The Optimal Design of a NOME-type Regulation in Greece[1]

Report prepared for the Greek Regulatory Authority for Energy[2]

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Final Report v.1 - July 2013

Chapter 5: Mechanisms for Capacity Allocation

Introduction

In this Section, we present the main alternative mechanisms applicable for the allocation of the NOME capacity. We also assess each of these mechanisms in terms of its main merits and disadvantages. Based on this first assessment, we select two mechanisms as the most appropriate ones, and we study and assess them in further detail. We consider two main types of mechanisms, namely rationing rules and auctions, and subsequently some mechanisms combining features of both types.

We assume that the following important parameters and features are exogenous to the mechanisms to be considered, and will have been decided by RAE prior to running the mechanism to be selected:

- The percentage α of the total lignite capacity K_λ of DEH[6] that will be allocated at most to the alternative providers[7].
- The value of the parameter φ specifying the proportions of lignite and gas productions in the NOME mix to be formed by the alternative providers.
- The reserve price r_α per unit of lignite capacity[8].
- The type of NOME contracts: We assume that the lignite capacity is offered only for constant-load contracts; that is, an alternative provider buys a constant band of lignite capacity applicable for all 24 hours of the day (regardless the hourly

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[1] We are grateful to Claude Crampes and Patrick Rey for useful discussions concerning the analysis contained in this report. Of course, all errors, ambiguities and omissions remain solely our responsibility.

[2] We are grateful to Eleni Metsiou and Angeliki Anastopoulou for research assistance during the preparation of this report.

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[6] For simplicity of the exposition we assume that the capacity of the DEH to be allocated to alternative providers is part of its lignite capacity only; our still study applies if we also assume that part of the hydro capacity is also allocated by means of NOME.

[7] To be consistent with the notation employed in other parts of the present study, the i-th alternative provider will be denoted for brevity as E_i.

[8] In fact, this applies to all mechanisms to be considered, except for that of multi-unit Dutch auction.

variations in demand) that covers a long time period, which is common for all providers.

Note that the maximum allowable quantity for a player E_i according to the constraint imposed by the parameter φ is $[\varphi/(1-\varphi)]* K_{gi}$, where K_{gi} is the gas-based production capacity of E_i; e.g. see Section 3, constraint in equation (19). Therefore, the value of the percentage α should be such that $\alpha*K_\lambda \leq [\varphi/(1-\varphi)]*(K_{g1}+\ldots+ K_{gn})$, where n is the number of alternative providers. It is henceforth assumed that the parameter α does obey this constraint, and thus all the lignite capacity of DEH made available (namely, $\alpha*K_\lambda$) can possibly be purchased by the players, if of course it is beneficial for them.

Note that in order to keep our analysis as general as possible, we assume the alternative providers can be potentially asymmetric, in terms of their gas-based production capacities, although we take that they have the same marginal costs of these productions. This situation may not accurately describe the situation of the current three alternative providers in Greece (whose gas capacity is similar), but is more consistent with what will emerge in the medium and long run when alternative suppliers will participate in NOME. Also, without loss of generality we can assume that a maximum value for the price p_α per unit of lignite capacity will also be applicable, either as an explicit constraint or because the price will never exceed some level in practice. E.g., we can assume that, for policy reasons, RAE will not allow that the lignite capacity is sold at the marginal cost of gas-based production c_g or higher; our analysis of wholesale market models in Sections 2 and 3 is based on this assumption. Moreover, if in the course of some mechanism, the price p_α exceeds some high enough level, then the alternative providers will not have the incentive to participate in NOME anymore, because they would make lower profits than without NOME. This is also undesirable for RAE, because even if one player abstains from NOME, then the market price may only increase.

Requirements for RAE

The assessment of the appropriateness of each of the mechanisms to be presented depends on both a multitude of more generally applicable criteria as well as on the goals and requirements of RAE on the wholesale and retail markets to emerge under NOME. In particular, regarding the general criteria employed for the assessment of mechanisms (most often auctions), their list is really long, and usually includes the following:

- social efficiency attained, i.e. opting for mechanisms that lead to allocations that maximize the total value to buyers and/or more generally to the society; this implies that the mechanisms used should also allow for differences in efficiencies among bidders to influence the outcome;
- seller’s profit;
- bidders' profits;

- time to run the mechanism;
- implementation complexity, i.e. opting for mechanisms that can be implemented in practice more easily and with lower administrative overhead;
- simplicity of rules of the mechanism;
- simplicity of strategies, i.e. opting for mechanisms for which bidders can easily determine their own optimal strategies;
- susceptibility to collusion, and implications of collusion to the outcome attained.

Most of the above criteria are to a large extent applicable to our case too. Yet, it is worth making certain interesting remarks: a) seller's profit actually refers to the profit of DEH and is clearly at odds with bidders' profits, due to the somewhat particular feature that the bidders will subsequently compete with the seller; b) susceptibility to collusion is in general considered a disadvantage of a mechanism, because it tends to restrict the profits of the seller; in our case, facilitating collusion may overall be beneficial, as will be discussed in detail later in this Section; c) in the specific context of the Greek market the E firms do not differ in efficiency (they all have the same marginal cost), so differences in efficiencies is not a factor that may justify asymmetric outcomes whatever the mechanism that is used; only differences in quantities of gas-based production can justify asymmetries in the lignite capacities to be allocated.

Regarding the requirements of RAE for specific case of NOME, it should be noted that the outcome of each mechanism determines:

- the allocation of lignite, and hence the level of symmetry among players in the wholesale market, which without NOME is heavily asymmetric with DEH having much more capacity than the alternative providers, and
- the price p_α at which lignite is purchased by the alternative providers.

