Semester assignment Part I: Trading and Control

Individual work

Concept

You are going to create a prediction and auction agent (PAA) that will be suited for trade in the financial and commodity market. The method to be used should be based on a neural network approach. The PAA should make advice about purchase and sale in the day-ahead-market. The test application should focus on electricity that constitutes a part of the Norwegian commodity market. Based on historical values the neural network exercise should create the basis for a system with 1 day "look ahead". This implies that the prediction must be asserted and shared with the bourse the day before the actual target date. The prediction should make a statement whether to sell or to buy on that day.

Each agent will be equipped with the following:

- A solar based generation facility with a peak capacity measured in kW and with generation profile dependent on how bright an clear the day is for generating solar power
- A daily consumption profile measured in kW per hour
- A temporary storage capacity
- License to sell an buy energy in the Nordpool Spot Market
- Access to free start capital

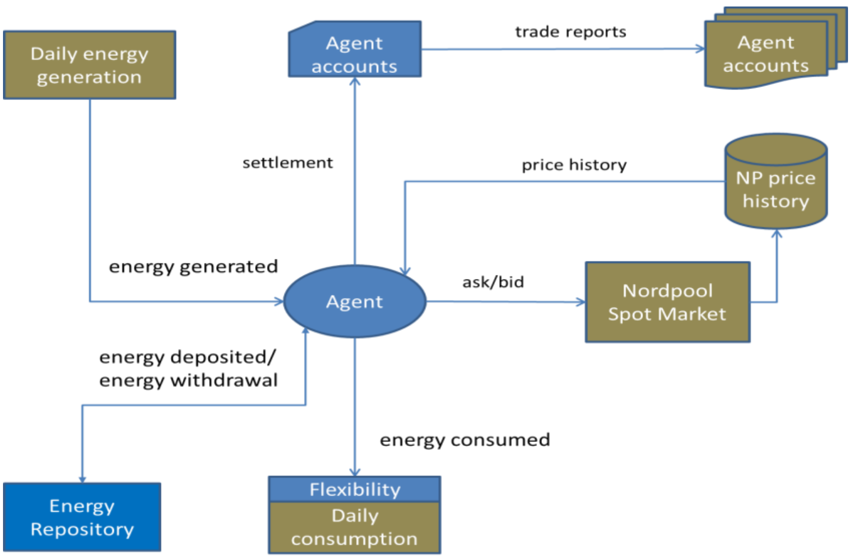


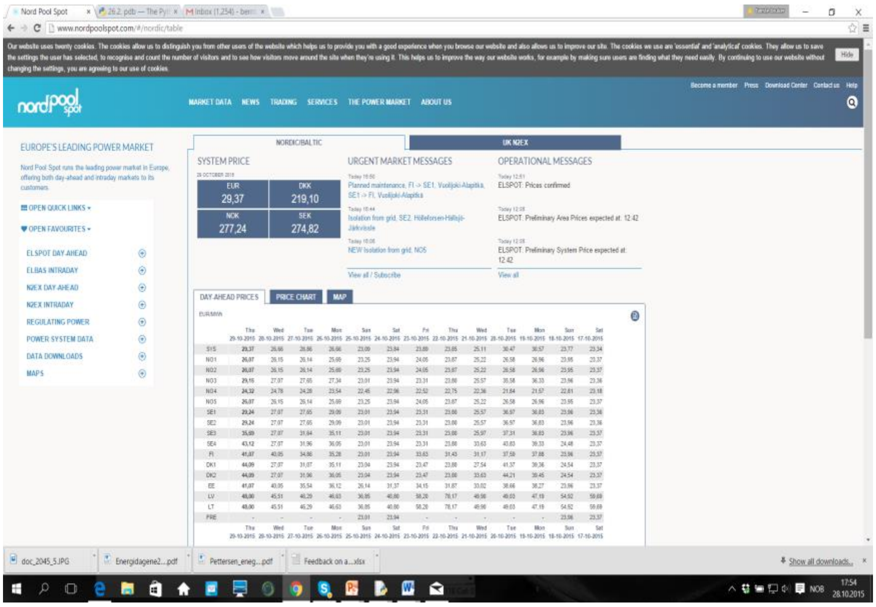
Figure 1 The agent and its interactions

It is up to the agent to decide how much it should buy, store and sell at all times. The agent is not able to control generation. However, some flexibility can be considered for consumption. This means that for certain hours consumption can be reduced by 15%. Such reductions are only allowed hours a day. The policy and actions needed to determine a competitive strategy must be decided by your agent. Should surplus energy be consumed, stored or sold the next day? How much energy should be bought for consumption or stored for future use? Here different techniques from the course might be applied.

