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Sebastian Rothe

Portfolio Analysis of Power Plant Technologies

A Simulation Approach to Rebalance Fuel
Mix Strategies

Sebastian Rothe
Köln, Germany

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Foreword

In recent years, there has been renewed interest in the fuel mix strategy of utility firms. The nuclear catastrophe in Japan demonstrated that existing power plant technologies carry risks which have not been adequately priced yet. In addition, energy consumption in the world is soaring. As a result new power generation capacities are needed. The emission reduction objectives of the European Union as well as the finiteness of fossil fuels require investments in new power plant technologies; moreover European utilities do have to replace over aged power plants in the near future. As a consequence, a wave of replacements and investments in power generation capacities is expected within the next years accompanied by a shift in the energy fuel mix.

The most efficient composition of power plant technologies, however, has hardly been an issue in the relevant academic literature so far. Sebastian Rothe aims to close this gap. To derive such a composition, he mainly draws on the traditional portfolio approach of financial theory. In this respect, the analysis sheds light on the determinant factors that result in an economically efficient portfolio and that help assemble an efficient power plant mix over time.

Furthermore the analysis takes the change of the CO₂ emission regulation into account.

The work of Sebastian Rothe contributes to the academic literature, as based on the work of Roques et al. (2008), Sebastian Rothe has managed within his doctoral thesis to handle an extremely complex and actual topic. His findings and recommendations are valuable not only for scientists but also for practitioners.

Hamburg, October 2011

Alexander Bassen

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I worked on this thesis during my time as an academic assistant at the Chair of Capital Markets and Management of Alexander Bassen at the University of Hamburg. Looking back feels good not only due to the fact of having finished my thesis but also, as I used to work with great people in an inspiring environment.

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Cologne, October 2011

Sebastian Rothe

Table of contents

LIST OF ABBREVIATIONS.....	XIII
LIST OF SYMBOLS.....	XVI
ENERGY UNITS AND CONVERSION FACTORS	XIX
LIST OF TABLES	XXI
LIST OF FIGURES	XXIII
1 INTRODUCTION	1
1.1 MOTIVATION	1
1.2 PREVIOUS RESEARCH	2
1.3 OBJECTIVES AND METHODOLOGY	5
2 ECONOMICS OF ENERGY MARKETS.....	9
2.1 LIBERALIZATION AND FUEL MIX	9
<i>2.1.1 Legislation and market design</i>	<i>9</i>
<i>2.1.2 Investments in liberalized electricity markets</i>	<i>11</i>
<i>2.1.3 Fuel mix in competitive electricity markets.....</i>	<i>14</i>
<i>2.1.4 Power plant technologies</i>	<i>18</i>
<i>2.1.5 Diversification of fuel mix.....</i>	<i>24</i>
<i>2.1.6 Power market system and merit order</i>	<i>25</i>
2.2 FRAMEWORK OF THE EU EMISSION TRADING SCHEME	30
<i>2.2.1 Historical emergence and objectives</i>	<i>30</i>
<i>2.2.2 Institutional framework.....</i>	<i>32</i>
<i>2.2.3 Appraisal of the first and second trading periods.....</i>	<i>35</i>
<i>2.2.4 Future outlook.....</i>	<i>36</i>
2.3 DETERMINANTS OF ENERGY COMMODITIES	38
<i>2.3.1 Electricity.....</i>	<i>39</i>
<i>2.3.2 CO₂ emissions</i>	<i>43</i>
<i>2.3.3 Coal</i>	<i>46</i>
<i>2.3.4 Oil.....</i>	<i>48</i>
<i>2.3.5 Gas</i>	<i>50</i>
<i>2.3.6 Interactions between energy commodities</i>	<i>52</i>
2.4 SUMMARY	55