Therefore, the outcome of such a mechanism feeds the wholesale and ultimately the retail markets, and thus determines the market equilibria when these providers compete subsequently with each other and with DEH. These equilibria have already been analyzed very thoroughly in this study, as a function of the NOME parameters, by means of two models; namely, for the "extreme" cases of uniform-price auction mandatory pool (see Section 2) and for competition with OTCs only (see Section 3). Therefore, for the final selection of a mechanism it is necessary to:

a) first identify more specifically the desired equilibria (using the above models for the wholesale market) together with the price p_α and the other parameters that have to be chosen by the regulator (i.e. the total fraction α of the DEH lignite to be offered through NOME contracts and the allowed parameter φ of the NOME mix) in order for these equilibria to arise, and

b) then decide on the precise mechanism for NOME capacity allocation whose outcome (i.e., the NOME price p_α and the allocation of the lignite among the providers) will influence the deregulated market under NOME in such a way to lead to these equilibria.

In our study of mechanisms to follow, we refrain from making use of the exact equilibria for the wholesale market under NOME. On the contrary, we resort to certain important properties thereof revealed by the analysis of the two models for wholesale market. These lead to certain desired (for RAE) properties for the outcome of the mechanisms to be considered. At the same time, we have to take into serious account the strategies to be employed by the players under the various mechanisms for allocating to them the NOME lignite capacity. Indeed, the outcome of a mechanism is effected by the strategies of the players, who choose them so as to optimally serve their own interests (i.e. profits) in the framework imposed by the rules of the mechanism.

Therefore, the appropriateness of each mechanism will be assessed by examining whether it gives rise to an outcome with the desired properties when the players follow their own self-interested strategies determined by their own incentives as well as by the rules of the mechanism.

Regarding properties desired by RAE on the outcome of the mechanisms, we note the following:

- A first such property is that equilibrium wholesale prices, in both OTC and uniform-price auction models, are lower when DEH competes with three (and in general with multiple) alternative providers rather than with one, due to the extra competition among the alternative providers themselves[9]. This implies that, according to the objectives of RAE, the mechanism to be selected should allow for the former possibility. Therefore, we will not consider mechanisms where the entire lignite capacity is "packaged" in a single contract to be allocated to a single alternative provider; e.g. the player giving the highest offer for it by means of a single-item first-price sealed-bid auction or in a single-item English auction. Hence, we reach an important requirement of RAE for the NOME mechanism regarding the allocation of capacity, namely that mechanism should allow for the flexible apportioning of the lignite capacity among multiple alternative providers. Of course, the outcome of such a mechanism need not necessarily be symmetric. However, if any asymmetries arise, this will be due to the demand of the alternative providers, rather than to restrictions of the mechanism. All mechanisms studied below have this property.
- We have also studied in the analysis of the wholesale market under the uniform-price auction model certain properties on the effect of the price p_α in the equilibrium wholesale price under NOME, which coincides with the cost of the NOME mix c^α_E for low enough demands. In particular, there arises an interesting

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[9] Note that while additional players may not affect prices in the very simple Bertrand oligopoly models with symmetric players with the same marginal cost and unconstrained capacities, this is not true in more realistic setting such as the ones we analyze in our case, due to the capacity constraints.

trade-off in such low demands, whereby increasing the price p_α of lignite has two effects: a) the level of the equilibrium price at c^α_E in low demands is increased, but b) at the same time the range of demands for which this low price equilibrium applies is broadened to include higher values. Therefore, for some demand values close to but higher than the threshold for this equilibrium under a certain price p_α (hence with the equilibrium price being at the marginal cost of gas-based production c_g or higher), a higher such price leads to a lower wholesale equilibrium price (at c^α_E) because the aforementioned threshold now exceeds this demand value. This applies because, by increasing p_α and hence increasing the cost of the NOME mix c^α_E, the equilibrium at the price of gas becomes less profitable for DEH compared to undercutting the price of the NOME mix, since in the latter case it serves the complete demand.

- A similar observation applies to the model of the wholesale market with OTCs, according to the analysis of Section 3 (pages 17 – 19). This effect can be briefly explained similarly as above. Indeed, when p_α increases, the marginal cost of the NOME mix increases. This increases the incentive of DEH for undercutting, because now equilibria resulting from undercutting, and thus getting a margin of c^α_E - c_λ , where c_λ is the marginal cost of lignite, are not that "bad" for DEH, since this margin increases with p_α. This fact implies that a higher demand is necessary in order for DEH to have an incentive to raise to its price to P_{max} rather than undercut, thus limiting the range of demand values for which high-price equilibria apply.

Thus, according to the discussion above, another property for the NOME mechanism applying to both models of a wholesale market is that keeping the price p_α of the lignite capacity as low as possible (i.e. at the level of the reserve price r_α, or very close to it) is not necessarily preferable for RAE for a range of low to medium demand values.

To summarize, the effect of the price p_α for fixed demand values (rather than to a daily demand-profile with hourly variations) is as follows:

- Low price: a price increase has a negative effect for low demand, since it leads to an increase of the equilibrium wholesale price under NOME, namely c^α_E. At the same time, a price increase can have a positive effect at medium demand, by leading to a reduction of the wholesale equilibrium price at a lower level (in the uniform-price auction model, reduction from c^α_E to c_g applies).
- Medium price: Once the above effect indeed happens, a further price increase has a negative effect at both low and medium demands, since it leads to an increase in c^α_E.
- High price: alternative providers may decide not to participate in NOME, which leads to an increase in the wholesale equilibrium price for low and medium demand values.
- For high enough demand, the wholesale equilibrium price is P_{max}, both with and without NOME; thus, the price p_α has then no effect.

Overall, as far as the NOME access price $p_α$ is concerned, the basic requirement of RAE is just that the NOME mechanism should not lead to very high prices $p_α$ so as to ensure participation of the alternative providers. This can be either enforced explicitly by the rules of a mechanism, or it can be brought about by the incentives of the alternative providers and their adopted strategies, as will be argued below.