Certain rules governed by the bourse must be followed. Bids and asks must be committed to the bourse by midnight before the day of trade. The reason for this is to let the market operator know the demand and supply for the next day so that balance can be achieved. The market operator is NordPool spot. In this exercise we create a dummy exchange that allows us to play the game. We will follow the prices on NordPool Spot, but will not place the agent's asks and bids in the actual market and play with real money. That is why a dummy market will be established. The crux of the game is that there is a degree of uncertainty. As self-interested agents they will seek the least cost and the maximum profit. This would generally suggest that the agent will sell when it thinks the energy prices will be high and buy when the price is low.   It might also buy and store energy when the prices are still low, and if the agent expects that prices will rise over the next few days. In the opposite case it might sell. Surplus energy needs to be sold if storage is full. Similarly, an exhausted storage capacity cannot receive more energy. It needs to be sold or consumed. Agents must learn the tactics of what suits it best.

These are the first questions that need to be answered: What is the best strategy? Can machine learning be applied to help the agent increase its knowledge and then improve its performance?

The sales or purchase order should be committed to the bourse before the target date no later than midnight the day before. In plain words it means that you are selling or buying a certain volume for an anticipated price. Settlement will be based on the actual price presented by NordPool on the actual day of trading. When this trading day arrives all bids are evaluated against this price which can be found on the web pages of NordPool. It is updated every day at noon. (see figure below)



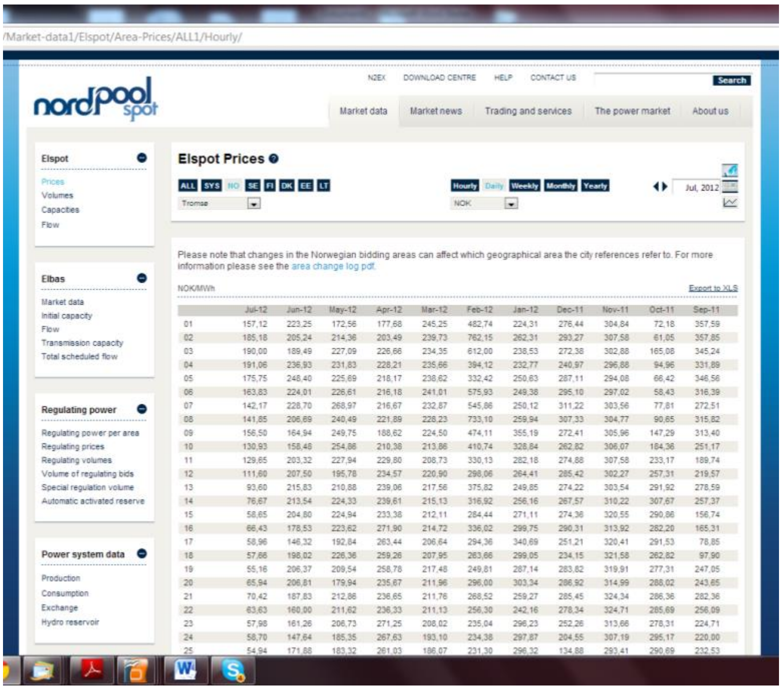


Figure 2 The NordPool website

All information that can be used to make the best prediction is useful. This determines whether your agent is able to sell or buy energy. Generation is uncertain, because it is dependent on the sun and the clouds. More information about consumption will be available. Predictions should be based on Neural Networks.

