CITIES
Centre for IT Intelligent Energy Systems

Optimal Control of District Heating Supply Temperatures to Greenhouses

Objective

The objective is to develop methods for optimal control of district heating supply temperature to greenhouses. This CITIES demo project will benefit from a parallel demo project on load forecasting in greenhouses, and another demo project on dynamic prices for DH systems.

A secondary objective is to derive methods for enabling and controlling the energy flexibility in greenhouses in order to use this flexibility to facilitate a better integration of the fluctuating wind power production.

Finally, grey-box models for the hydro-thermal dynamics of greenhouses will be established, and these models might be used for deriving Model Predictive Control for the internal greenhouse energy system.

Partners

- Fjernvarme Fyn A/S
- DTU Compute
- DTU Byg
- Neogrid Technologies ApS
- Eurisco (?)
- Enfor
- Danfoss
- SDU (knowledge on optimal light control for greenhouses) (Bo Nørregaard)
- Greenhouse owners (?)

Background

Greenhouses are major energy consumers in some District Heating networks, and for Fjernvarme Fyn it is expected that the needed energy supply to the greenhouses often determines a lower bound on the supply temperature. Hence, in order to minimize the supply temperature and consequently to reduce the heat losses in the DH network, models and methods for finding the optimal (minimum) supply temperature are needed.

For systems like TERMIS TO and PRESS TO the minimum temperature is found using optimization techniques related to the pipe network. However, for DH systems with dominant consumers, like a greenhouse, it is expected that a determination of the minimum temperature calls for a good forecast of the needed minimum supply temperature for the greenhouses.

It is well-known that some plants are rather flexible with respect to the needed temperature level, and the assumption in this project is that an optimal joint control of the inside air temperature and light, while taking into account the future varying DH water prices, can be used to enable energy flexibility in DH systems with greenhouses. For the owners we assume that the total bill for the energy supply can be reduced, which obviously will lead more competitive situations for those greenhouse owners.

Connection with CITIES WP’s

- WP3: Models for heat dynamics of buildings, models for the pipe systems.
- WP5: Forecasts of electricity prices and load, methodologies for model predictive control.
- WP7: Optimal decision making

