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Prediction of Solar Heating Plant Performance

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**Introduction**

- Denmark’s goal is to be CO₂ neutral in 2050
- More and more renewable energy
- >39% wind power in 2014
- >60% District heating (DH)
- >44% of DH supplied by biomass

**Solar heating in Denmark**

Fig 1: Installed solar collector area in EU in 2014 [m²]

**Facts:**
- 585,539 m² in EU, 66% in DK
- 14 out of 16 plants >10,000 m² in DK
- 1.3 mio m² in 2016 in DK
- Economy of scale → build large

**Problem of many renewables:**
- Depending on weather conditions
- Difficult to predict
- System imbalances
- Fluctuations of power prices

**Solution:**
- Improve forecasts of generating power and heat from renewables:
  - Objective: Predict thermal performance of large scale solar heating plants

**Reference plant:**
- Gram, 802 collectors, 10,000 m²

**Method**

Weather data → Model → Calculation of thermal performance → Plant data

**What you need:**
- Weather data: solar irradiation, wind speed and ambient temperature
- General plant data: location, size, orientation, tilt, collector type, etc.

**What you get:**
- Energy output, outlet temperature and volume flow rate

**Model characteristics:**
- Calculations based on basic heat transfer instead of efficiency expression
  \[
  \eta = \eta_0 - a_1 (T_{in} - T_{a}) + a_2 (T_{in} - T_{a})^2
  \]
- More complicated calculations, but accurate in off-design conditions
- Inlet temperature adjusted based on previous day
- Model chooses between:
  - Minimum volume flow rate \( V_{min} \)
  - Maximum outlet temperature \( T_{max} \)

**Results & conclusion**

- Entire plant modelled by single collector
- Constant time delay of 40 min to represent system inertia of the plant
  → Heat capacity of material
  → Running time of fluid through plant
- Validation based on reference plant using measured irradiation on the collector tilt, volume flow rate and inlet Temperature

**Example of 11.05.2015:**

**Calculated vs. measured energy output:**

**Conclusion:**
- Prediction of thermal performance possible
  → Reduced heat supply
  → Higher flexibility and stability
- Applicable for any location, plant and time
- Compatible with energy system optimization tools like Mentor Planner