Records

Records must be maintained. Daily records of consumption, generation and storage level must be maintained and shared. Similarly all predictions must be recorded and shared. Records of bids and asks likewise. Finally the settlement must be marinated each day and the agent accounts updated.

Consequently a file needs to be stored and shared every day. This should apply the following format.

- Heading: Sold or Bought
- Name of agent owner:
- Date:
- Time of record:
- Sold/purchased: +/- volume (negative volume means purchase)
- Price:
- Debit/credit: (price * volume sold/purchased)
- Status accounts:
- Generation this day:
- Consumption this day:
- Storage level:
- Actual temperature from Yr.no
- Actual weather from Yr.no

The commitment to the market for the next day is also recorded together with the predictions made:

- Heading: Expectations
- Name of agent owner:
- Date:
- Time of record:
- Anticipated price
- Ask/bid: +/- Volume committed
- Forecasted temperature from Yr.no
- Forecasted weather from Yr.no
- Predicted consumption
- Predicted generation

Both records will be kept in a file that must be exported to a folder maintained by the bourse.

Predictions

Historical records from NordPool (http://www.nordpoolspot.com/Market-data1/Elspot/Area-Prices/ALL1/Hourly/) (see also figure 2) and www. YR.no constitute the basis for training. The latter provides forecasts for sun and temperature.

For price be careful to use the daily system price. Use a LTSM Neural network. Training should be based on a X day running prediction window where X is either a week or a month. This means that you create an input vector of minimum X nodes. The factual value determining the iteration is the price on the day X+1. In other words the system uses the prices for the X days prior to the target day to estimate the price for that day. Based ton he value of X that yields the best relative result. Once training is completed you can transfer the architecture and weights to your agent. Decide the number of iterations and epochs that you need and inject the final network in your agent.

The weather forecast for noon the next day determines anticipated generation and consumption. The actual weather and temperature on the day of trade determines the actual generation and consumption.

Both actual and forecasted generation/consumption can be expressed with these formulas:

Consumption = 50 + 100 *(25 – t) [kwh/day] where t is outdoor temperature at noon and t < 25C

Consumption = 50 [kwh/day] when t >= 25C

Generation of energy is a function cloudiness and daylight. We will assume summer conditions when it comes to sunlight. Consequently electricity will be generated during the hours between 7 o'clock AM until 7 o'clock PM. During those hours the following formula for generation will be applied:

Generation =12 * peak power * R [kwh/day]

Peak power is: 20 kW

R is dependent on cloudiness and is:

Clear skies- full sun (Klarvær): 1.0

Lightly clouded (Lett skyet) : 0,7

Partly clouded (Delvis skyet) : 0,5

Cloudy (Skyet): 0,3

Rain (Rain/snow): 0,1

Storage has a max capacity of: 900 [kWh]

Agent

Define a simple set of rules to reflect your trading policies. Improve the performance of your agent with simply machine learning. Include the execution part of the neural network into the agent (weights and architecture). The agent should be able to take the prices of the last X day where index 1 of X (x1) is the date of the actual calculation from NordPool. The agent should then predict the price, generation and consumption of day X+1 (tomorrow's price). Based on this the agent should determine whether to sell or to buy and how much to store. Next it should decide the volume of purchase or sale and make a nomination. Purchase is limited to the funds available. Sale is limited to the assets (energy) available. Storage space can never be exceeded. These constraints should never be violated. If there is a mismatch between your predicted volume to buy and your actual need you simply have to discard it, unless you are able to store it. If you sell more than you can deliver then you will have to pay for the difference. This will be deducted from your account.

The nomination is passed on to the bourse before midnight. By 18:00 o'clock the next day the trade will be settled. If sale is granted the volume traded (<= volume nominated) and the sales income (volume traded * price nominated) will be returned. The reward will be added to the agent's funds. The delivered volume will be deducted from the agent's assets. If energy is purchased, the energy received will be added to the agent's assets. The payment for this will be deducted from the agent's funds.