Players' Demand Function and Strategies

Next, in order to assess any such mechanism (and its outcome), we turn attention to the strategies of the players (i.e. alternative providers) to be adopted when "playing" in the NOME mechanism. To this end, we should first study the demand of the players for units of the good sold, namely the lignite capacity of DEH, as a function of the price $p_α$. For our case of NOME, the purchasing of lignite capacity by some player E_i generates value to him due to the fact that it will be resold in the market (either in the wholesale or directly in the retail), subject to both the restrictions of: a) being mixed with gas-based production at the proportion implied by the parameter φ; b) incentive compatibility, that is, player E_i should be making higher profits when NOME is applied and the player participates to it by purchasing the lignite capacity that leads him to the highest possible profits, rather than when the player does not participate in NOME; below, we define precisely what is meant by "non-participation".

In order to study the demand function of alternative providers, we should address:

- the quantity of lignite capacity that players wish to purchase in order to attain the highest possible profits, and
- the impact of the price $p_α$ thereon.

We henceforth consider that the alternative providers are symmetric, for simplicity reasons. From the analysis of the wholesale market as a uniform-price auction (Section 2), we have derived the following conclusions, applicable to fixed demand values (rather than to a daily demand-profile with hourly variations):

- For high demand values, the wholesale-market equilibrium price is P_{max} regardless the price $p_α$. NOME is then profitable for all alternative providers, who buy and resell the entire quantity of NOME lignite (mixed with gas production) to which they are entitled [namely $(α*K_λ)/n$ each] as well as their gas capacity, regardless the price $p_α$. Indeed, for these demand values, DEH is the so-called price setter (see Section 2); if demand is high enough, then one of the alternative providers can also be the price-setter as well, but this possibility is ignored for simplicity. For the present range of demand values, the equilibrium price without NOME is again P_{max}, which implies that participation in NOME is highly beneficial for each player. However, the higher the price $p_α$, the lower the additional profits of each of the alternative providers from NOME. Also, the higher the value of α, i.e. the higher the lignite capacity of DEH offered to the player by means of NOME, the higher the profits made by them for high demand values. The range of demand values for which the equilibrium price is P_{max}, and thus the above arguments apply, depends on the value of α but not on that of the price $p_α$.

- For a range of medium demand values, starting just below the high demands discussed above, the equilibrium price under NOME is at the marginal cost of gas c_g. Each alternative provider still makes profits under NOME, regardless the price $p_α$. In this case, the alternative providers buy and resell only a part of the quantity of NOME lignite (mixed with gas production) to which they are entitled, say $(α'*K_λ)/n$ each, where $α' < α$, from which they make their only profits. Note that for a given value of medium demand, the parameter α′ depends on the value of the parameter φ and the price $p_α$. Indeed, α′ corresponds to the highest portion of DEH lignite capacity which when allocated to the alternative providers still results in this equilibrium at c_g under NOME. Under this equilibrium (and for a given value of medium demand and parameter α′), if the price $p_α$ decreases then the profits of each alternative provider are increased, since the wholesale equilibrium price is not affected and the marginal $c^α_E$ cost of the NOME mix decreases. (Note that c_g is set as equilibrium price by DEH). On the contrary, if the price $p_α$ increases slightly, then the profits drop abruptly to 0, because the equilibrium price drops to the marginal cost of the NOME mix. Also note that for these medium values of the demand, the price would have been either c_g or P_{max} without NOME; in the latter case, the alternative provider can possibly make higher profits without NOME in certain cases of demand.
- For the remaining demand values, namely the low demand, the equilibrium price under NOME is $c^α_E$. In this case, the alternative providers may possibly buy and resell only a part of the quantity of NOME lignite (mixed with gas production) to which they are entitled, but without making any profits. Without NOME being employed, the price would have been at the marginal cost of gas, and the alternative providers would still make no profits.

As already explained, for different fixed demand values, alternative providers would buy different quantities of lignite capacity if NOME is profitable for them, or in the opposite case they would abstain. Let us now consider a daily demand-profile with hourly fluctuations. Each player E_i should decide whether to abstain from NOME or to participate and in the latter case which constant-band of lignite quantity to purchase. To simplify the analysis, we assume a demand profile with three different levels, namely a low a medium and a high one, and suppose that the price $p_α$ is given.

The low demand level does not affect the decision of a player whether to participate in NOME or not and what quantity of NOME lignite to purchase. Regarding the medium and the high demand levels of the profile, according to the previous discussion on equilibria, an interesting trade-off arises for each player E_i regarding the lignite quantity of the constant-band to purchase:

A) Either exhaust the lignite capacity, buy $(\alpha * K_\lambda)/n$ each, and make profits only during the high demand period from selling the entire NOME mix and the remaining gas capacity, since the equilibrium wholesale price at the medium demand period will drop to the marginal cost of the NOME mix,

B) Or buy each the lower quantity $(\alpha' * K_\lambda)/n$ introduced above in order to keep the equilibrium wholesale price at the medium demand period at the marginal cost of the gas-based production, and make profits during both periods, but by reducing the profits during the high demand period, due to selling this lower quantity compared to option A.

