FICHTNER

Value of Renewable Power
可再生能源电力定价

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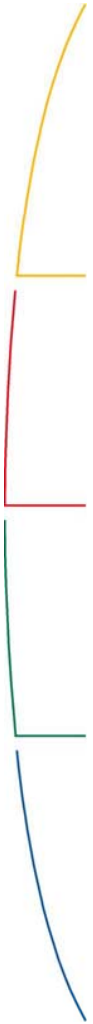
Contents 内容



Cost Determination – Calculation Base 成本确定—计算基准

Nominal Levelised Electricity Generation Costs

名义上的平准化发电成本

$$\text{Levelised Electricity Cost} = \frac{\text{Annuity of Life Cycle Costs}}{\text{Mean Annual Electricity Generation}}$$

Life Time
生命周期

Investment
投资

Operation & Maintenance Costs
运营维护成本

Interest Rate
利率

$$\text{Annuity} = \sum_{t=0}^{T} (I_t + OM_t)(1+r)^{-t} \cdot \frac{r \cdot (1+r)^T}{(1+r)^T - 1}$$

Present Value of Life cycle costs

Annuity Factor

Cost Determination – Principles In Germany成本确定—德国实施的原则

Four-year revision cycle 4年更新成本

Cost based price setting 基于成本定价

Cost determination ex-post via evaluation of realised power plants by independent consultants

通过由独立咨询机构评估运行中的电厂来进行成本确定后评估

Including evaluation of cost development over time

包括对成本随时间变化进行评估

Supplemented by expert judgements, particularly on future progress

由专家评价进行补充，尤其是对未来的发展预测

Determination of average costs and cost ranges

确定平均成本和成本范围

Example German Wind Power 2004 Review 案例：德国风电2004年回顾

Two independent reports (Windguard, ISET) 两份独立报告（ Windguard, ISET）

Data sources for costs 成本计算的数据来源

Windguard: survey among plant operators
1880 power plants covered
Windguard：通过对1880个风电场运营商进行调研获得的数据

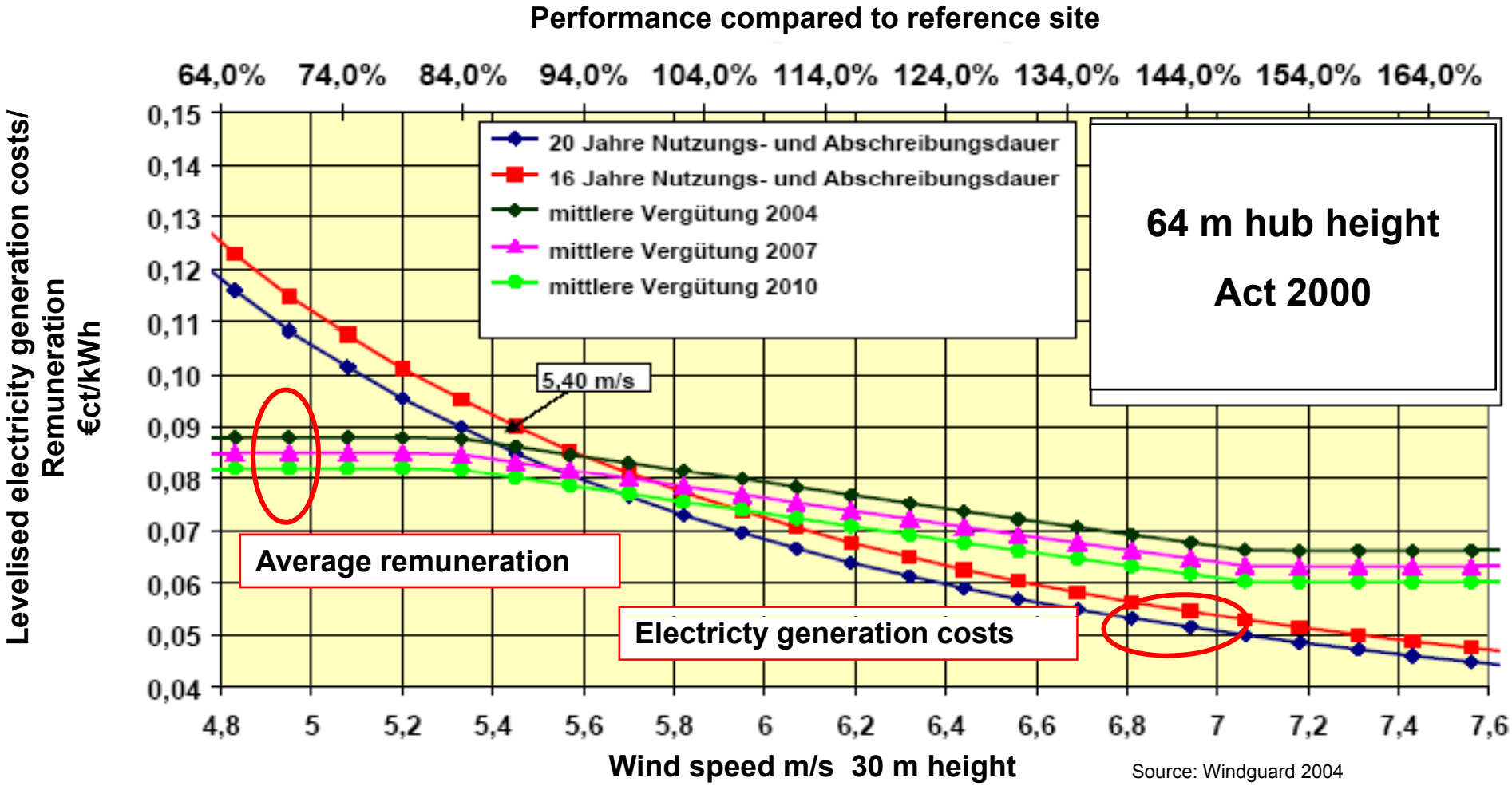
ISET: public available information from offers for participation
751 power plants = 70 Projects = 1122 MW =
15% of plants in the period 2001 – 2003
ISET：公开的可获取的信息
751个风电场=70个项目=容量1122MW=2001-2003年间15%的风电场

Specific investment costs, Operation & Maintenance costs, replacement costs, interest rate
具体投资成本，运营维护成本，重置成本，利率

