

# Energy Commodities, Operational-Production

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## Total gas recovery maximization

### Mathematical models

In the short term operation, the most important problem is related to the **Total Gas Recovery Maximization**. In order to withdraw as much natural gas from a reservoir as possible, one option is to use waterflooding. This leads to the problem of finding an optimal water injection rate with respect to different objectives, such as the maximal ultimate recovery, or the total revenues. Indeed there are several objective functions due to different aspects of the problem.

### Modeling and algorithmic considerations:

Consider two wells drilled on the surface of the gas reservoir, one for gas recovery and one for water injection. Therefore, let  $r(t)$  denote the withdrawal rate of gas which is bounded by the maximum rate of gas extraction  $r_m(t)$ . Through the water injection, well water is injected into the reservoir at the nonnegative rate  $s(t)$ . This model assumes a constant  $g$  which is the ratio of gas entrapped behind the injected water to the volume of water at any time. The model aims at maximizing the ultimate gas recovery and can be posed in a nonlinear form. Some author discuss other several other objective functions. For example, the objective function to maximize the present worth value of the net revenues for internal rate of return.

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## Combined Heat and Power Production Management

### Introduction

The future development of energy production and distribution relies on the combined exploitation of different, renewable energy sources, each one with its own costs and profits, sometimes dependent on weather and/or daylight hours (e.g., thermal solar). In this context Combined Heat and Power (hereafter CH&P) assumes a increasing relevance due to its high efficiency when compared to conventional condensing power plants.

We consider CH&P Energy production optimization a tactical and operational issue, because the management cycle has a yearly horizon and subsequent short term planning, with the aim of maximization of EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization).

### Mathematical models

The Mixed Integer Linear Programming (MILP) problems arising in this business are particular cases of the well-known Unit Commitment (UC) problem (see, e.g. \cite{padhy2004unit, wood2012power}), in which the goal is to determine how to dispatch the committed units in order to meet the demands and other constraints cost-efficiently. As presented in \cite{bettinelli2016}, a plant manager has to serve one or more demands (heat demand mainly, but also chill demand and/or electricity demand if the plant is connected to a building or to an industrial facility) and these demands can be satisfied by producing energy using different machines, depending on the plant configuration and the various economic drivers of input and output commodities. Also, if the electricity produced by the plant is sold to the National Electricity

Network, there is an additional variable (the amount of energy sold) and an additional constraint (the amount of electricity committed to the market the day before for the following day).

Manual management relies on several elements to manage the typical business processes:

- budgeting, to define the overall energy production for the year to come;
- revised budgeting, to modify the budget objectives on the basis of the results of (at least) the first semester;
- weekly and daily operations, most of the times based on the experience of the plant manager (in respect of the previous years).

The goal of a plant manager is to satisfy the customers' demands by choosing the best energy production mix to maximize the EBITDA. Consequently, the decision-making process must take into account the following factors:

- costs, profits and fiscal advantages (if any) of each energy source;
- technical constraints of the plant itself and of the machines;
- regulatory constraints;
- ordinary and extraordinary maintenance requirements.

For each machines, the workload has to be optimized for each time window. Possible non-linear efficiency curves of the machines are can be approximated in non-convex piecewise linear functions and linearized in the model. Time is discretized in a finite set of time intervals, having a duration defined by the user. Smaller time windows yield to more detailed production plans but also increase the size of the associated problems and the corresponding computational effort required for their resolution. Fiscal advantages, as well as power production regulatory constraints are defined by the legislator over indicators that measure the performances of the plant over a solar year and play a fundamental role in economic terms, since strict respect of certain energy/heat rations is the condition to leverage on incentives that are often fundamental to economic sustainability of the plant. This explains why even for operational day-ahead optimization, an extended time horizon including the entire month or, more often, the remaining part of the solar year should be considered. The presence of thermal energy collectors, as well as plant-specific period constraints (maximum number of start-up over period) are other examples that binds together what otherwise may be considered as single time-windows problems.

## Optimization methods

UC problems, even when CH&P is not considered, are complex in practice. The solution methods used to solve UC problems span from Lagrangian relaxation, as proposed in (Borghetti, 2003) and (Li, 2005) to genetic (Kazarlis,1996) or Tabu search (Mantawy,1998) heuristics. Attention has been put as well on obtaining efficient MILP formulations (see e.g. (Carrion, 2006) and (Ostrowski, 2012)). Interdependencies between power and heat productions make realistic CH&P power units even more difficult to be optimized (Song, 1999). In some cases general purpose MILP techniques are applied, such as the Branch and Bound (see (Illerhaus, 1999)). Resolution methods may otherwise rely on time-based decomposition, as in (Lahdelma, 2003), dynamic programming (Rong, 2009) or again Lagrangian relaxation (Thorin, 2005). In the business case considered in (Bettinelli, 2016) a Matheuristics based on time and machines decomposition have been implemented to reach near optimal solutions in a reasonable amount of time. The key idea of the heuristic strategies consists in the resolution of several easier sub-problems rather than directly addressing the original large MILP formulation.

## Data and Software

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