1. Answer the following question briefly (6 points)
   (1) Explain why the COP of an air-to-air heat pump for heating is worse during cold days than in warm days?
   (2) Discuss briefly how to use thermal energy storage to deal with peak demand. You can draw a figure to illustrate.
   (3) Among the following technologies, choose three that are suitable for satisfying the base load for district heating or district cooling
      (a) Biomass based trigeneration
      (b) Gas boiler
      (c) Heat pump
      (d) Electric heater
      (e) Waste combustion
      (f) Oil boiler
      (g) Absorption chiller

   (4) Among three CHP cost allocation methods between heat and electricity, called Alternative heat generation method, Alternative power generation method and Benefit allocation method, Rank them according to the decreasing order of allocated heat cost.
   (5) Describe how water flow, temperature and pressure are controlled in the Finnish district heating system? (2 points)

2. Degree days (6 points)
   Let us define the following notation for the known parameters

   $S_{hel,2014}$: Heating degree days of Helsinki in 2014
   $S_{hel,2015}$: Heating degree days of Helsinki in 2015
   $S_{hel,avg}$: Heating degree days of Helsinki for ten year average
   $S_{oul,2014}$: Heating degree days of Oulu in 2014
   $S_{oul,2015}$: Heating degree days of Oulu in 2015
   $S_{oul,avg}$: Heating degree days of Helsinki for ten year average
   $Q_{hel,2014}$: Total heat demand of a given apartment building in Helsinki in 2014
   $Q_{hel,2014,space}$: Space heating demand of the same apartment building in 2014
   $Q_{hel,2014,water}$: Domestic hot water demand of the same apartment building in 2014

   (b) Give the formula for the normalized heat demand of the given building
   (c) Give the formula for the heat demand of the given building in 2015
   (d) Assume that an identical building is located in Oulu. Give the formula for heat demand of that building in 2015
   (e) Assume that a similar building, but with better insulation according to local condition is located in Oulu. Give the formula for heat demand for that building in 2015.

   Please use the given notation in the formulas.

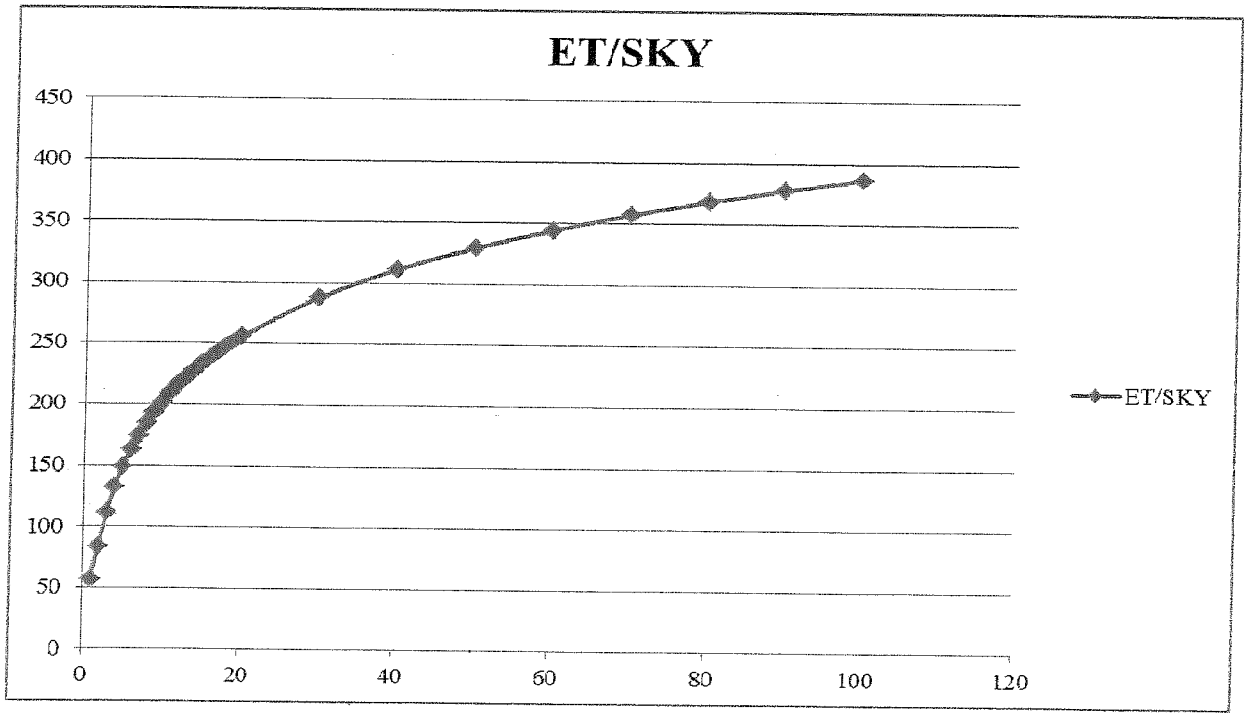
3. Cost-tariff (6 points)
An energy company has a biomass-operated trigeneration plant, a heat pump, an gas-driven absorption chiller for producing district cooling (DC). The table below shows the proportional capacity & DC energy production and variable & fixed (investment) costs of the DC production facilities and the network. The trigeneration costs are those allocated for the cooling production.