Example German Wind Power 2004 Review案例：德国风电2004回顾

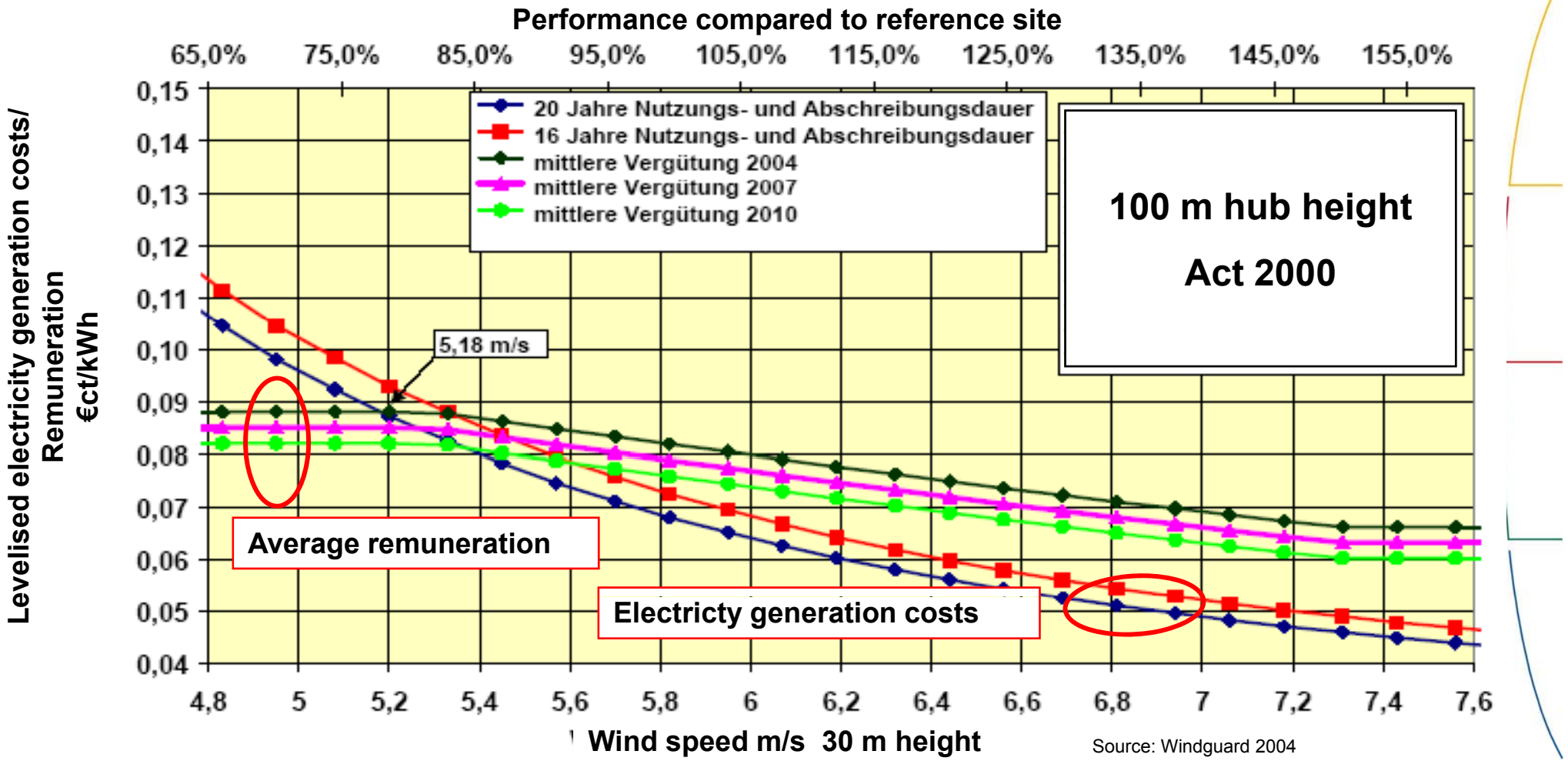
Investment Costs Plant: 风场投资成本	**895 €/kW =** **390 €/MWh$_{REF}$**
Balance of System Costs: 系统成本核算	**30 % of plant Investment =** **269 €/kW**
Annual O&M Costs: 年运行维护成本	**3 %/yr of plant investment =** **27 €/kW/yr**
Replacement costs: 重置成本	**1st 10 yrs: 1,8 % of plant investment =** **16 €/kW/yr** **2nd 10 yrs: 3 % of plant investment =** **27 €/kW/yr**
Inflation rate: 通货膨胀率	**2 %/yr**
Interest rate: 利率	**Equity （资产）12 % (30 % share)** **Debt （负债）5,5 % (Soft loan, 70 % share)** **= mean rate 7,45 %**