3 MEAN-VARIANCE VALUATION APPROACH FOR POWER PLANTS 57

3.1 FUNDAMENTALS OF CAPITAL MARKET-BASED VALUATION 57

 3.1.1 *Discounted free cash flow valuation* 58

 3.1.1.1 Methodology 58

 3.1.1.2 Deriving free cash flows 61

 3.1.1.3 Estimating the cost of capital 63

 3.1.1.4 Critical acclaim 66

 3.1.2 *Monte Carlo simulation* 67

 3.1.2.1 Background 67

 3.1.2.2 Procedure 68

 3.1.2.3 Implementation 69

 3.1.2.4 Critical acclaim 70

3.2 PORTFOLIO THEORY: MODEL OF MARKOWITZ (1952) 72

 3.2.1 Assumptions 72

 3.2.2 Notation 74

 3.2.3 Portfolio selection 75

 3.2.4 Analytical determination of the global minimum variance portfolio 77

 3.2.5 Analytical determination of the efficient frontier 80

 3.2.6 Critical acclaim 81

3.3 MODEL OF ROQUES ET AL. (2008) 82

 3.3.1 Methodology 83

 3.3.2 Results and implication 84

 3.3.3 Critical acclaim 85

3.4 PORTFOLIO APPROACH FOR POWER GENERATION ASSETS 87

 3.4.1 Assumptions 88

 3.4.2 Analytical framework 90

 3.4.3 Discount rates for power plant technologies 92

 3.4.4 Relative efficiency of power plant portfolios 94

 3.4.5 Development of hypotheses 98

3.5 SUMMARY 102

4 SIMULATION BASED MODEL FOR ANALYZING GENERATION PORTFOLIOS 103

4.1 DEFINING MODEL REQUIREMENTS 103

4.2 RISK ANALYSIS PROCESS 105

 4.2.1 Risk variables 105

 4.2.2 Probability distributions 106

 4.2.3 Correlated variables 108

4.3 ASSUMPTIONS 114

 4.3.1 Technical and cost assumptions 114

 4.3.2 Projected commodity price development 117

 4.3.3 Renewable energies 125

4.4 MODELING PROCEDURE 130

 4.4.1 Power generation 135

 4.4.2 Replacements 138

 4.4.3 Investments in generation capacity 143

4.5 MONTE CARLO BASED VALUATION OF GENERATION PORTFOLIOS..... 146

 4.5.1 *Expected value and risk*..... 146

 4.5.2 *Loop programming*..... 149

 4.5.3 *Optimization*..... 154

 4.5.4 *Economic efficiency*..... 155

 4.5.5 *Technical efficiency*..... 156

4.6 SUMMARY 159

5 EMPIRICAL ANALYSES OF EUROPEAN GENERATION PORTFOLIOS..... 161

5.1 DESCRIPTION OF THE STOCHASTIC VARIABLES 161

 5.1.1 *Data*..... 161

 5.1.2 *Descriptive statistics* 164

 5.1.3 *Empirical correlations* 167

 5.1.4 *Simulated correlations* 172

5.2 GENERATION PORTFOLIO ANALYSES - A DISAGGREGATED APPROACH 176

 5.2.1 *Sample power plant portfolio*..... 176

 5.2.2 *Investment strategy*..... 179

 5.2.3 *Feasibility set* 186

 5.2.4 *Determining efficient frontiers* 196

5.3 ANALYZING COUNTRY-SPECIFIC GENERATION PORTFOLIOS 202

 5.3.1 *Power plants located in Germany*..... 203

 5.3.2 *Power plants located in the United Kingdom* 207

 5.3.3 *Power plants located in the Netherlands* 210

 5.3.4 *Power plants located in Spain*..... 213

 5.3.5 *Summary*..... 218

5.4 DETERMINING THE DEGREE OF RELATIVE EFFICIENCY OF GENERATION ASSETS 220

 5.4.1 *Efficiency of the target portfolio* 221

 5.4.2 *Efficiency of the domestic portfolio*..... 223

 5.4.3 *Efficiency of international generation portfolios* 224

 5.4.4 *Robustness*..... 226

5.5 REBALANCING 229

5.6 IMPLICATIONS 233

5.7 SUMMARY 235