Each agent will be initialized with 6000 NOKs. Each agent will start with assets equivalent to 100 kwh in their storage. A seller can never sell more than is accumulated at all times. A buyer can never exceed the limits of the funds that he has available at all times.

Plan

Carry out your work in steps according to the following plan:

Preliminary steps

Determine the basic rules of operations and determine what ML approaches could be used to increase performance of your agent during operation. Determine which NN code you wish to use. Could other sources be used to increase predictions? Present on Friday Oct. 30.

NN training

Select LTSM network component from a Python library or similar. Start creating your network. Train and test on price history from NordPool. Follow the rules for training. Determine the rules of operations and start testing the ML technique that you have chosen.

Testing and tuning

Test your system over a month to determine the accuracy of your system.

Demonstration

You might be asked to demonstrate your system before finalization.

Reporting

Report should follow a standard UiT report template.

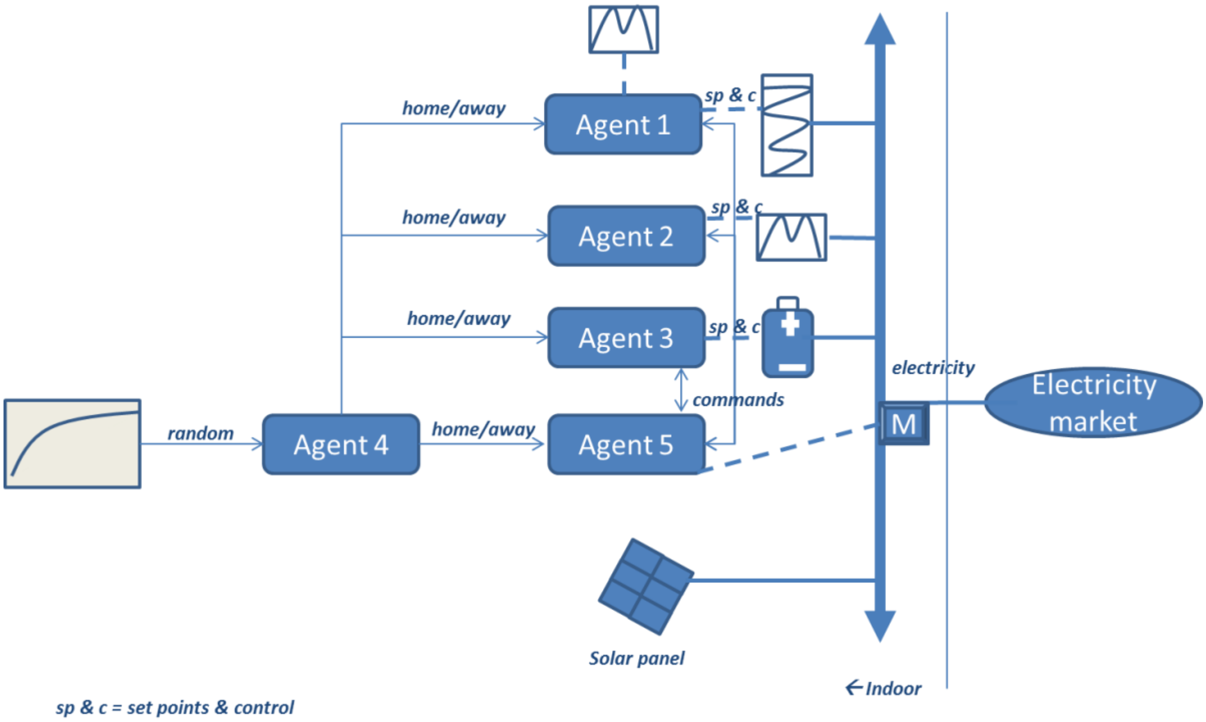
Semester assignment Part II: Prediction and trading system

Individual work

Concept

You are going to create a suite of control and trading agents for assignment Part II. These agents constitute the basic platform for a smart home installation in a house that is going to be built. The building will have solar panels and is also equipped with multiple devices and gadgets under the agents' control. This includes a battery. However, it cannot be discharged to a lower level than 20% of the full capacity.