In general RAE would prefer for alternative providers to lead the market to case A, thus buying and reselling the maximum lignite capacity they are entitled to, and therefore resulting in a more symmetric market, which can only lead to lower wholesale equilibrium prices. We next argue that case A is also preferable for the alternative providers themselves. Indeed, case B is inspired by the equilibrium at c_g for fixed medium demand. However, when considering the daily profile, case B does not correspond to an equilibrium anymore. Indeed, assume that we have n=3 alternative providers, which is the most likely case for Greece. If players E_1 and E_2 are committed to buying only $(\alpha' * K_\lambda)/3$, then player E_3 can either buy the same quantity of lignite or deviate and buy more. (Clearly by buying less, he would be making lower profits, and thus this is not a beneficial option for him.) If player E_3 buys slightly more than $(\alpha' * K_\lambda)/3$, then he incurs a loss, because this move brings an abrupt drop of the equilibrium price at the medium demand from c_g to c^α_E, thus making zero profits in that period, while leading to slightly more profits in the high demand period; thus, this is not a beneficial option either. However, despite the vanishing of profits during the medium demand period, it is beneficial for player E_3 to deviate from buying $(\alpha' * K_\lambda)/3$ by purchasing as much lignite capacity as possible for him; indeed, he can buy the whole of the lignite capacity left by the other two players, i.e. $(\alpha - 2\alpha'/3) * K_\lambda$, provided that this does not exceed the maximum allowable quantity for him, namely $[\varphi/(1-\varphi)] * K_{g3}$. In fact, it can be seen numerically that player E_3 will in general be making much higher profits by deviating from buying $(\alpha' * K_\lambda)/3$ and purchasing the maximum possible quantity of lignite, namely $\min\{(\alpha - 2\alpha'/3) * K_\lambda, [\varphi/(1-\varphi)] * K_{g3}\}$. Furthermore, this intuition is also confirmed by the analysis of the market with just OTC contracts in Section 3 (see below).

To summarize, due to high profitability at the high demand period, each alternative provider will demand for each price p_α (up to a threshold) the maximum lignite capacity he can buy, namely $\min\{\alpha * K_\lambda, [\varphi/(1-\varphi)] * K_{gi}\}$. In the symmetric case, this will lead to each player actually buying $(\alpha * K_\lambda)/3$, and thus case A above will prevail. When the price exceeds a certain threshold, then it is more profitable for the alternative providers to abstain from NOME, rather than to participate, which implies that the demand function then drops to 0.

Therefore, under the uniform-price auction model for the wholesale market, the demand function of each alternative provider for NOME lignite capacity is piece-wise constant, starting with a single positive level and then dropping to zero for a high enough price, as depicted in the figure below. Although the study above that led to this conclusion covered the case of symmetric players, it is straightforward that the same incentives, and thus the same shape of the demand function apply to asymmetric cases too.

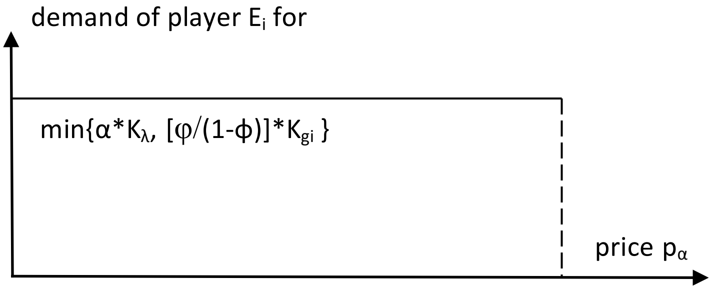

Figure: The demand function of player E_i for lignite capacity.

As already mentioned, Case A above is preferable for RAE, because alternative providers have the incentive to buy and resell the entire quantity of NOME lignite (mixed with gas production) to which they are entitled [namely $(\alpha*K_\lambda)/3$ each], thus introducing a higher level of competition in the market and resulting in lower wholesale equilibrium prices. The selling of lignite capacity to the alternative providers in constant-bands is a very important tool, which ensures that they participate in NOME and with the maximum allowable quantity.

To summarize, the various mechanisms to be considered below should be assessed by taking into account the above described shape of the demand function of the players.

It should be noted that throughout the above study, we assume that non-participation to NOME is equivalent for a player to the case where NOME is not applied at all, i.e. $\alpha=0$. To see why this assumption is correct, provided that alternative providers are symmetric, we argue on its validity in the typical case of three such players. In this case, one of them (say E_3) could possibly have the incentive to abstain from NOME (and let the other two purchase more lignite capacity, namely $(\alpha*K_\lambda)/2$ rather than $(\alpha*K_\lambda)/3$). This can apply only if the equilibrium wholesale price would increase by this move of E_3, namely from the marginal cost of gas-based production to P_{max}. Indeed, we have seen in the analysis of the wholesale market as a uniform-price auction that there are some medium demand values where NOME with less players (here with 2 instead of 3) leads to such an increase in the equilibrium wholesale price of the medium demand. In such a case, the player that abstained from NOME (say E_3) is selling only his gas-based production but at the highest price, namely P_{max}, which gives rise to the possibility of his making higher profits. However, it should be recalled that in our case the lignite capacity allocation and the price p_α are applicable for the entire daily demand profile. Therefore, even if during the time-zone of medium demand player E_3 has the incentive to abstain from NOME, by doing so he misses the opportunity to sell additional capacity [i.e. the lignite-based one $(\alpha^*K_\lambda)/3$] at price P_{max}, at the time-zone with high demand, which is unlikely to apply provided that the lignite capacity offered by means of NOME is not very low (i.e. if α is not very small). Nevertheless, if this is indeed the case, then the two other players E_1 and E_2 will benefit even more from this move of E_3, because they will be selling profitably more capacity than him in both the medium and the high demand values. Therefore, a mixed equilibrium may be applicable here, which is rather complicated to further analyze.

The above analysis for the demand function of the alternative providers applies to the uniform-price auction model for the wholesale market. The main conclusions apply to the model of the electricity market with OTCs (see Section 3, particularly the last part, pages 26 - 31). While the analysis in Section 3 relies on the assumption that the E firms (alternative providers) are symmetric, the implications of introducing asymmetries are quite straightforward. We can then see that if in condition (32), that measures an E firm's incentive to raise price to the maximum level, the parameter α refers to the fraction of NOME allocation of two of the E firms[10], the other (third) E firm will always have an incentive to demand the maximum possible NOME allocation – and thus minimizing the amount that is allocated to the other two - subject to the constraint that it has enough gas to mix it with (so constraint (19), or more correctly (19′), in Section 3 is satisfied) and that its final capacity does not exceed its demand at price P_{max} given by expression (16) . Thus we expect that again we will end up with the three E firms sharing the maximum NOME capacity to be allocated.