6 CONCLUSIONS..... 237

 6.1 SUMMARY 237

 6.2 IMPLICATIONS FOR MANAGEMENT AND RESEARCH..... 240

 6.3 FUTURE OUTLOOK AND CONCLUDING REMARKS 243

REFERENCES 244

APPENDIX 258

List of abbreviations

AAU	Assigned Amount Unit
APT	Arbitrage Pricing Theory
APX	Amsterdam Power Exchange
Bn	Billion
BnetzA	Bundesnetzagentur
CAGR	Compound Average Growth Rate
CAPM	Capital Asset Pricing Model
CARMA	Carbon Monitoring for Action
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CH ₄	Methane
CHP	Combined Heat and Power
CITL	Community Independent Transaction Log
CML	Capital Market Line
CO ₂	Carbon dioxide
DCF	Discounted Cash Flow
DWD	Deutscher Wetterdienst
EAT	Earnings after Taxes
EBITDA	Earnings before Interest, Taxes, Depreciation and Amortization
ECX	European Climate Exchange
EDF	Électricité de France
EEFA	Energy Environment Forecast Analysis
EEG	German Renewable Energy Act
EEX	European Energy Exchange
EnWG	Energiewirtschaftsgesetz
ERU	Emission Reduction Units
e.g.	for example

etc.	et cetera
et al.	et alli
ETS	European Trading Scheme
EU	European Union
EUA	EU Allowance
EWI	Energiewirtschaftliches Institut der Universität zu Köln
FCF	Free Cash Flow
G	Gram
GDP	Gross Domestic Product
GER	Germany
GMRP	Global Maximum Return Portfolio
GMVP	Global Minimum Variance Portfolio
GT	Gas Turbine
GW	Gigawatt
HFC	Hydrofluorocarbon
IAEE	International Association of Energy Economics
IEA	International Energy Agency
ICE	Intercontinental Exchange
i.e.	id est
JI	Joint Implementation
K€	Thousand Euro
LNG	Liquefied Natural Gas
MRP	Market Risk Premium
M&A	Mergers and Acquisitions
NAP	National Allocation Plan
N ₂ O	Nitrous oxide
NBP	National Balancing Point
NL	The Netherlands
NPV	Net Present Value
O&M	Operation and Maintenance
OLS	Ordinary Least Squares

OMEL	Operador del Mercado Ibérico de Energia
OPEC	Organization of Petroleum Exploring Countries
OTC	Over the Counter
p.	Page
pp.	Pages
PFC	Perfluorocarbon
PV	Photovoltaic
SML	Security Market Line
SF ₆	Sulphur hexafluoride
Std. Dev.	Standard Deviation
s.t.	subjected to
T	Ton
TTF	Title Transfer Facility
TSO	Transmission System Operator
TV	Terminal Value
UBA	Umweltbundesamt
UK	United Kingdom
UN	United Nations
US	United States of America
VBA	Visual Basic for Applications
VER	Voluntary Emission Reductions
WACC	Weighted Average Cost of Capital

List of symbols

α	Alpha
$\&$	And
$\bar{r}_F$	Average realized yield of fund F
$\bar{r}_f$	Average risk-free interest rate
D_{base}	Base load
β_i	Beta coefficient of asset i
L	Cholesky's matrix
$c_{O\&M}$	Cost of operation and maintenance
ρ	Correlation coefficient
σ_{ij}	Covariance between two random variables i and j
D_t	Depreciation
$\$$	Dollar
$E[.]$	Expectation operator
μ	Expected return/ value
c_{fix}	Fixed generation costs
$\bar{P}_t^E$	Fixed remuneration of generated electricity for renewable energies in period t
g	Growth rate
δ	Horizontal distance to the efficient frontier
A	Initial matrix
I	Investment
λ	Lambda
τ	Marginal tax rate
D_M	Market value of debt
E_M	Market value of equity
b	Maximum value
a	Minimum value
m	Mode

