Errata and Clarifications

Further to the preliminary examination process, this Section itemizes corrections and clarifications to Papers I, III and IV, whereby *Erratum* appears at the beginning of each correction.

Paper I

i. Page 4110: Binary variables for ramping decisions are not used because as an approach this would make the KKT conditions invalid. Furthermore, unit commitment decisions are not typically considered in models of the Nordic and Western Europe power markets.

ii. Page 4111: The assumption that VRE producers cannot exert market power is based on the recognition that (i) VRE owners are mostly small companies who are not in a position to influence market prices, (ii) VRE production depends on weather conditions, which would make it hard to conceal any associated market power and (iii) it is profitable to use all available VRE energy, because its marginal costs are practically zero due to the combination of feed-in-tariffs and priority grid-access.

iii. Page 4111: As in Hobbs (2001), the grid owner is assumed to be a profit-maximizer who takes transmission decisions in a system which is based on congestion fees. The question of if, and to what extent, the maximization of social welfare by the grid owner would lead to more preferred outcomes for some market stakeholders is not in the scope of this paper. This question could be answered only through significant modelling and computational efforts which are left for future research, as they would provide the foundation for a sequel paper.

iv. *Erratum*, Page 4111: "brackets" should read "round brackets".

v. Page 4112: As shown in Fig. 4, the average wind generation in Germany is relatively stable during the four-hour period, and thus it is adequate to build a stylized scenario tree for VRE generation by using equiprobable scenarios. However, the proposed approach could be readily extended to more general settings in which these probabilities vary from one scenario to the next. The computational burden in solving these kinds of complementary models depends primarily on the number of scenarios rather than on the numerical values of their probabilities.

Paper III

i. Throughout this paper, the term *variable renewable energy* is used as a synonym for *intermittent renewable energy*.

ii. Page 5265: The references to data in the introductory Section I.A serve to motivate the general research questions in this paper. In contrast, the consolidated data in Tables III-V are employed as an input for actual modelling and computation of numerical results.

iii. Page 5266: The approach of introducing a parameter for the minimum share of district heating to be covered by heat-only is convenient for modeling purposes. In this approach, the difficulties of modeling the details of the district heating network can be avoided while still ensuring that not all district heating demand can be covered with CHP (which would be impossible due to the geographical distribution of CHP plants).

iv. Page 5266: The focus of this paper was primarily on the analysis of the impact of CHP on power markets, whereby the relatively low costs of heat storage would play a minor role. The assumption of zero operating costs for heat storage is also similar to the assumption for power storage in Paper I. At the time of writing, reliable data on the costs of heat storage were not available for this paper. Yet further analyses could be produced by employing realistic costs estimates.

v. Page 5267: The quantity of VRE production is technically a decision variable whose value is governed by weather-dependent parameters which represent conditions for generating of solar and wind power. This flexible approach is similar to that in Paper I and makes it possible to explore alternative assumptions concerning, for instance, the impacts of curtailing of VRE generation.

vi. *Erratum*, Page 5271, Figure 6: "Case 3 vs. 1" should read "DE-PC vs. SQ-PC" and "Case 4 vs. 2" should read "DE-CO vs. SQ-CO".

vii. *Erratum*, Page 5271, Figure 7: "Case 2 vs. 1" should read "SQ-CO vs. SQ-PC" and "Case 4 vs. 3" should read "DE-CO vs. DE-PC".

viii. *Erratum*, Page 5274, Reference [14]: Authors should be "X. Chen, C. Kang, M. O'Malley, Q. Xia, J. Bai, C. Liu, R. Sun, W. Wang, and H. Li".

Paper IV

i. The motivation for the paper has been to combine optimization models with the added realism which can be gained by simulating how some market stakeholders are likely to behave; but this also implies that conclusive statements concerning the attainment of market equilibria can be only produced for the optimization models alone. This multi-methodology approach has nevertheless strengths in capturing behaviors which can not be readily captured through optimization models.

ii. Further topics related market coupling, most notably of the co-ordination of power exchanges and transmission system operators, have been addressed by Oggioni and Smeers (2012) who assess inefficiencies arising from the lack of integration whilst assuming price taking agents.

iii. Page 1642 and 1644: The simulation-based decision models for hydro power and CHP producers are relatively simple: for example, these models do not account for risk preferences and they also involve unrealistic assumptions about future hydro-inflows. In order to account for realistic hedging decisions, these simulation models would have to be extended by describing risk preferences while relevant future uncertainties would also have to be estimated. These extensions would lead to much more complex models and require data that is not readily available.

iv. Page 1644: For extraction plants, the area for power and heat output in Equation (10) is assumed to be convex. For backpressure plants (which are simpler than other CHP plants), there is a linear relationship between power and heat output.

v. Page 1645: The linear objective function Equation (11) leads to a cost-minimization problem which be solved with ease. It would possible to consider even non-linear convex objective functions, for instance, in order to examine questions of social welfare maximization or elastic demand.

vi. Page 1648: For each region, the marginal costs of power and heat generation are in this paper assumed to be the same. In reality, the costs may vary somewhat; but because the costs are primarily based on fuel costs and the markets for these are global, the differences are unlikely to vary significantly between neighboring countries in Europe. Moreover, the development of realistic models containing different marginal costs would be complicated by the difficulties of obtaining regional data.