in groundwater abstraction permits as a result of the implementation of the water framework directive and has already begun to investigate options for using desalination of seawater from the Baltic Sea in their water supply (Kortenbach 2008). On the energy supply side, the current Danish government, as reported in Thorn et al. (2011), is focusing on biomass as one of its primary renewable energy resources by 2050. The increased water needed to produce this biomass is significant, and could have a large impact on the Danish water resources. This is not only with respect to a potential increase in irrigation, but also less groundwater recharge due to the higher evapotranspiration rates from the biomass crops. However, the impact of increased biomass production on groundwater resources in Denmark has yet to be conducted. Therefore, the editors believe that, though the water-energy connection in Denmark might not be significant today, the relationship, even in relatively water-rich countries like Denmark, should not be ignored.

References

Kortenbach, T. (2008). *Vand er ikke blot vand (Translated title: Water is not just water).* Dynamo, nr. 14. Denmark's Technical University, September 2008

Marielyst Vandværk (2011). *Årsrapport for perioden 1. januar – 31. december 2010 (Translated title: Yearly report for the period 1st of January to the 31st of December 2010).* Marielyst Water Works, www.marielystvandvaerk.dk

Solrød Vandværk (2010). *Årsrapport for året 2009 (Translated title: Yearly report for the year 2009).* Solrød Water Works, http://www.sv-amba.dk

Thorn, P., Schroll, H. and Kjærgaard, B (2011). *Inseperability of energy and water.* The Journal of Transdisciplinary Environmental Studies vol. 10, no. 1, p. 68-70