D_{peak}	Peak load
%	Percent
Z_i	Performance ratio of portfolio i
p	Probability
ϕ	Probability space
Q_t^C	Quantity of carbon in period t
Q_t^F	Quantity of fuel in period t
Q_t^E	Quantity of generated electricity in period t
S	Supply
σ_ε	Random error
r_i	Return of asset i
r_f	Risk-free interest rate
σ_i	Standard deviation of a random variable
E	Technical efficiency
L^T	Transpose of Cholesky 's matrix
w^T	Transpose matrix of portfolio weights
TV	Terminal value
$\tilde{P}_t^C$	Uncertain price of a carbon in period t
$\tilde{P}_t^E$	Uncertain price of electricity in period t
$\tilde{P}_t^F$	Uncertain price of fuel in period t
V	Value
σ^2	Variance of a random variable
S	Variance-covariance matrix
η	Vertical distance to the efficient frontier

$\tilde{Q}_t^E$	Volume risk of generated electricity from renewable energies in period t
w_i	Weight of asset i

Energy units and conversion factors

Work

kWh	Kilowatt hour
MWh	Megawatt hour
GWh	Gigawatt hour
TWh	Terawatt hour
Btu	British thermal unit
MMBtu	1,000,000 Btu
t.c.e.	ton of coal equivalent
t.o.e.	ton of oil equivalent

Power

kW	Kilowatt
MW	Megawatt
GW	Gigawatt
TW	Terawatt

Conversion factors

Coal	1 t.c.e = 8.14 MWh
Gas	1 BTU = 0.0293071MWh
Oil	1 t.o.e. = 11.63 MWh
Barrel	158.988 l
	1 Barrel oil = 147 kg

List of tables

TABLE 2.1	DEVELOPMENT OF ELECTRICITY GENERATION IN SELECTED EUROPEAN COUNTRIES	16
TABLE 2.2	CLASSIFICATION OF POWER PLANT TECHNOLOGIES.....	23
TABLE 2.3	ALLOCATION VS. CARBON EMISSIONS	35
TABLE 3.1	FREE CASH FLOW SCHEME.....	61
TABLE 4.1	TECHNICAL AND COST PARAMETERS FOR POWER PLANT TECHNOLOGIES	115
TABLE 4.2	COMMODITY PRICE ASSUMPTIONS.....	118
TABLE 4.3	HISTORICAL MEAN AND STANDARD DEVIATION OF RISKY PARAMETERS	120
TABLE 4.4	EXPECTED DEGRESSION OF THE REMUNERATION OF RENEWABLE ENERGIES	126
TABLE 4.5	OPERATING HOURS AND REMUNERATION OF RENEWABLE ENERGIES.....	128
TABLE 4.6	PREPARATION OF OPERATING POWER PLANTS	136
TABLE 4.7	IDENTIFYING THE NEED FOR REPLACEMENTS	139
TABLE 4.8	IDENTIFYING THE NEED FOR REPLACEMENTS CONTD.....	141
TABLE 4.9	INVESTMENT PLANNING	144
TABLE 4.10	CLASSIFICATION FOR VBA-MACRO.....	149
TABLE 4.11	TECHNICAL AND ECONOMIC EFFICIENCY	158
TABLE 5.1	DESCRIPTIVE STATISTICS: AVERAGE MONTHLY COMMODITY PRICES (MAY 31ST, 2005 TO DECEMBER 31ST, 2009).....	165
TABLE 5.2	DESCRIPTIVE STATISTICS: AVERAGE MONTHLY METEOROLOGICAL DATA (MAY 31ST, 2005 TO DECEMBER 31ST, 2009).....	167
TABLE 5.3	EMPIRICAL CORRELATIONS OF RISKY VARIABLES	170
TABLE 5.4	ADJUSTED CORRELATION MATRIX BASED ON EMPIRICAL DATA.....	174
TABLE 5.5	CORRELATION MATRIX BASED ON SIMULATION	174
TABLE 5.6	POWER PLANT PORTFOLIO IN 2009	177
TABLE 5.7	POWER PLANTS PLANNED AND UNDER CONSTRUCTION	179