Below, we consider two main types of mechanisms, namely rationing rules and auctions, as well as some mechanisms combining features of both types. As already explained, we focus on mechanisms allowing for the flexible apportioning of the lignite capacity among multiple alternative providers. To this end, we assume that the lignite capacity K_λ of DEH is infinitely divisible, so as to avoid complications relating to discretization of the quantities than can be allocated to the various alternative providers. This implies that any splitting of K_λ among the players is permissible. In the practical implementation of such a mechanism, there will be defined a minimum level of granularity, which however is ignored in the sequel, for simplicity.

Rationing Rules

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[10] So instead of α we have $\delta_k^*\alpha$, where δ_k is the amount of the total lignite allocated through NOME to firm E_k.

These mechanisms decide on the apportioning of the capacity at the reserve-price level $r_α$, without allowing for any possibility for price increase. This is their main characteristic, together with simplicity of implementation in practice. In general, as already discussed keeping the price at the lowest level is an advantage for RAE, provided that the wholesale equilibrium at the medium demand level of the daily profile is at the marginal cost of the NOME mix. Below, we propose and assess various possible such mechanisms:

1. Equal-share allocation, i.e. each alternative provider (player) takes an equal share 1/n, where n is the number of players. This number is assumed to be known to RAE in advance, in the sense that there will be a few and well-known players in the Greek market that are indeed eligible for lignite capacity. In practice, if one (or more) of the eligible players declares that he is not interested for the respective amount of lignite, then the lignite capacity will be shared equally among the others; we henceforth ignore this possibility, for simplicity reasons. For each player, his allocated lignite capacity $(α*K_λ)/n$ should not exceed $[φ/(1-φ)]*K_{gi}$, where g_i is his installed production capacity based on. Otherwise, this allocation should be reduced accordingly for the player, and then the lignite capacity made available should be redistributed equally among the remaining players that can still utilize it. In fact, the full allocation of lignite so that the constraint due to φ is satisfied for all players may require a few iterations. Note also that as $α*K_λ \leq [φ/(1-φ)]*(K_{g1} + … + K_{gn})$ is assumed, all the NOME lignite capacity will be allocated at the end of this procedure.
   Example: We assume that $K_λ$ =3800 and that RAE has decided on α=0.45 and φ=0.6. There are n=3 alternative producers, which have to share $α*K_λ$=1710 units of lignite capacity. The fair share for each player E_i is $(1/n)*(α*K_λ) = 570$, provided that this does not exceed $[φ/(1-φ)]*K_{gi} = 1.5* K_{gi}$. Therefore, if for all E_i, the gas-based capacity K_{gi} is at least 570/1.5=380, then each alternative provider can get his fair share. If only E_1 has a lower than 380 gas capacity, e.g. $K_{g1} = 300$, then he gets only $1.5*K_{g1}$=450 and the other two players take $(1/2)*(α*K_λ- 450) = 630$ each, provided again that this does not exceed $1.5*K_{g2}$ and $1.5*K_{g3}$, or equivalently if K_{g2} and K_{g3} both are at least 630/1.5=420. If say this constraint is not satisfied for E_2, e.g. because K_{g2}=400, then E_2 is allocated only $1.5*K_{g2} = 600$. Finally, E_3 gets all remaining capacity out of $α*K_λ$, namely 660, provided again that his constraint relating to φ is still satisfied, i.e. that his gas-based capacity K_{g3} is at least 660/1.5=440.
   The main advantage of this rule is that it leads to as symmetric as possible allocation of the NOME lignite capacity among the alternative providers. As already mentioned this is a very desirable property, according to the analysis of the wholesale market. On the other hand, the disadvantage of this rule is that players do not express their interests in terms of required lignite quantity at all; the same applies to rules 2 and 3 below.

2. Pro-rata allocation proportionally to the gas-based production capacity g_i of each player, with the constraint that each player's portion does not exceed $[\varphi/(1-\varphi)]*K_{gi}$. In this case, each player E_i initially gets $(\alpha*K_\lambda)*[K_{gi} / (K_{g1} +\ldots+ K_{gn})]$. Hence, this restriction is met for all players, as $\alpha*K_\lambda \leq [\varphi/(1-\varphi)]* (K_{g1} +\ldots+ K_{gn})$ is applies[11]. The main advantage of this rule is that it copes very simply with the constraint related to leads to the φ parameter, contrary to the rule of equal allocation. Moreover, the rule rewards the alternative producers that have already made higher investments in gas-based electricity production, by offering more lignite to them. On the other hand, if alternative providers are asymmetric, then this rule maintains the asymmetries, thus possibly leading to higher equilibrium prices in the wholesale market after NOME.

3. Combination of the above rules, in two phases. In the first phase, a pre-specified part of the lignite capacity is allocated equally among the alternative providers, the part of each of which of course should have been chosen so not to exceed $[\varphi/(1-\varphi)]*K_{gi}$ for all players. In the second phase, the remaining lignite capacity part is allocated pro-rata according to the gas-based productions. The main advantage of this rule compared to pro-rata allocation rule is that it both ensures a minimum quantity per player and rewards those that have already invested more in gas-based production. Also, similarly to rules 1 and 2 above, if the inequality $\alpha*K_\lambda \leq [\varphi/(1-\varphi)]*(K_{g1} +\ldots+ K_{gn})$ applies, then all the NOME lignite capacity will be allocated at the end of the procedure.