The agents should be initialized and their activities monitored from a single panel. For simplicity we will reduce the number of controllable energy loads. However, we will allow the possibility for trading (buy/sell) energy in the NordPool market every day.



Agents

These are the agents:

- Agent 1 controls the heated floor in the bathroom and the boiler. The temperature in the bathroom when the house is inhabited must be within a specified interval to maintain comfort. The highest temperature in this interval implies the best comfort that is possible to achieve. The hot water maintains a temperature of 75C.
- Agent 2 controls the central heater that assures that the house maintains a comfortable temperature when people are at home. Similar considerations as for Agent 1.
- Agent 3 controls the battery. This agent controls a battery management system (BMS) that charges and discharges the battery.
- Agent 4 controls the security of the house and makes sure that the doors and windows are closed and secured when people leave the house. This agent emits a Home/Away signal too. This information is used by the other agents.
- Agent 5 makes decisions about purchase and sale of energy to and from the market.

The objective

The objective is to create a self-learning Home Automation System (HAS) that minimizes the cost of energy (or even makes a profit if possible). This will be managed by software agents.

Abstract

The family members work and go to school at regular hours, apart from Saturdays and Sundays. The probability for being home and away can be described as P(Home) = 1 – P(Away) and the histogram with these probabilities are found at the back of this document. A Monte Carlo engine that picks random numbers in the interval [0,1] drives the daily routines, hour by hour. Example: If a random number generates 0,6 and the probability for being home is 0,76 then the house is occupied. If it generates another random number i.e. 0,8 the house is vacant. This is the method to be used.

When the other agents receive a signal from the security agent (No. 4) that the house is in the AWAY or HOME state they will respond accordingly. Agent 1 and Agent 2 will reduce the set temperatures when in AWAY mode and restore the original levels in time before the family gets home. When set temperatures are lowered the electricity consumption per hour goes down.

Agent 3 will use every opportunity to request energy to recharge a battery which is not full. Energy levels must never fall below the 20% level. However, the request for energy must be accepted by Agent 5 that monitors the energy flow of the building. On the contrary Agent 5 will request Agent 3 to fill up energy if the price in the market is affordable or if there is a surplus from the solar panels.

Agent 5 figures out how much energy the solar panels will produce by checking the weather forecast. It also estimates the price the next day and decides how much to sell or buy every day to sustain the necessary consumption and to keep the battery in shape.

Agents 1 and 2

Agents 1 and always pursue the best possible comfort in every state. They cannot negotiate the signal from Agent 4 so it must shift to set points Home or Away. But beyond that they demand the best possible comfort and will get as much electricity for that as possible. Agent 1 and 2 sells comfort for a price. This is seen as a penalty by Agent 3 when he considers a reward for a given state. This determines the R and in turn the Q-Value for the state action pair.

Actions that they can do:

- Maintain max comfort
- Yield to Agent 4 on Home/Away signals
- Disconnect or reduce set point on demand from Agent 5 for a penalty
- Expected value for one kWh in reduced comfort is 20 credits.

Agent 3

Agent 3 maintains the battery. It always wants to keep the battery full. But it must yield when Agent 5 provides instructions for discharging.

Actions that it can do:

- Pursue max energy capacity
- Discharge the battery on demand from Agent 5 for a penalty
- Expected value for one kWh in reduced battery level is 5 credits.