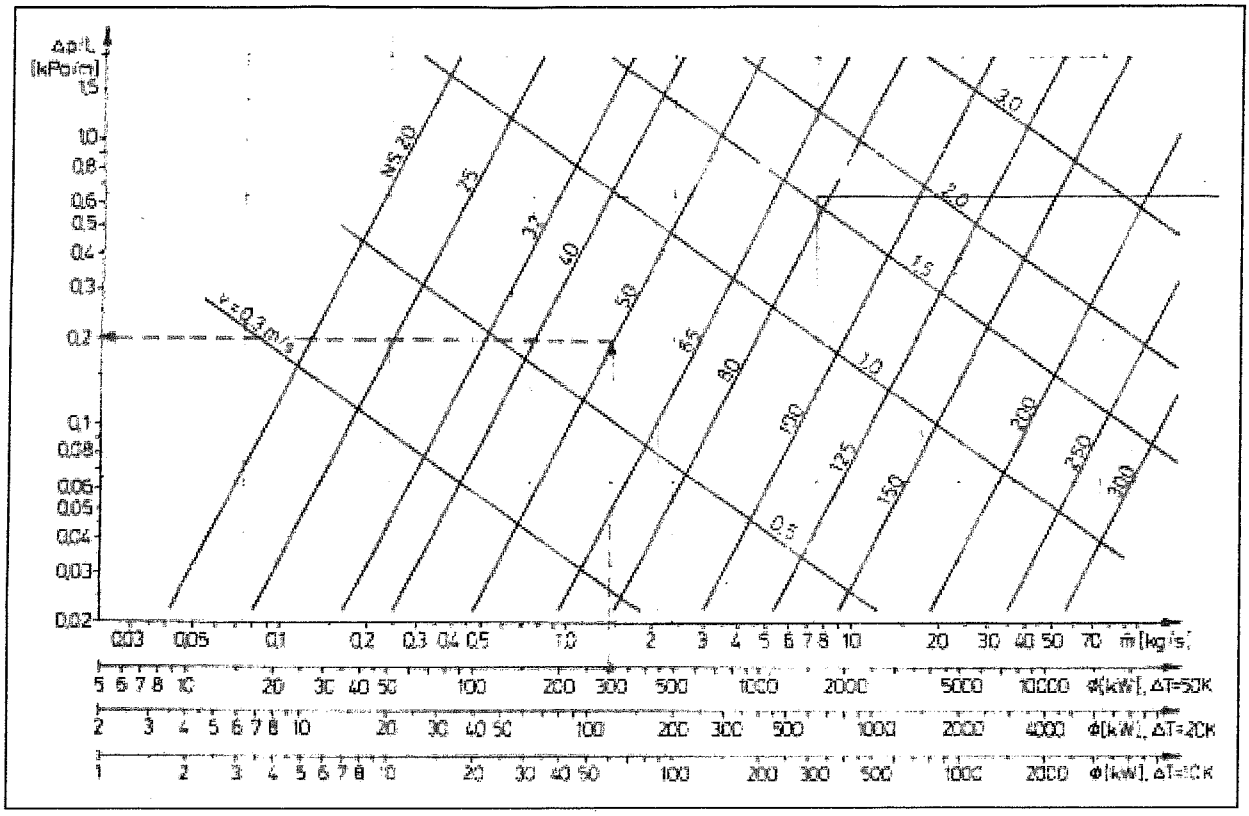
(a) What is the running sequence of these plants (base, middle and peak load)?
(b) Form the DC production cost tariff for the company.

Plant/*laitos*, fuel/*polttoaine*	Capacity Kapasiteetti	Energy Energia	Variable costs *Muuttuvat kustannukset*	Fixed costs *Kiinteät kustannukset*
Chiller/*jäähdytin*, natural gas/*maakaasu*	50%	5%	50 €/MWh	600 €/kW
trigeneration, biomass/*biomassa*	30%	50%	20 €/MWh	1200 €/kW
Heat pump/*lämpöpumppu*	20%	45%	35 €/MWh	2000 €/kW
Network/*jäähdytysverkko*			5.5 €/MWh	250 €/kW

(annuity factor a≅ 0.1 (year n=15, r=6%)

4. Pipe dimensioning (6 points).
What is the suitable steel pipe diameter to provide DH for 50 apartments, when maximum space heating power is 7 kW/apartment. Δt=40K, max pressure loss 1 bar/km. See diagrams on next page. ET/SKY diagram shows tap water heating power as function of number of apartments. To compute mass flow, use specific heat capacity of water c_p = 4200 J/kg,K.




Δp/L [kPa/m]
v = 0,3 m/s
m [kg/s]
Φ[kW], ΔT=50K
Φ[kW], ΔT=20K
Φ[kW], ΔT=10K