   As a final remark for rules 1-3 above, it should be noted that if symmetry in the lignite allocation is the most desirable feature, then rule 1 (equal allocation) is preferable. On the other hand, under neither of these rules players have the opportunity to express their interests in terms of required lignite quantity; however, this applies to rationing rule 4 below.

4. Allocation pro-rata to declared quantities demanded by the players. Each alternative provider E_i is asked to submit a quantity q_i of lignite demanded per this player, where of course q_i should not exceed $[\varphi/(1-\varphi)]*K_{gi}$. Then, the allocation of it lignite is done as follows:
   - If the total demand does not exceed the supply of the lignite capacity to be allocated by means of NOME, i.e. if $(q_1 +\ldots+ q_n) \leq \alpha*K_\lambda$, then each player is given its own demanded quantity q_i.
   - If the total demand exceeds supply, then pro-rata allocation is employed: that is, each player E_i is given a capacity $(\alpha* K_\lambda)*[q_i/(q_1 +\ldots+ q_n)]$; this quantity is lower than the originally requested quantity q_i, and thus clearly satisfies the constraint of not exceeding $[\varphi/(1-\varphi)]*K_{gi}$.

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[11] Since all gas-based productions are known, RAE can choose appropriate values of α and φ, so that the constraint involving φ is "automatically" met for all players, unless of course some of the alternative providers decides (after the parameters are chosen) not to participate at all.

The main advantage of this rule compared to the three previous ones is that each player now does express the lignite quantity he is interested in, although he does not necessarily get this quantity. On the other hand, this feature may now lead the players to be strategic, rather than truthful with respect to their declared demanded quantities. In particular, suppose that a specific player, say E_1, wishes to get a lignite quantity q_1, that is considerably less than the maximum allowable for him, namely $\min\{\alpha^* K_\lambda, [\varphi/(1-\varphi)]^* K_{gi}\}$, because the player has not established enough bilateral contracts yet, to resell the NOME mix[12]. Note that the quantity that each player expects to resell by means of contracts is private information to him. Facing the threat of getting a part of the quantity q_1 in pro-rata allocation, due to total demanded quantity exceeding the supply $\alpha^* K_\lambda$, player E_1 may opt to overbid; that is, to declare a demand Q_1 that is higher than q_1, so that if he only gets a part of this quantity Q_1 in pro-rata allocation this part meets his actual demand q_1. However, it is thus possible that he either gets the entire quantity Q_1, if pro-rata allocation does not have to be applied, or a smaller quantity that is still higher than q_1 (although less than his declared demand Q_1) as an outcome of pro-rata allocation. Getting a higher quantity than the actual demand as a consequence of the outcome of the mechanism is an undesirable case, because it will reduce the profits of E_1 from NOME, and may in the longer run make him less inclined to participate in the mechanism. Later in this Section, we propose an auction mechanism that includes the present rationing rule as a special case, thus mitigating the negative effects of overbidding.

The problem of some players getting a higher quantity than they would truthfully demand also applies to rules 1-3 above, because players do not express their demand at all. However, the problem can be dealt with rather simply as follows: If after the allocation, one or more players decide that they wish to purchase a lower quantity than that assigned thereto by the rule, then they can declare this to RAE; the remaining quantities of lignite capacity that become available again are reallocated among the rest of the players, by applying the same rationing rule again.

Auction mechanisms

The main advantage of auctions is that they constitute market mechanisms, in which players can express better their demand function. In general, this would imply that the final price of an auction is in general higher than the reserve price r_α, if competition does arise. Also, in a multi-unit auction, the price can possibly be different for different units of the good sold if a discriminatory-price auction is employed.

We consider several alternative auction mechanisms below. It will be seen though, that due to the already established properties of the demand function of alternative providers for lignite capacity, the extra gain by running an auction mechanism (rather

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[12] This restriction applies also for the demand to be exhibited by a player in the other mechanisms.

than rationing) is actually not significant. The main reason for this is that alternative providers prefer to buy as much lignite capacity as possible while keeping the price p_α as low as possible.

5. Ascending clock auction[13]: This mechanism can be employed for selling quantities of an infinitely divisible good. The price per unit of the good increases according to a clock; each player submits at each price his demanded quantity, which should be non-increasing in time and price. The process terminates at that value of the price where for the first time the total demanded quantity equals the supply. If the quantities demanded at the reserve price are in total less than the supply, then the auction terminates at the starting level of the reserve price. Since this is a uniform-price auction, players can employ demand reduction in their bidding. Note that this is a well-known issue arising in uniform-price auctions, and can be summarized as follows: At a particular price level p, mainly in the early stages of the auction, a player with high demand does not place a truthful bid equal to the quantity suggested by his demand function; on the contrary, by placing a lower bid (hence the term demand reduction), the player leads the auction to a faster termination, where he takes fewer units at a lower price, but ending up with a higher net benefit. In symmetric cases, players employ the same level of demand reduction and thus the auction will be led to the same symmetric allocation with truthful bidding, while the price will not be raised as much. As already explained, in our case, alternative providers prefer that the price p_α is kept as low as possible. Therefore, even if each such provider places, at the reserve price r_α, a bid for the maximum possible quantity of lignite capacity he aims, soon he will resort to demand reduction for the reason explained above. In fact, players also know that their demand function is initially constant and then abruptly drops to 0.Thus, in the symmetric case, truthful bidding would not lead to auction termination, unless the price raises so much that demand for some players indeed drops to 0, which is an undesirable outcome since it will produce an asymmetric allocation of lignite. In the symmetric case, the demand drops to 0 for all players at the same price level, and no lignite would be actually allocated. This argument further advocates for the fact that the players will soon resort to demand reduction. Therefore, the allocation and price outcomes of this auction mechanism would be similar to the rationing rule 4. The equilibrium set of strategies suggests that all players perform demand reduction from the start to terminate soon the auction, which can also be viewed as a form of tacit (i.e., indirect) collusion. The only possible difference of the present mechanisms with rationing rule 4 relates to overbidding. That is, say that player E_1 wishes to purchase a quantity q_1, smaller than $\min\{\alpha*K_\lambda, [\varphi/(1-\varphi)]*K_{gi}\}$, according to the bilateral contracts he has established. Then, under the present mechanism, E_1 does not have to demand a higher quantity Q_1 at the reserve price, because he has the opportunity to “insist”