Agent 5 is a Q learner

Agent 5 is a Q-learner. It must learn how to minimize the cost of energy for the benefit of the household while maintaining the comfort levels that the other agents wish to maintain. It sells surplus energy to the market for 0,3 NOK and buys for 1,2 NOK between the hours 6-24. Between 0 and 6 it pays 0,8 NOK. Obviously it is a good deal to spend as much

Actions that it can do:

- Manage balance between demand and supply at all times
- Buy and sell energy
- Minimize cost
- Request support from Agent 3 battery for a price
- Request support from Agent 1 and 2 to reduce consumption for a price

State chart

Start by creating a state chart for all agents and in particular Agent 5. Then construct the R and Q matrix. Here is a tip.

Agent 5 may find itself in three different major states. Balance, Negative unbalance and Positive Unbalance. By balance we mean that there is perfect balance between supply and demand and there is no need to do anything. However, in order to secure the same state in the next hour the demand and supply must be calculated. If there is more consumption than supply (which happens most often) this Agent must perform one or more of the following actions: Buy externally, discharge the battery or reduce consumption. The mix determines the optimal state. Similarly, if there is positive unbalance the agent must sell, charge the battery or increase the demand.

One way to specify a state space for negative balance would be:

State Kwh unbalance / Action	-4	-3	-2	-1	0
Buy 1kWh	Price	Price	Price	Price	Reward - price
Discharge 1kWh	Price	Price	Price	Price	Reward - price
Reduce load 1kWh	Price	Price	Price	Price	Reward -price

The idea is to determine the most optimal mix and strategy to handle the problem. A similar state space could be constructed for positive balance. You might split this up for Away and Home too.

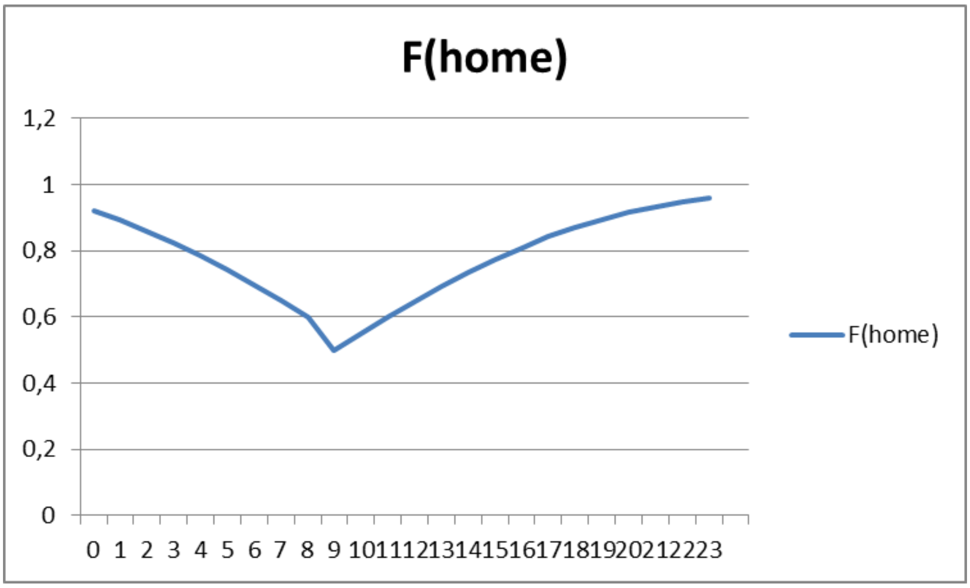
Simulation

Run the simulation for 100 days using the Monte Carlo approach. Run 6 replications. Find out how Agent 5 learns. Record and document the performance. Reinitialize before each run.

Computational support

Probability for being home and away. P(Away) = 1 – P(Home)

The cumulative probability for being home consists of two functions connected at hour 9 each day.



F(home)	0,92	0,891	0,859	0,823	0,784	0,741	0,696	0,649	0,6	0,5	0,55	0,599	0,646	0,691	0,734	0,773	0,809	0,841	0,87	0,894	0,92	0,9	0,9	0,96
Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

Consumption - Boiler

0,5 kW per hour. It is either on or off. Set point temperature in boiler can hold for 3 hours. After disconnection it consumes 2kW for the first hour, then 0,5kW.