Example German Wind Power 2004 Review案例：德国风电2004 结果



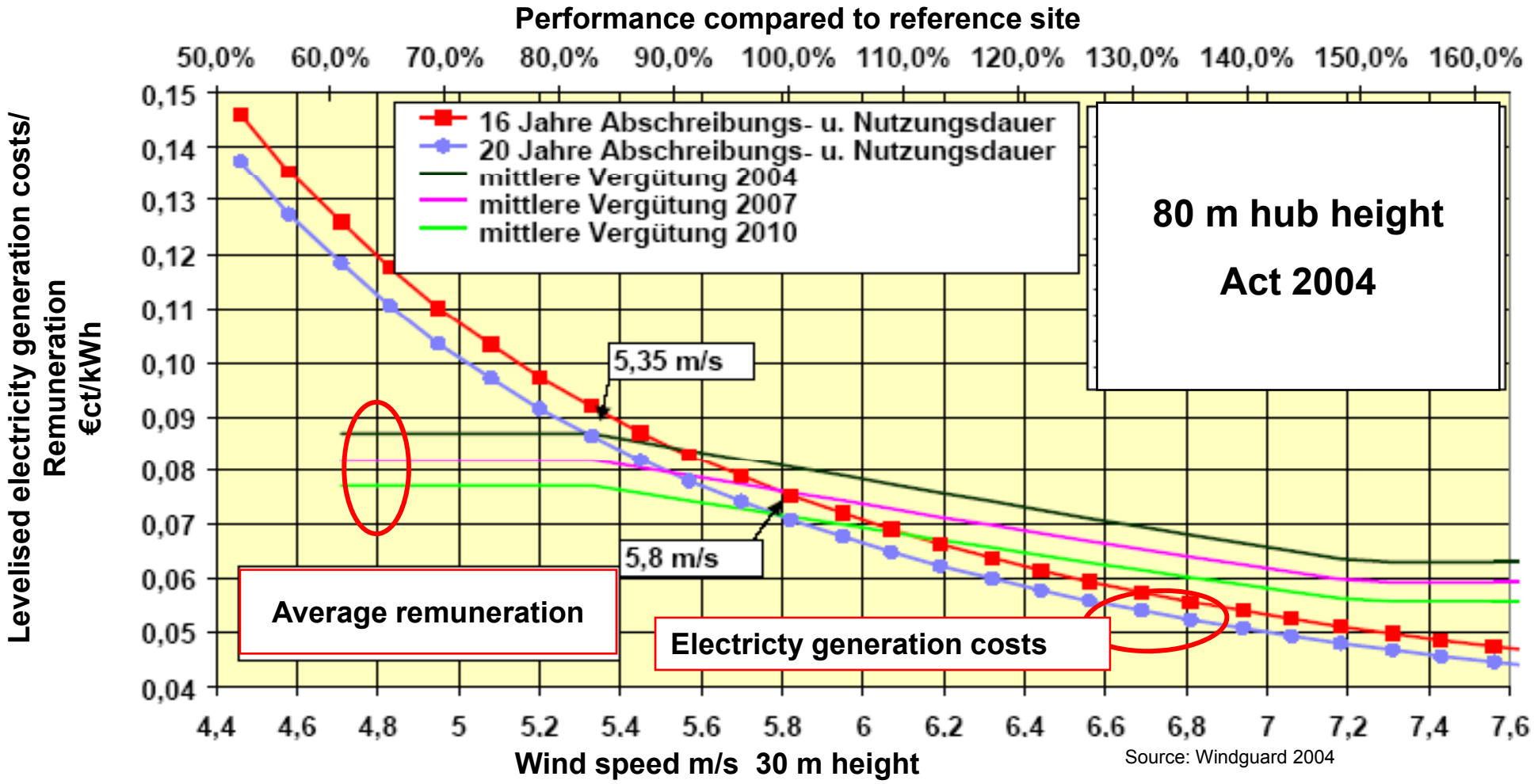
Source: Windguard 2004

Example German Wind Power 2004 Review案例：德国风电2004 结果



Source: Windguard 2004

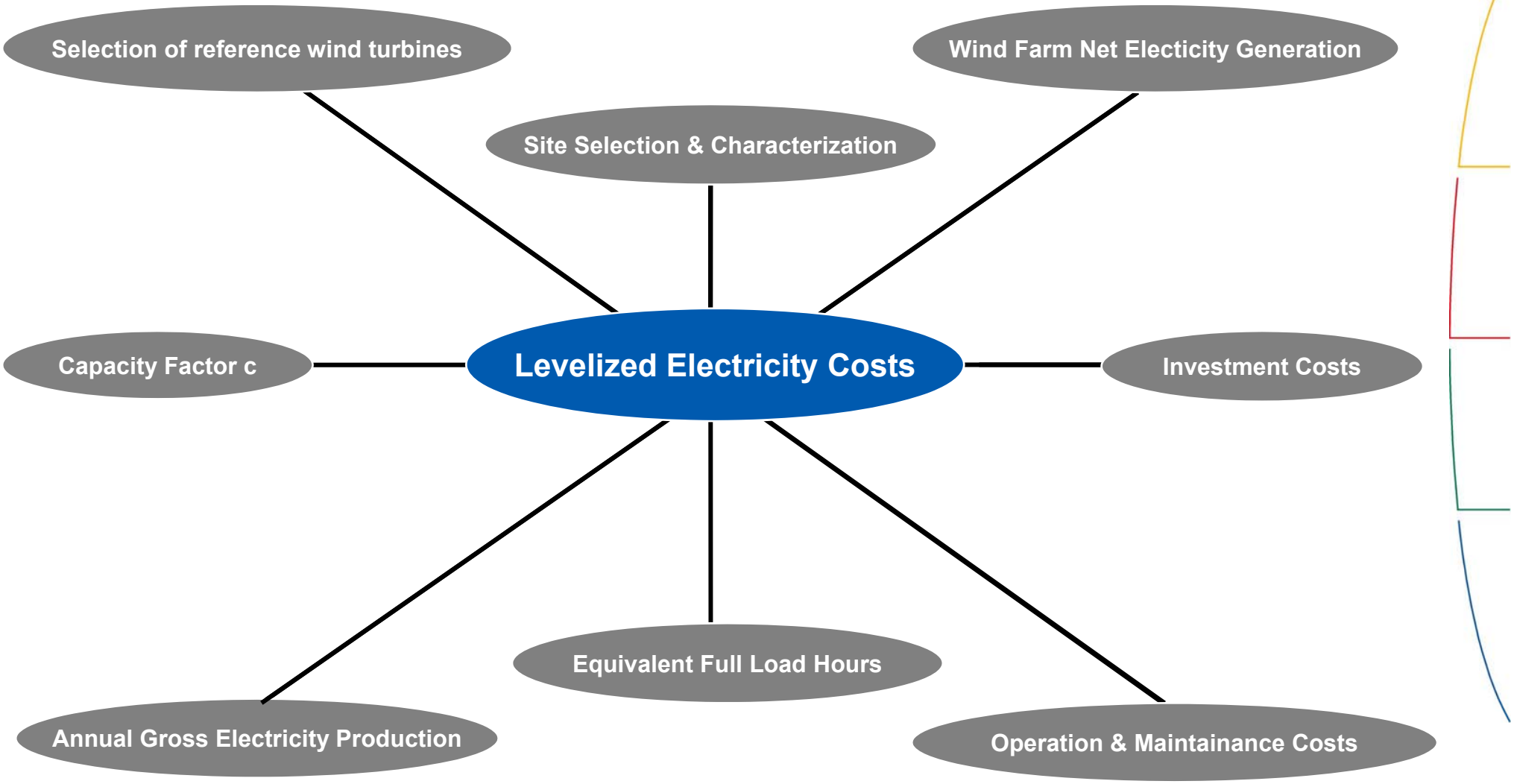
Example German Wind Power 2004 Review案例：德国风电2004 结果



Source: Windguard 2004

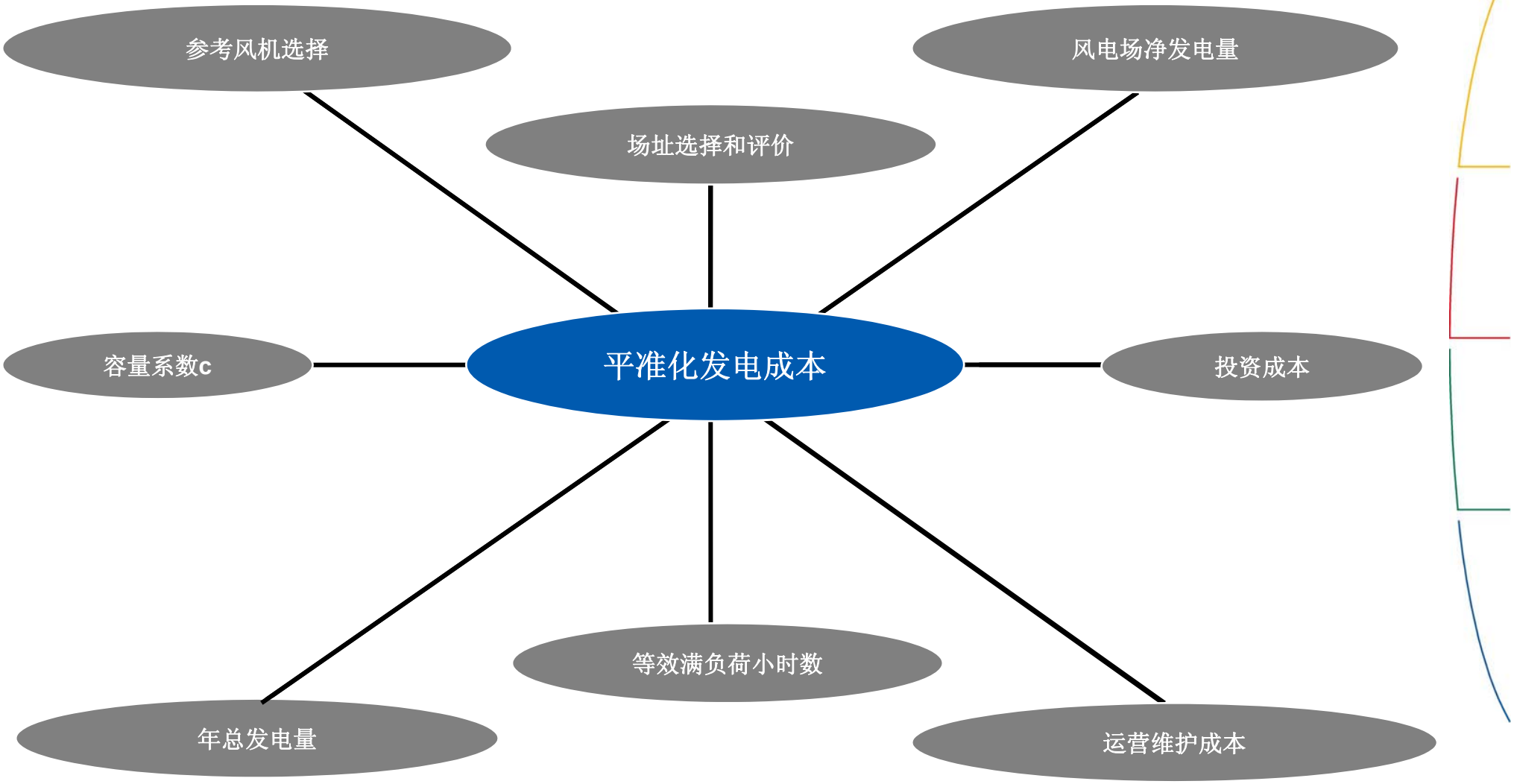
Vietnam: Calculation of the Levelized Electricity Costs (LEC)