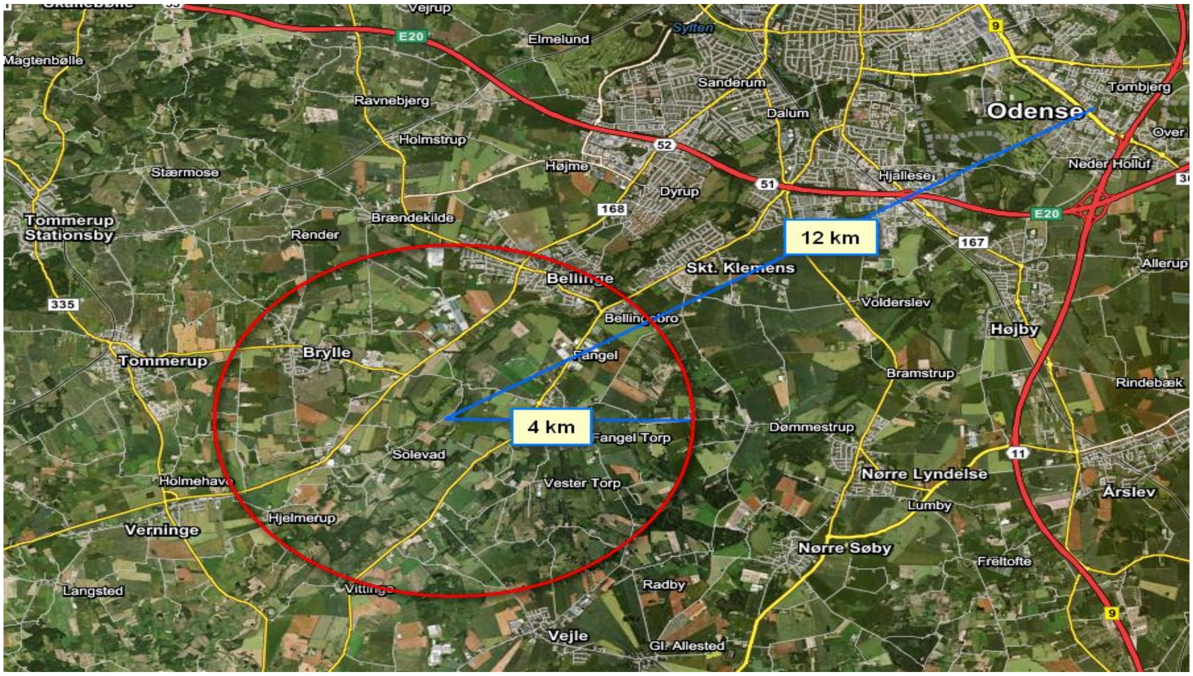
Description

Greenhouses are characterized by having a large heating demand and being very sensitive to the solar radiation and humidity. All together this implies that the heat load are fluctuating much more for greenhouses compared to ordinary family houses. It is expected that the dynamics of the greenhouses depend on the actual mixture of plants in the greenhouses.

The project can be seen as an extension of existing methods for Model Predictive Control of the supply temperature in district heating networks, as they exists in TERMIS TO (simulation based optimization) and PRESS TO (data and forecast based optimization). However, the solution will be published for potential integration in other systems for optimal operation of DH systems.

Available data

We will consider greenhouses in the area controlled by Fjernvarme Fyn. As shown on the figure below the greenhouses are situated around 12 km southwest of Odense. The consumption is recorded hourly as accumulated energy, accumulated volume flow, temperature forward and return. Weather observations are recorded (approx. 12 km +/- 4 km, see picture below). More specifically temperature, wind speed, wind direction, and solar radiation (global radiation spectrum 380-1100 nm) radiation hourly (running average logged every hour, raw data sampled every 1 minute). The meteorological observations are available from a site placed rather far (approx. 12 km +/- 4 km, see picture below) from the greenhouse.



Stochastic model for greenhouse hydro-thermal dynamics

Grey-box modelling techniques will be used to derive stochastic state space models for the hydro-thermal dynamics of a greenhouse. Compared to ordinary buildings the hydro-dynamical aspects play an important role, and have to be embedded in the model. The derived grey-box models can be used for model predictive control of the heating systems of the individual greenhouses.

Dynamic models for the DH network

Dynamic models for the relationship between the supply temperature at the plant and the supply temperature delivered at the greenhouse will be developed. Here two options exists: 1) use of TERMIS simulation models, or 2) used of PRESS dynamical models. It is, however, important the the models can be calibrated using data from the DH network.

Cost function defining the optimal control

It is expected that the cost function defining the optimal control will put a special focus on the cost of the energy supply, and with the expected future variation of the prices for the supply temperature levels the savings related to these variations might be large enough to motivate the use of time-varying indoor air temperatures. These temperatures must, however, be varied jointly with the lighting systems to ensure optimal production.

Model predictive control of supply temperature

The models and the cost functions will be used to derive new methods for optimal control of the supply temperature of DH systems. The predictive controllers will take advantage of load forecasts and forecasts of the prices. The controllers must be able to take into account the constraints given by e.g. constraints for variations of the water temperature in the network.

Deliverables

- Greenhouse observations (Fjernvarme Fyn)
- Weather observations (Fjernvarme Fyn)
- Weather forecasts (Fjernvarme Fyn / Enfor)
- Models for load forecasts (DTU Compute)
- Models for the hydro-thermal dynamics of greenhouses (DTU Compute/Neogrid)
- Controllers for the heat supply in greenhouses (Neogrid/DTU Compute)
- Controllers for the supply temperature from the plant (Enfor/Neogrid)
- Report (all)

Time schedule

April 2016 to June 2017