TABLE 5.8	DEVELOPMENT OF THE POWER PLANT PARK FROM 2010 TO 2020	182
TABLE 5.9	INVESTMENTS AND REPLACEMENTS OF POWER PLANT TECHNOLOGIES FROM 2010 TO 2020	183
TABLE 5.10	POWER PLANT PORTFOLIO IN 2020	185
TABLE 5.11	VALUATION RESULTS FOR POWER PLANT TECHNOLOGIES	186
TABLE 5.12	COMPOSITION AND WEIGHTS OF SAMPLE GENERATION PORTFOLIOS	189
TABLE 5.13	VALUATION RESULTS FOR POWER PLANT SAMPLE	191
TABLE 5.14	VALUATION RESULTS FOR POWER PLANT SAMPLE CONTD.	193
TABLE 5.15	VALUATION RESULTS FOR NEW POWER PLANT TECHNOLOGIES	196
TABLE 5.16	COVARIANCE MATRIX OF NEW POWER PLANT TECHNOLOGIES	198
TABLE 5.17	COMPOSITION AND WEIGHTS OF EFFICIENT TARGET GENERATION PORTFOLIOS	199
TABLE 5.18	VALUATION RESULTS FOR EFFICIENT TARGET GENERATION PORTFOLIOS	202
TABLE 5.19	COMPOSITION AND WEIGHTS OF EFFICIENT GERMAN GENERATION PORTFOLIOS	205
TABLE 5.20	COMPOSITION AND WEIGHTS OF EFFICIENT BRITISH GENERATION PORTFOLIOS	209
TABLE 5.21	COMPOSITION AND WEIGHTS OF EFFICIENT DUTCH GENERATION PORTFOLIOS...	212
TABLE 5.22	COMPOSITION AND WEIGHTS OF EFFICIENT SPANISH GENERATION PORTFOLIOS	215
TABLE 5.23	COUNTRY-SPECIFIC OVERVIEW OF VALUATION RESULTS FOR EFFICIENT GENERATION PORTFOLIOS	219
TABLE 5.24	COMPOSITION AND WEIGHTS FOR VERTICAL AND HORIZONTAL EFFICIENT GENERATION PORTFOLIOS	220
TABLE 5.25	DEGREE OF EFFICIENCY FOR SAMPLE GENERATION PORTFOLIOS BASED ON ECONOMIC CRITERIA	222
TABLE 5.26	DEGREE OF EFFICIENCY FOR SAMPLE GENERATION PORTFOLIOS BASED ON TECHNICAL CRITERIA	226
TABLE 5.27	VALUATION RESULTS FOR SELECTED SINGLE POWER PLANT TECHNOLOGIES IN EUROPE	230