Main Influencing Factors



越南：平准化发电成本（LEC）计算方法

主要影响因素



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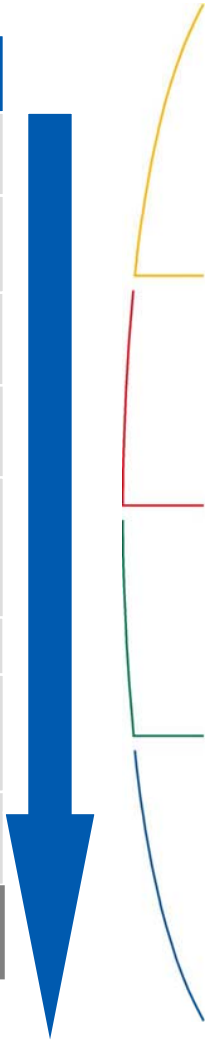
Vietnam: Calculation of the Levelized Electricity Costs (LEC)

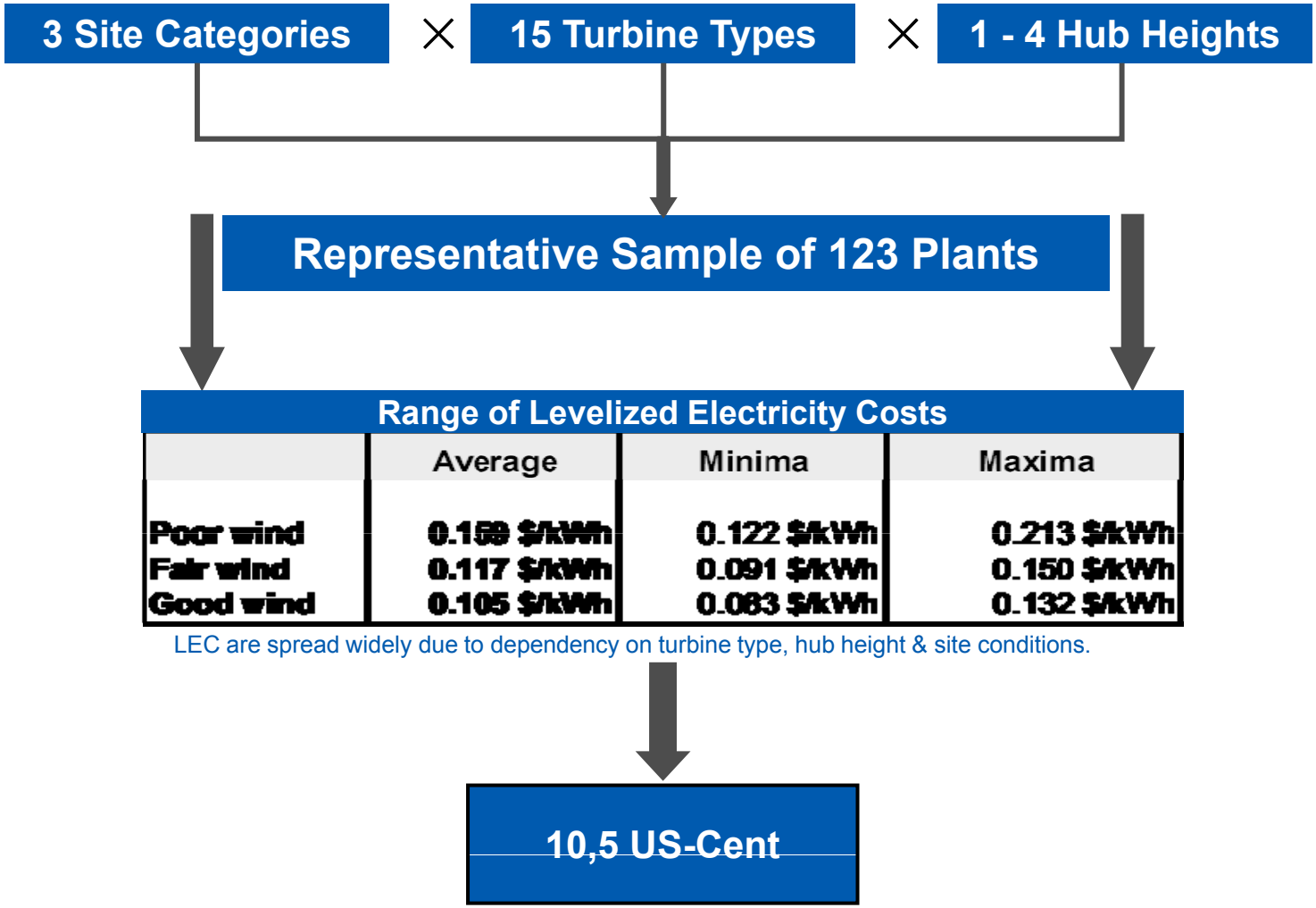
	Methods / Factors	
Site Selection & Characterization	mathematical and statistical analysis of wind-speed distribution depending on height, terrain properties and annual mean wind-speed at representative sites	
Selection of Reference Wind Turbines	different manufacterers, categorization regarding size, power curve, etc.	
Capacity Factor c	dependent on hub height: power production per year according to probalistic wind function in relation to maximum power production per year under permanent full load	
Annual Gross Electricity Production	calculated using wind data of specific site and power curve of turbine	
Wind Farm Net Electicity Generation	wind plant auxiliary power demand (0,15% of gross plant generation) and shadowing effects withing wind park (96% park efficiency)	
Investment Costs	**Wind Turbine**	capacity, hub height, raw material price, market situation
	Incidentials	application case, grid voltage-level, local labour costs **25.1% of ex-works price of a wind turbine** (22% less than in EU)
Operation & Maintainance Costs	fixed/variable costs, maintainance costs rise during technical lifetime, WACC, etc. O&M-Costs mathematically levelized to an annual rate	
Levelized Electricity Costs	**(Levelized O&M costs + WACC) / total annual net electricity generation**	



越南：平准化发电成本（LEC）计算方法

	方法 / 因素	
场址选择和评价	在代表性场址根据不同高度，地形特征和年平均风速对风速分布进行数学和统计分析	
参考风机选择	不同设备制造商，不同机型（容量、功率曲线等）	
容量系数 c	取决于轮毂高度：按照风速分布计算的年发电量，与持续满载情况下最大年发电量相关	
年总发电量	根据特定场址的风数据和风机的功率曲线计算得出	
风电场净发电量	风电场辅助电力需求（总发电量的0.15%）和风电场本身的塔影效应（风电场效率的96%）	
投资成本	风机	容量，轮毂高度，原材料价格，市场形势
	附属	应用情况，并网电压水平，当地劳动力成本 一台风机出厂价格的25.1%（比欧洲少22%）
运营维护成本	固定/可变成本，维护成本在运行周期内增加 运营维护成本通过数学计算均化为一年的水平	
平准化发电成本	**(平准化运营维护成本+ WACC) / 年净发电量**	