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[13] Lawrence M. Ausubel and Peter Cramton, Demand Reduction and Inefficiency in Multi–Unit Auctions, Mimeo, University of Maryland, March 1998.

on q_1 as the clock raises and wait for the others to perform demand reduction. However, this can drive the price at high levels, and diminish the profits of this player. Therefore, although the above scenario is possible, according to the rules of the auction mechanism, it is actually unlikely to happen. Soon this player will perform demand reduction too, thus implying that he will have to overbid at the reserve price in order to avoid being allocated a lower quantity than q_1.

6. Ascending clock with clinching[14]: This mechanism is a variation of the previous one. The price increases according to a discrete clock, and each player submits at each price his demanded quantity, which should again be non-increasing. The idea is that players are allocated units of the good sold gradually. This works as follows: if at a certain price the total demand q_{-i} of all players except E_i is less than the total supply K, then player E_i has already clinched in total a quantity $K-q_{-i}$; indeed, this quantity is not claimed by the others, and will not be claimed in higher prices either, because their submitted demand can only decrease. The auction's termination rule is the same as in the ascending clock mechanism above. The total payment of each player can be calculated by keeping track of the differences of the quantities clinched by the same player in successive price-levels, and charging him for each quantity accordingly. For example say that we have 3 players competing for K=60 units, and at the reserve price, each of them requests 27 units; then each player clinches 6 (=60-2*27) units at that price level; in the sequel, the price increases at the next level, where each player requests 25 units; then each player clinches 10 (=60-2*25) units up to that price level, 6 of which were already clinched in the previous level and the remaining 4 in the present one. It should be noted though that this mechanism is of discriminatory pricing, which may be a disadvantage from the point of view of RAE policy. On the other hand, under certain assumptions on the demand function, this mechanism incites players to bid truthfully, rather than resort to demand reduction. (In practice though, it has proven difficult for players to realize that they benefit by bidding truthfully.) However, this mechanism is not appropriate for our case, since demand is non-decreasing, unless the price gets very high, where it drops to 0. What would happen is that initially each player E_i would clinch some lignite capacity if $\alpha * K_\lambda - q_{-i} < 0$. Then, since demand is constant for a range of prices, the next possible clinches can happen when the demand of some player drops to 0. This would lead price at high levels, which is not desirable. Therefore, the present mechanism is not appropriate for our case.

7. First-price sealed-bid auction: So far, we have only dealt with open auction mechanisms, in which the offers by players are placed publically. For the purpose of the mechanism of multi-unit first-price sealed-bid auction, the available lignite supply $\alpha * K_\lambda$ is discretized in M small indivisible units, say of 20 MW. The same

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[14] See same references as before and Ausubel, Lawrence M. (1997), "An Efficient Ascending-Bid Auction for Multiple Objects," Working Paper 97-06, University of Maryland.

discretization is applied to the maximum quantity $[\varphi/(1-\varphi)]*K_{gi}$ of lignite capacity for which alternative provider E_i is eligible; let the corresponding number of units be denoted as m_i. Then, each player is asked to submit in a sealed envelope the price that he is willing to offer for the 1st unit, for the 2nd unit, etc. up to at most the m_i–th unit. These prices submitted per player should be non-decreasing. All these offers are ranked and the top M ones win. There can arise ties; e.g. the M-th and the (M+1)-st offers can be identical and not be both granted. Thus, a tie-breaking rule should also be specified; e.g. either random or pro-rata resolution (see below). This is the complete allocation rule for this mechanism. The payment rule is first-price, i.e., "pay-as-you-bid"; that is, each unit is acquired by the corresponding player in the price he has offered for it. Since players wish to maintain a high profit margin for the NOME mix, it is expected that most or all offers will be at the level of the reserve price, or close to it. Thus, the tie-breaking rule is very influential for the final outcome, particularly if the prices allowable to be placed in the offers are discretized. If ties are broken in a randomized way, then asymmetric allocations may arise, which is undesirable for RAE, since it affects adversely the wholesale market price. Facing the possibility of a purchasing a lower quantity due to being "unlucky" in the tie-break, a player may place higher offers too. This is an advantage of the mechanism, in the sense that it promotes competition among players. On the other hand, this possibility again may lead to asymmetric allocations. If prices are not discretized, then there will be fewer ties, but still the outcome can be asymmetric. Moreover, in this case, another possibility arises: a player can get a much higher quantity than some other player because of the fact that he has bided a slightly higher price for the relevant units. Besides the fact that this leads to an asymmetric allocation, it may also be undesirable for RAE from the point of view of communications policy. Therefore, it is preferable to employ discrete prices and non-randomized tie-breaking rule, such as pro-rata. That is, if, for the last 10 units of lignite capacity to be allocated, we have a tie of an offer for 16 units by player E_1 and an offer for 4 units by player E_2, then player E_1 gets 8 units and player E_2 gets 2 units. On the other hand, such an accurate pro-rata allocation is not always feasible. E.g. if two offers tie for the last unit, then a random selection will have to be done anyway. If pro-rata tie-breaking is employed, then players could collude, by all agreeing to place bids at the reserve price, in order to share the lignite capacity. However, one player can deceive the others, and bid for his targeted units at a slightly higher price, and thus get a much higher quantity than his pro-rata share. This feature of the mechanism makes collusion among players unstable. While this may be highly desirable in other contexts, in our case it may lead to very asymmetric allocations that are due neither to differences in the relative underlying efficiencies of the different E players (since they have the same costs) nor to their differences relating to gas-based production; such asymmetries can lead to higher prices in the wholesale and ultimately in the retail markets. To summarize, the present mechanism is not recommended in our case, mainly due to the possibility of asymmetric allocations.