List of figures

FIGURE 2.1	POWER MARKET SYSTEM.....	26
FIGURE 2.2	TYPICAL MERIT ORDER ON POWER MARKETS	28
FIGURE 2.3	FUEL SWITCH	29
FIGURE 2.4	INSTRUMENTS OF THE KYOTO PROTOCOL	31
FIGURE 2.5	SUPPLY AND DEMAND IN EUROPEAN CARBON MARKET.....	34
FIGURE 2.6	PRIMARY ENERGY CONSUMPTION BY TYPE OF FUEL IN 2008	38
FIGURE 2.7	AVERAGE MONTHLY EUROPEAN BASE LOAD PRICES 2005 TO 2009	41
FIGURE 2.8	EEX HOURLY SPOT PRICE IN 2009.....	42
FIGURE 2.9	EU ETS PRICE DEVELOPMENT 2005 TO 2009	43
FIGURE 2.10	COMMODITY PRICE DEVELOPMENT 2005 TO 2009.....	53
FIGURE 3.1	SECURITY MARKET LINE OF THE CAPM.....	64
FIGURE 3.2	FEASIBLE PORTFOLIOS AND THE EFFICIENT FRONTIER	79
FIGURE 3.3	THE SHARPE PERFORMANCE RATIO	95
FIGURE 3.4	MEASURING THE DEGREE OF EFFICIENCY	97
FIGURE 4.1	RISK ANALYSIS PROCESS	113
FIGURE 4.2	EXPECTED AND SIMULATED EEX BASE LOAD PRICE DEVELOPMENT	121
FIGURE 4.3	EXPECTED AND SIMULATED CO ₂ PRICE DEVELOPMENT	121
FIGURE 4.4	EXPECTED AND SIMULATED OIL PRICE DEVELOPMENT	122
FIGURE 4.5	EXPECTED AND SIMULATED GAS PRICE DEVELOPMENT	123
FIGURE 4.6	EXPECTED AND SIMULATED COAL PRICE DEVELOPMENT	124
FIGURE 4.7	EXPECTED DEGRESSION OF THE REMUNERATION OF RENEWABLE ENERGIES	127
FIGURE 4.8	AVERAGE MONTHLY WIND SPEED AND TOTAL SUN HOURS (MAY 31ST, 2005 TO DECEMBER 31ST, 2009).....	130
FIGURE 4.9	LOOP DIAGRAM OF THE PORTFOLIO VALUATION MODEL	133

FIGURE 4.10 SPREADSHEET PLANT VALUATION.....	151
FIGURE 4.11 SPREADSHEET PLANT VALUATION CONTD.	152
FIGURE 4.12 A) FREQUENCY DISTRIBUTION AND B) DENSITY FUNCTION OF POWER PLANTS NET PRESENT VALUE	153
FIGURE 5.1 AVERAGE MONTHLY EUROPEAN PEAK LOAD PRICES 2005 TO 2009	166
FIGURE 5.2 EXPIRING LIFETIME CURVE OF SAMPLE'S POWER PLANT PARK	178
FIGURE 5.3 COMMUNICATED TARGET PORTFOLIO	180
FIGURE 5.4 DEVELOPMENT OF POWER PLANT TECHNOLOGIES FROM 2010 TO 2020.....	184
FIGURE 5.5 VALUE AND STANDARD DEVIATION OF AFFILIATED POWER PLANT TECHNOLOGIES	188
FIGURE 5.6 PORTFOLIOS VALUE AND STANDARD DEVIATION TRADE-OFF	190
FIGURE 5.7 GENERATION ASSETS VALUE AND STANDARD DEVIATION	195
FIGURE 5.8 EFFICIENT FRONTIERS FOR TARGET GENERATION PORTFOLIO.....	201
FIGURE 5.9 VALUE AND STANDARD DEVIATION TRADE-OFF FOR GERMAN GENERATION ASSETS	203
FIGURE 5.10 EFFICIENT FRONTIERS FOR GERMAN GENERATION PORTFOLIOS	206
FIGURE 5.11 VALUE AND STANDARD DEVIATION TRADE-OFF FOR BRITISH GENERATION ASSETS	207
FIGURE 5.12 EFFICIENT FRONTIERS FOR BRITISH GENERATION PORTFOLIOS	210
FIGURE 5.13 VALUE AND STANDARD DEVIATION TRADE-OFF FOR DUTCH GENERATION ASSETS	211
FIGURE 5.14 EFFICIENT FRONTIERS FOR DUTCH GENERATION PORTFOLIOS	213
FIGURE 5.15 VALUE AND STANDARD DEVIATION TRADE-OFF FOR SPANISH GENERATION ASSETS	214
FIGURE 5.16 EFFICIENT FRONTIER FOR SPANISH GENERATION PORTFOLIOS	217
FIGURE 5.17 HORIZONTAL AND VERTICAL DISTANCE OF THE TARGET GENERATION PORTFOLIO TO THE EFFICIENT FRONTIERS.....	221