Vietnam: Creating of an artificial sample of wind power plants



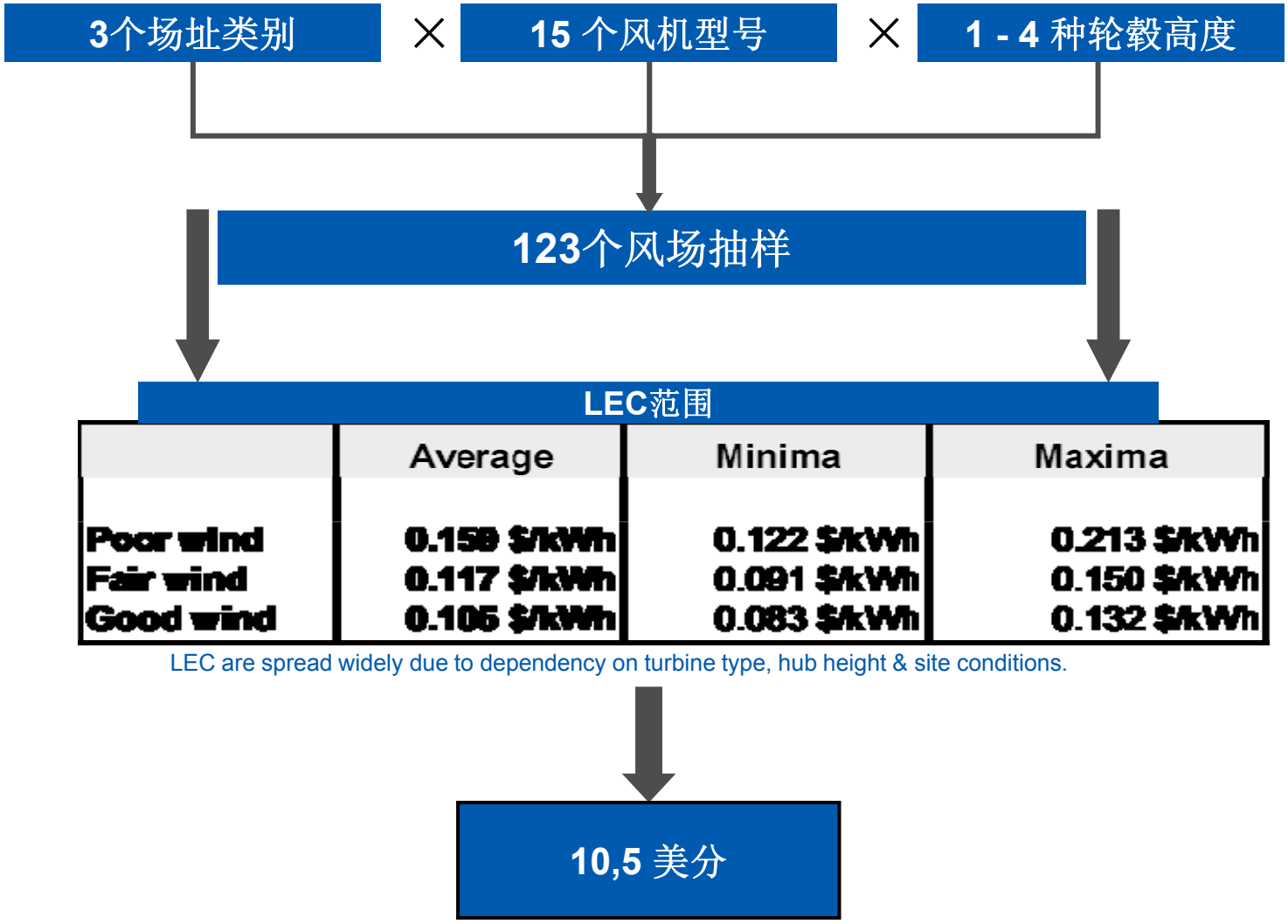
Range of Levelized Electricity Costs

	Average	Minima	Maxima
Poor wind	0.159 $/kWh	0.122 $/kWh	0.213 $/kWh
Fair wind	0.117 $/kWh	0.091 $/kWh	0.150 $/kWh
Good wind	0.105 $/kWh	0.083 $/kWh	0.132 $/kWh

LEC are spread widely due to dependency on turbine type, hub height & site conditions.

10,5 US-Cent

越南：建立风电场抽样案例



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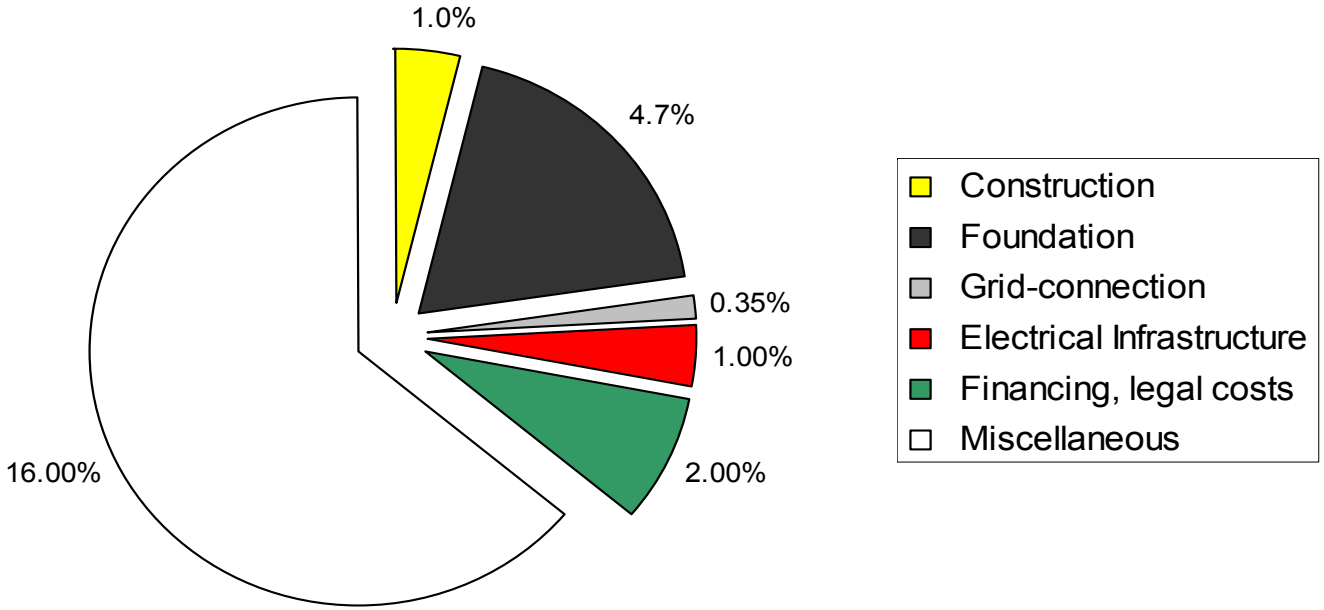
Vietnam: Structure of Local Costs



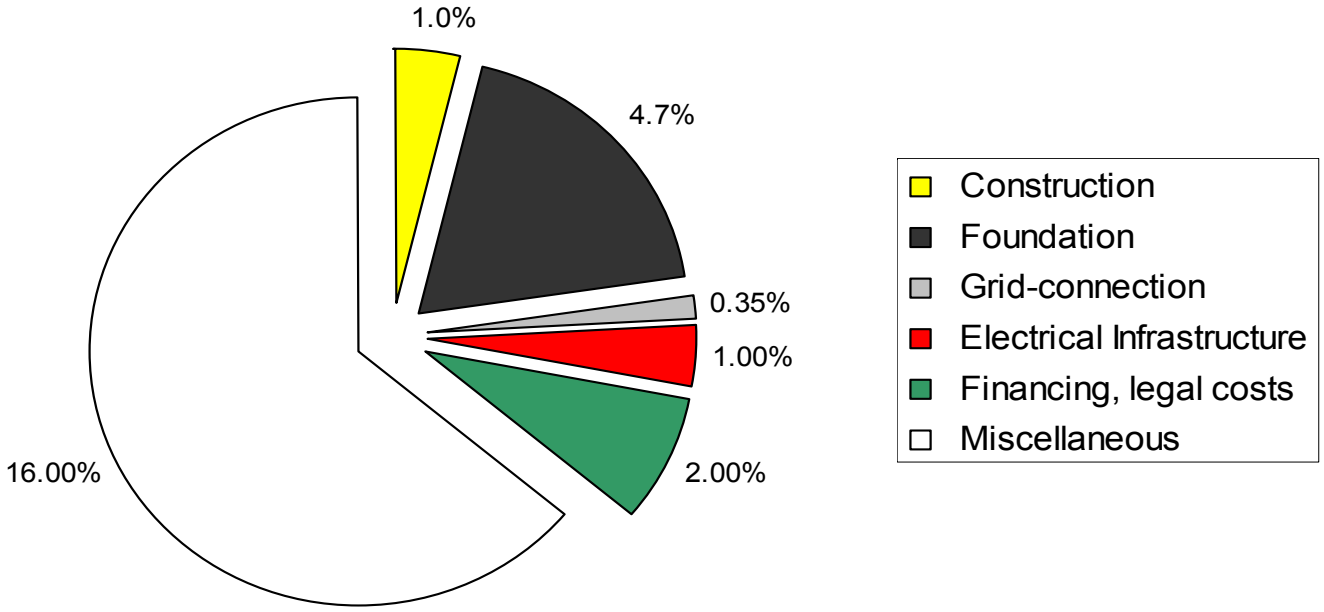
Literature states 20 – 40 % of wind turbine costs as incidentals in Europe.
For Vietnam, local prices apply to Foundation Works, Construction Works, Grid connection Services and Internal Electrical Infrastructure.