8. Multi-unit Dutch auction: This mechanism is an open one, in which the price decreases according to a clock, starting at a high price (perhaps just below the marginal cost of gas), contrary to the variations of ascending clock (where the price increases). At each price, a player can submit his demanded quantity, which should not exceed the remaining available quantity. (Conformance with the restriction regarding already allocated lignite quantities to players to their respective gas production should be checked too.) The clock is continuous, so that ties are avoided; e.g. each player can be equipped with a button, which when pressed (by the player, so as to submit its demanded quantity at the corresponding price level) freezes the clock and blocks the buttons of other players until the allocation is performed. The process of descending price is then continued, until exhaustion of the available quantity of lignite capacity. Similarly to the First-price sealed-bid auction, the present mechanism can give rise to a highly asymmetric allocation. E.g., at a price level close to the maximum, a player can ask for the maximum quantity he is entitled to, given his gas capacity. This can happen particularly if a player is risk-averse, and does not want to wait for the price to drop, fearing that he may not be able to purchase enough capacity. Thus, this player bids for a high quantity (even for the maximum he is entitled to, namely $\min\{\alpha^*K_\lambda, [\varphi/(1-\varphi)]^*K_{gi}\}$), which he is instantly allocated, before other players decide or manage to place any bids. By the same argument, collusion among players is unstable under this mechanism too. The possibility for an asymmetric allocation (which as mentioned above is not related to differences in underlying efficiencies of the different players) is the main reason why this mechanism is not recommended for our case. One could consider a variation with a discrete clock. In this case, a tie-breaking rule is needed, since players could wait until the price drops to the minimum acceptable level and place their offers (or most of them) at that level. In fact, RAE could prescribe that if there is some capacity that is still left unallocated, then it cannot be sold at a lower price, and should be kept by DEH. RAE could in fact also ask DEH to determine this minimum level. In such a case though, DEH can strategically select a high minimum price, close to the starting price, so that either it earns a high revenue from selling lignite to the alternative providers, or it discourages such providers from participating to NOME, thus maintaining its dominant position in the market. Therefore, although under a multi-unit Dutch auction DEH could be assigned a more active role, it is not expected that this would serve the purposes of RAE for NOME.

Combination of Auction and Rationing

In order to avoid the potential price increase in the aforementioned auction mechanisms, the following combinations of auctions and rationing can be employed:

9. Ascending clock auction with price ceiling: This mechanism evolves as the pure ascending clock, however the price cannot exceed a certain ceiling level. If the

price does reach that level, then the lignite capacity is allocated to the players proportionally to their quantities demanded at that price level which should not exceed some maximum predetermined value. If players expect that they will reach the price ceiling, then acting strategically they can collude implicitly, by employing demand reduction from the start. Therefore, and taking into account the assessment of pure ascending clock, it turns out that the outcome of this mechanism too would be in our case similar to rationing rule 4.

10. Ascending clock auction with the option of rationing[15]: This mechanism evolves as the pure ascending clock but with a discrete clock; moreover, at each intermediate step where demand still exceeds the available lignite supply, the players are asked if they agree with proportional allocation of the lignite among them according to their quantities demanded at the corresponding price level. If all players agree, then the auction terminates. This mechanism gives the signal to the market that the auction is performed as an allocation rule rather than for attaining a higher price of the lignite; thus players do not have to collude implicitly anymore, if of course they all agree at some allocation. On the other hand, the mechanism allows a player to "insist" on pursuing a higher quantity of lignite than its share from rationing, which may be considered as an advantage from the point of view of communication policy of RAE, because it gives players the capability to compete for the lignite capacity if they want to. Besides this, it is expected that the present mechanism too will be terminated explicitly by the players at the level of the reserve price, thus leading to the same outcome as to rationing rule 4.

Conclusion

In this chapter, we have dealt with the selection of a mechanism appropriate for the allocation of the lignite capacity of DEH to alternative providers under NOME, on the basis of the requirements of RAE as well as of the demand function of the players for lignite and the strategies stemming from this. In particular, we have established that the demand function of each alternative provider for NOME lignite capacity is piece-wise constant, starting with a single positive level and then dropping to zero for a high enough price. Thus, alternative providers prefer to buy as much lignite capacity as possible, while keeping the price p_α as low as possible, in order to make higher profits.

We considered two main types of mechanisms, namely rationing rules and auctions, as well as some mechanisms combining features of both types. It follows from the assessment of these mechanisms, that rationing rule 4 (allocation pro-rata to declared quantities demanded by the players) and auction mechanism 10 (ascending clock auction with the option of rationing) are the most appropriate ones for allocating

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[15] To the best of our knowledge this is an innovative mechanism that has not been previously introduced elsewhere in the literature on auctions.

lignite capacity. In principle, the latter has the advantage of allowing for a player to insist on pursuing a higher quantity at a higher price, thus being more of a market mechanism that allows players to compete if they want to. In practice though, it is not expected that some player will make use of this capability[16], thus implying that the outcome will most probably be the same as in rationing rule 4, which is a simpler mechanism from the point of view of implementation. Indeed, rationing rule 4 only requires the submission of the demanded quantity per player in a sealed envelope; auction mechanism 10 comprises multiple rounds of this form. The choice of reserve price is of course very important for the incentives of the players under both mechanisms, since in the initial phase of the application of NOME alternative providers should be incentivized enough so as to participate in NOME, develop capability as retailers and look for OTC bilateral contracts.

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[16] At least, not for "good" reasons, such as being more efficient than other players.