Consumption - Heated floor

Consumption = 0,2 + 0,5 *(s – t) [kwh/hour] where t is outdoor temperature at noon and t < s

S is the temperature set point measured in Celcius. It must be between s ϵ [23,25] when Home

S is the temperature set point measured in Celcius. It must be between s ϵ [20,23] when Away

Consumption = 0,2 [kwh/hour] when t >= S.

Get a data set for the outdoor temperature per hour from YR.no

Consumption - Central heating

Consumption = 0,8 + 1 *(s – t) [kwh/hour] where t is outdoor temperature at noon and t < s

S is the temperature set point measured in Celcius. It must be between s ϵ [21,23] when Home

S is the temperature set point measured in Celcius. It must be between s ϵ [18,21] when Away

Consumption = 0,8 [kwh/hour] when t >= S.

Get a data set for the outdoor temperature per hour from YR.no

Battery

The battery charges at the rate of 1kW/h

The battery discharges at the rate of 1kW/h

The battery capacity is 7kWh. It can never be lower than 20% of its capacity.

Solar panel

Generation of energy is a function cloudiness and daylight. We will assume summer conditions when it comes to sunlight. Consequently electricity will be generated during the hours between 6 o'clock AM until 7 o'clock PM. During those hours the following formula for generation will be applied:

Generation =20 * peak power * R [kwh/day]

Peak power is: 0,25kW

R is dependent on cloudiness and is:

Clear skies- full sun (Klarvær): 1.0

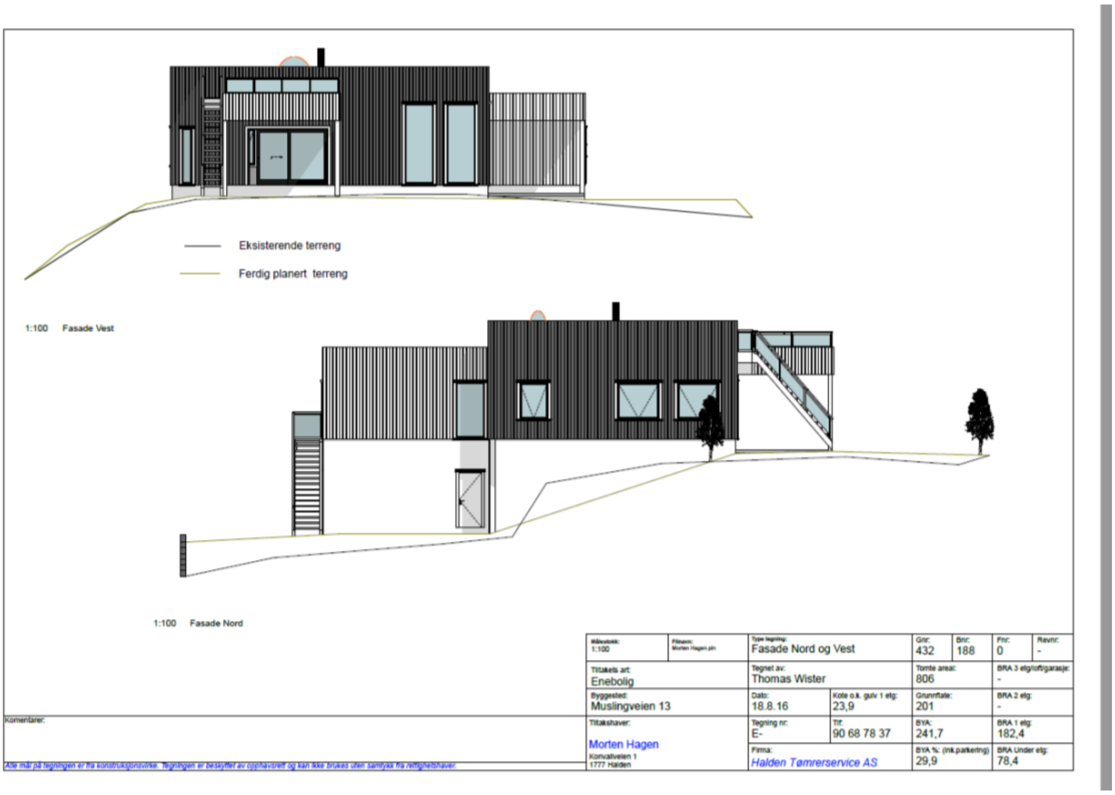
Lightly clouded (Lett skyet) : 0,7

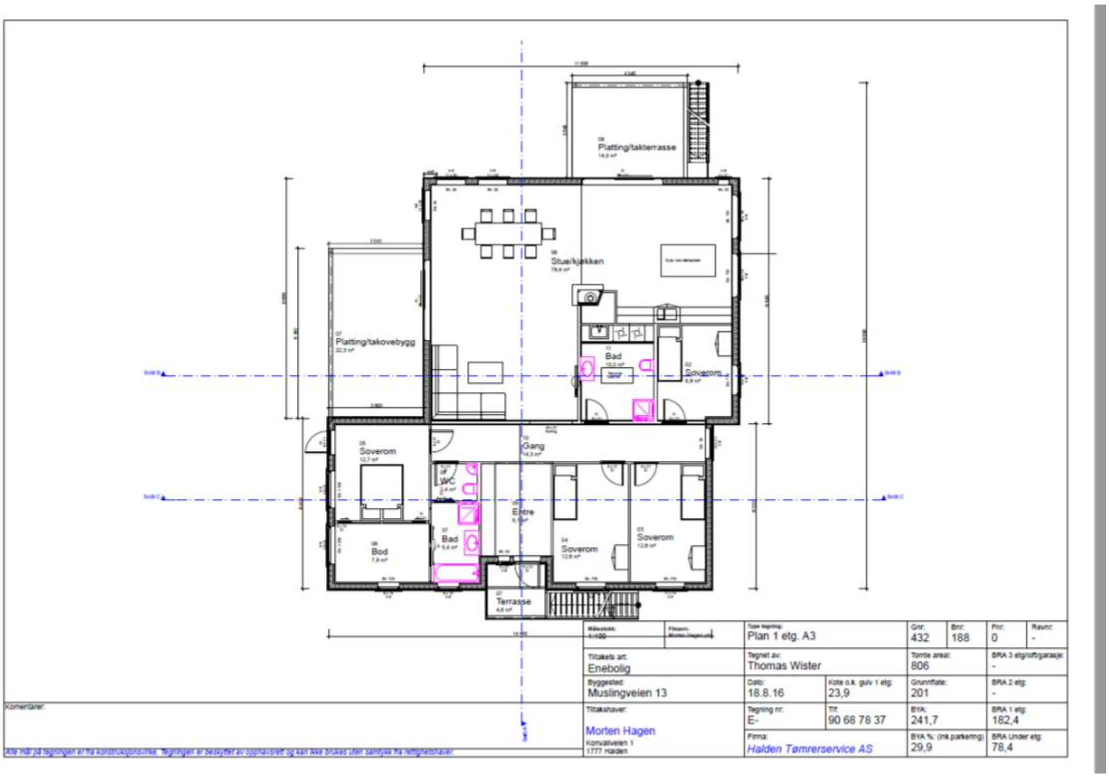
Partly clouded (Delvis skyet) : 0,5

Cloudy (Skyet): 0,3

Rain (Rain/snow): 0,1

The house





Currency

Energy and comfort need a common currency. Externally the price of energy is traded in NOK. Price (p) of energy varies between 0,2 – 0,5 NOK/kWh. Tariff and tax impose an extra cost of energy per kWh. The total cost per kWh can be set to (p + 0,5) * 1,25.

Internally the cost of energy and comfort is traded in credits. At this time it is uncertain what the conversion factor is, but you may assume 10 credits per krone.

Report

Document your work in a structured report and upload your results (code, executable etc.)