The local prices have been determined by obtaining offers from local companies for an assumed 30 MW wind park project scenario consisting of 20 wind turbines with a hub height of 85 m each.

Incidentals were calculated as percentage of the ex works-price of a Nordex S70 refecence-turbine (US-$ 2,172,344).

These evaluated percentages for the Nordex S70 wind turbine have been transferred on and equally used for the LEC calculation of the other turbines.

越南：本地发电成本构成



文献表明在欧洲附属成本占风机成本的20-40%。
对于越南而言，当地价格应用于基建、并网和内部输电线路建设。
当地价格通过当地企业对假定的30MW风电场项目（规模为20台风电机组，单机轮毂85米）进行投标的价格而确定。附属成本按照NordexS70出厂价的比例计算得出（US-2,172,344）.
这个比例已经应用到其他风机的平准化发电成本计算中。

Wind Energy Potential in Vietnam 越南风能资源开发潜力

Modified Wind Potential Analysis 修正后的风能开发潜力分析						
Wind Class风等级	**POOR 贫乏区**	**FAIR 一般区**	**GOOD 较丰富区**	**High 丰富区**	**Very high 非常丰富区**	**Sum 合计**
Average Wind Speed 平均风速	**< 6 m/s**	**6-7 m/s**	**7-8 m/s**	**8-9 m/s**	**> 9 m/s**	
Area面积 (km^2)	197.242	100.367	25.679	2.178	111	
Area 比例(%)	60.60%	30.80%	7.90%	0.70%	>0%	
Potential 开发潜力(MW)	40,000	94,230	24,110	2,053	106	**120,500**
Percentage of tot 占总开发潜力的比例		78.2%	20.0%	1.7%	0.1%	

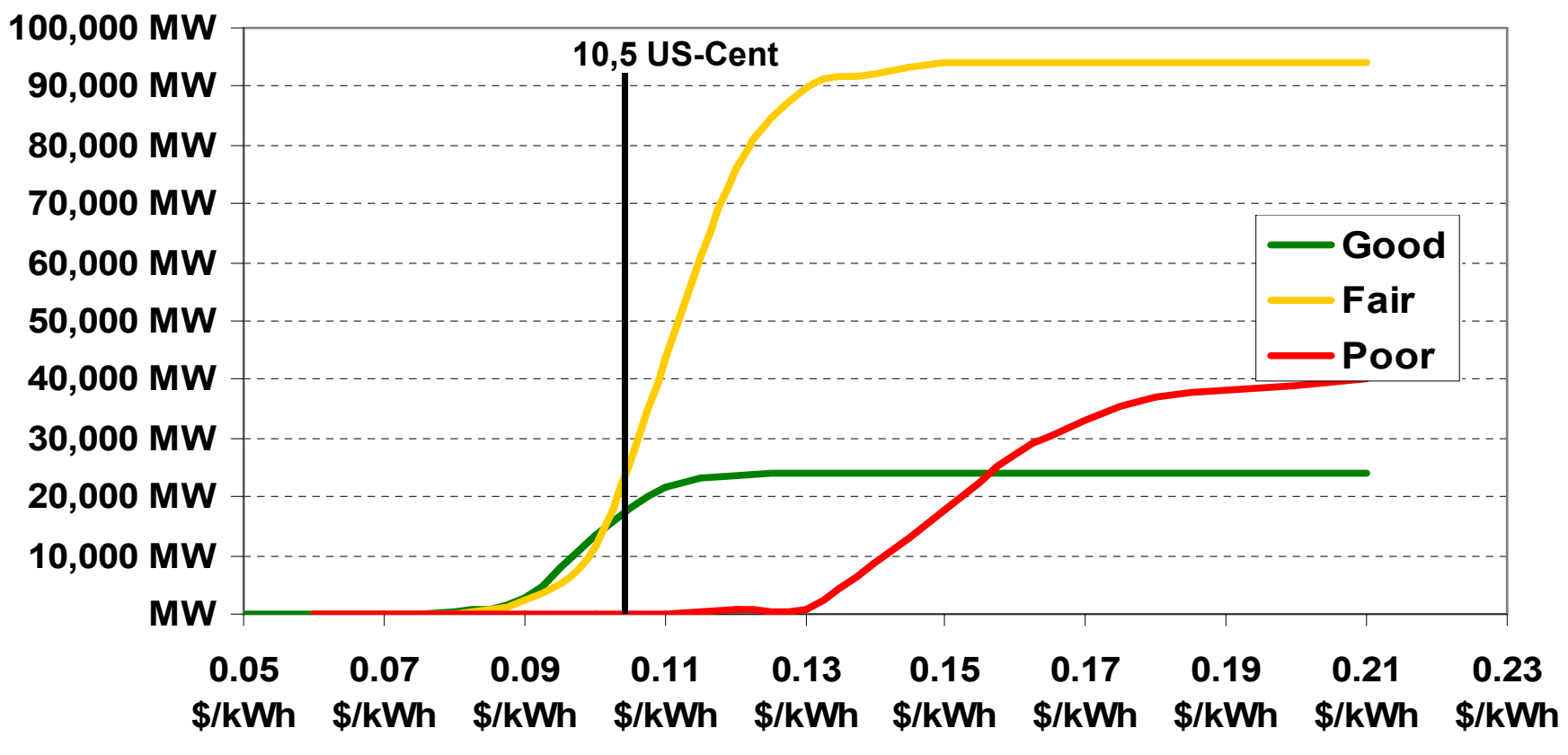
No information available about the Potential at locations with “poor” wind resources. A value of 40,000 MW has been assumed.
没有贫乏区的比例数据，40,000MW是估算值。

Sources来源:

- World Bank, *“Wind Atlas of South East Asia”*
- Study of Mr. Kahn Nguyen

Vietnam: Proposed Tariff Level 越南：建议的电价水平

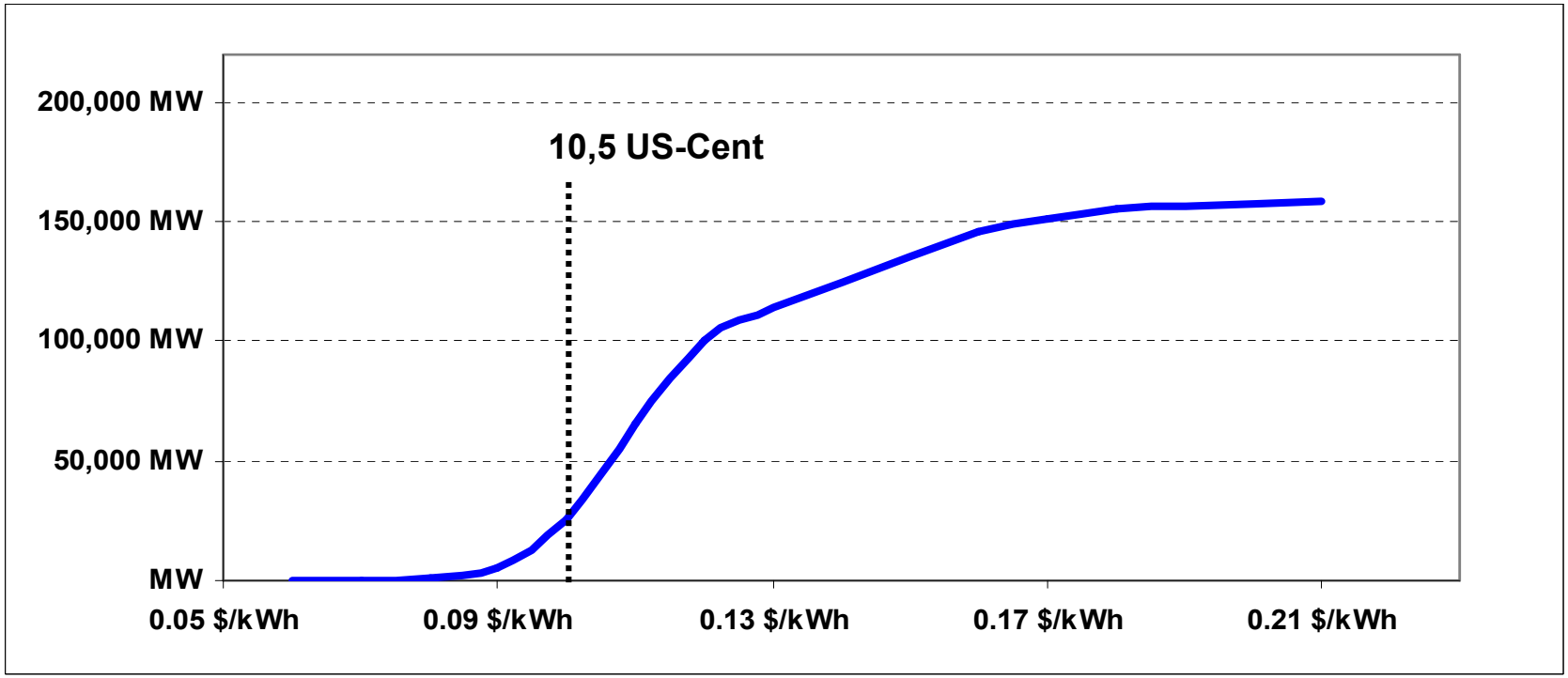
Potential New Capacity in Dependence of Tariff-Level 不同电价水平下新增容量预测



Category specific wind energy potential multiplied with the cumulative frequency distribution of LEC leads to the amount of capacity which can be added at a certain tariff-level. 风能开发潜力乘以LEC累积频数分布得出在某一特定电价水平下可以相加的容量值。

Example Vietnam 越南案例

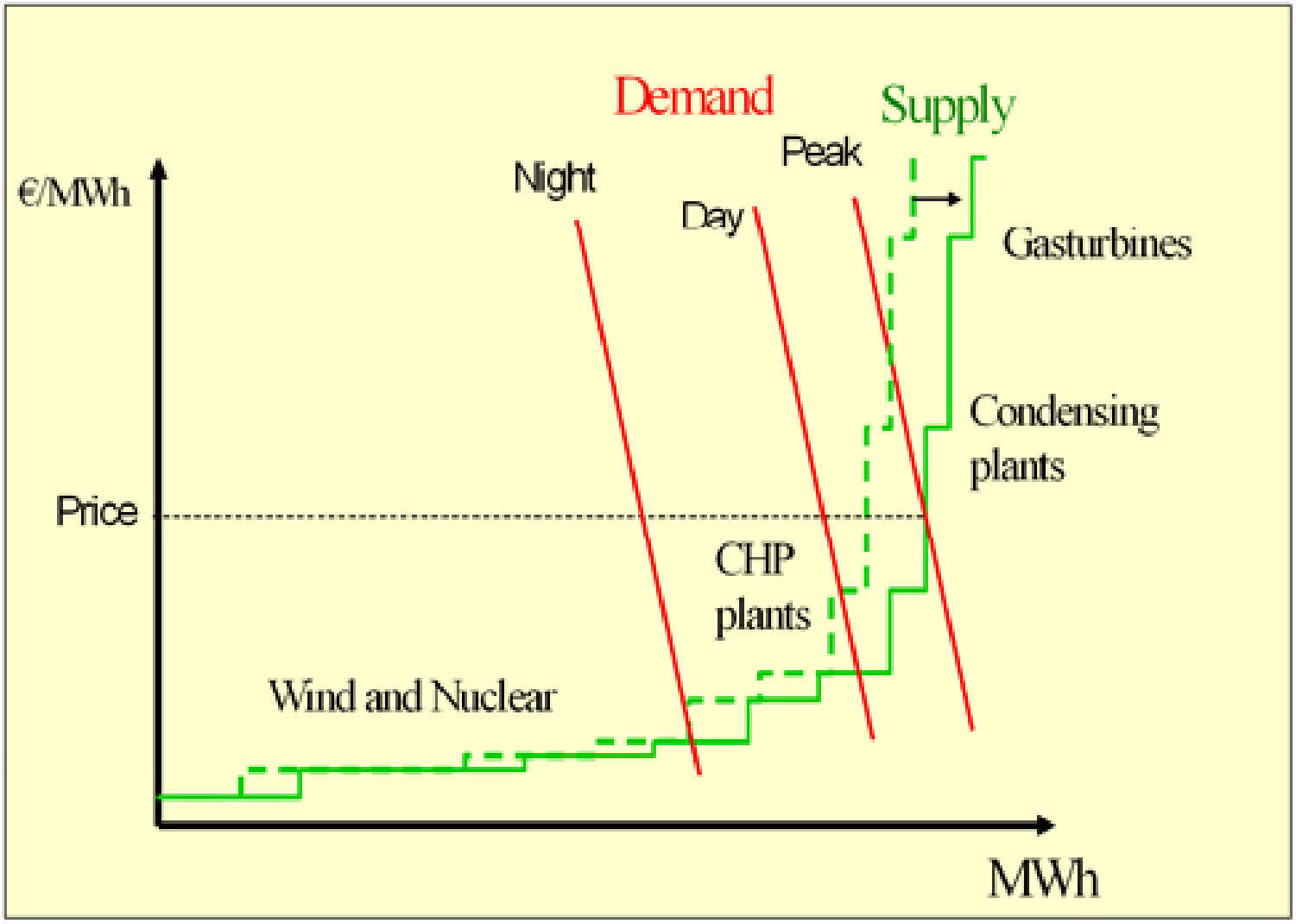
Potential New Capacity in Dependence of Tariff-Level不同电价水平下新增容量预测



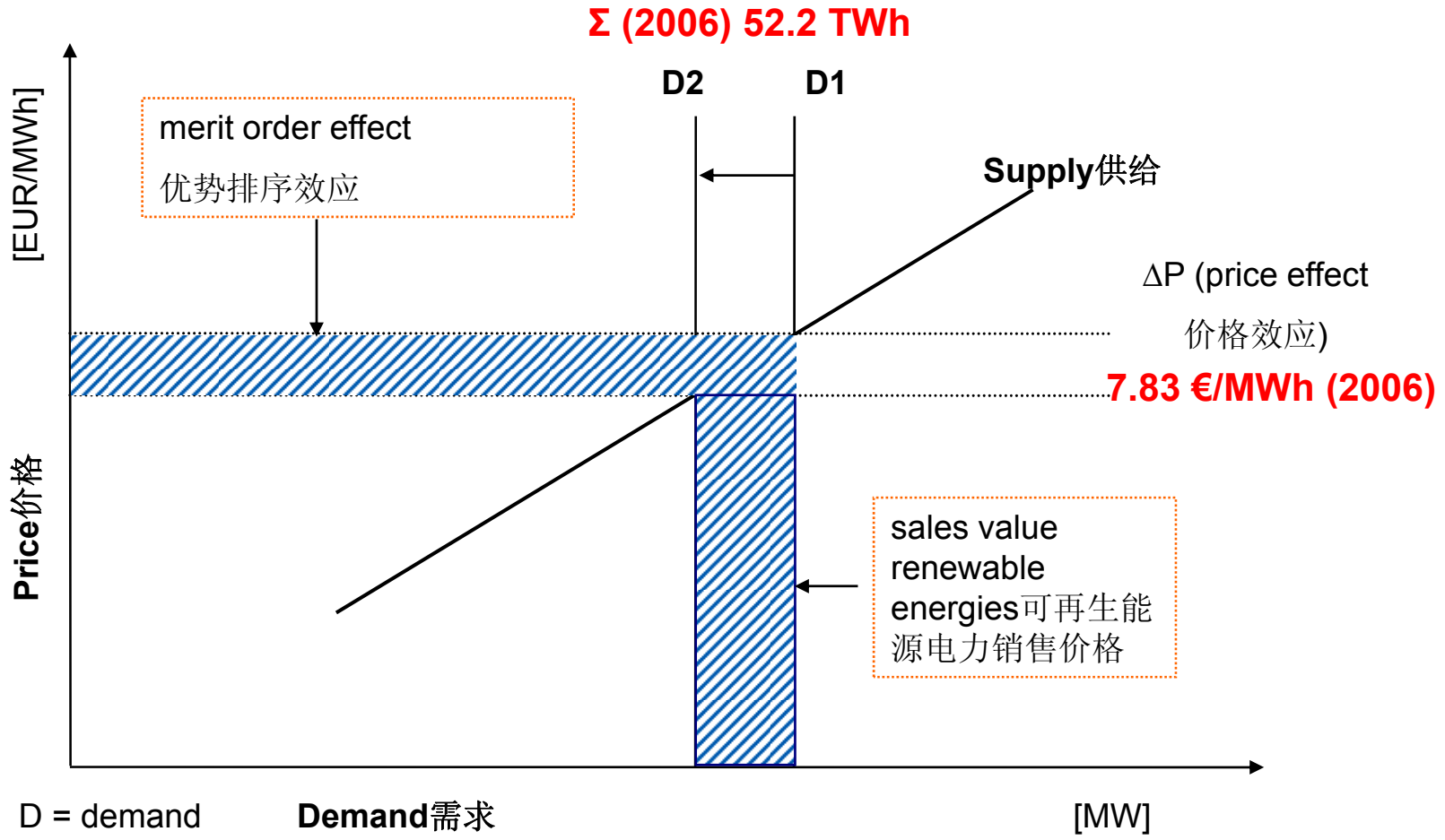
Recommendation for New Tariff Level:
0.105 USD/kWh for the year 2010
建议的电价水平：2010年0.105美元/kWh

- allows developing an average site with good wind conditions允许在风资源好的区域实行平均价格
- a capacity of 25 GW could be mobilized at these costs 按照这个成本计算，可以装机25GW （不考虑风资源之外的因素） *(not considering site restrictions beyond pure wind conditions)*
- tariff thus sufficient to meet the target of 629 MW by 2020 这个电价可以实现2020年装机他到629MW的目标

The value of wind power - Denmark Case风电定价--丹麦的案例



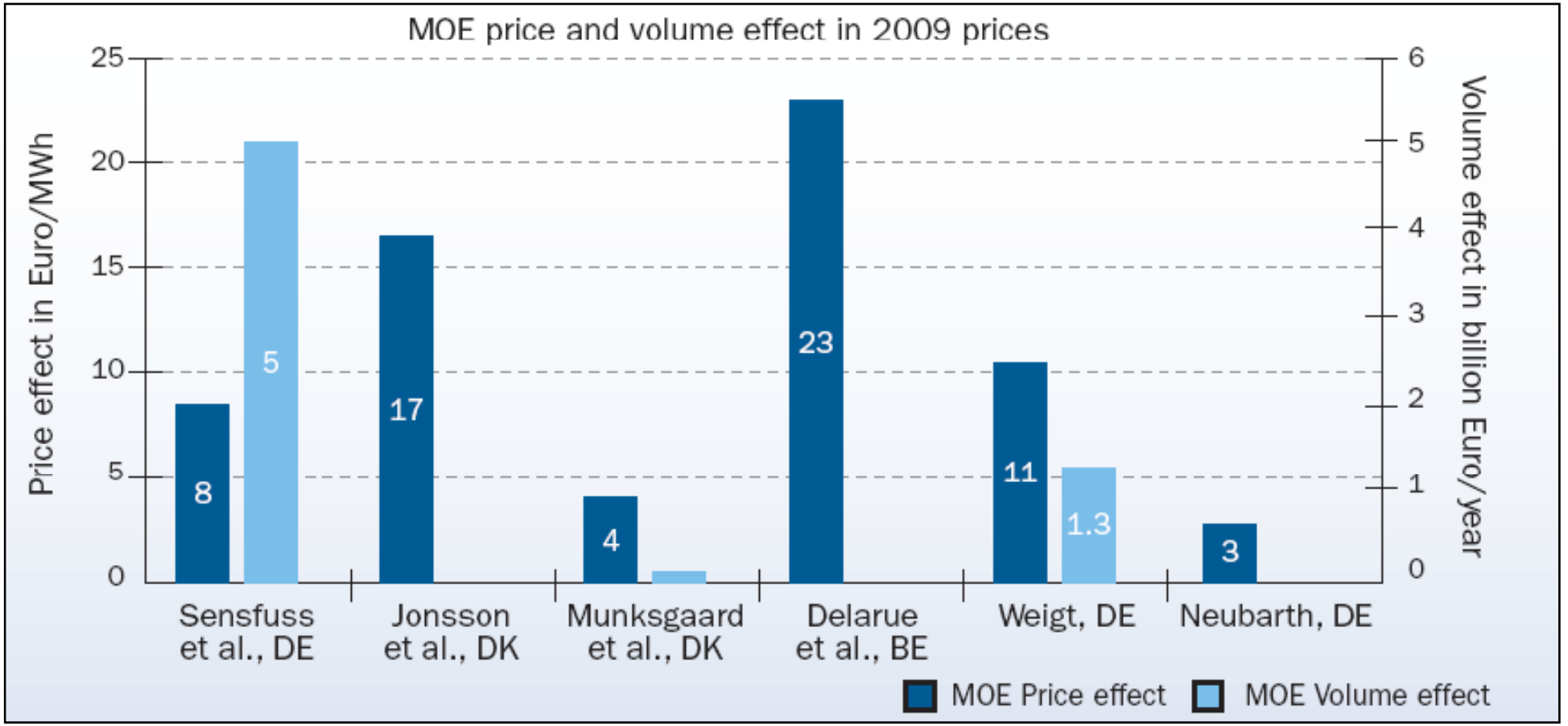
Merit-Order Effect of Power Supply through Feed-In Tariff
通过固定电价政策产生了电力供应的优势排序效应



Total volume merit-order effect (2006): € 4.98 billions

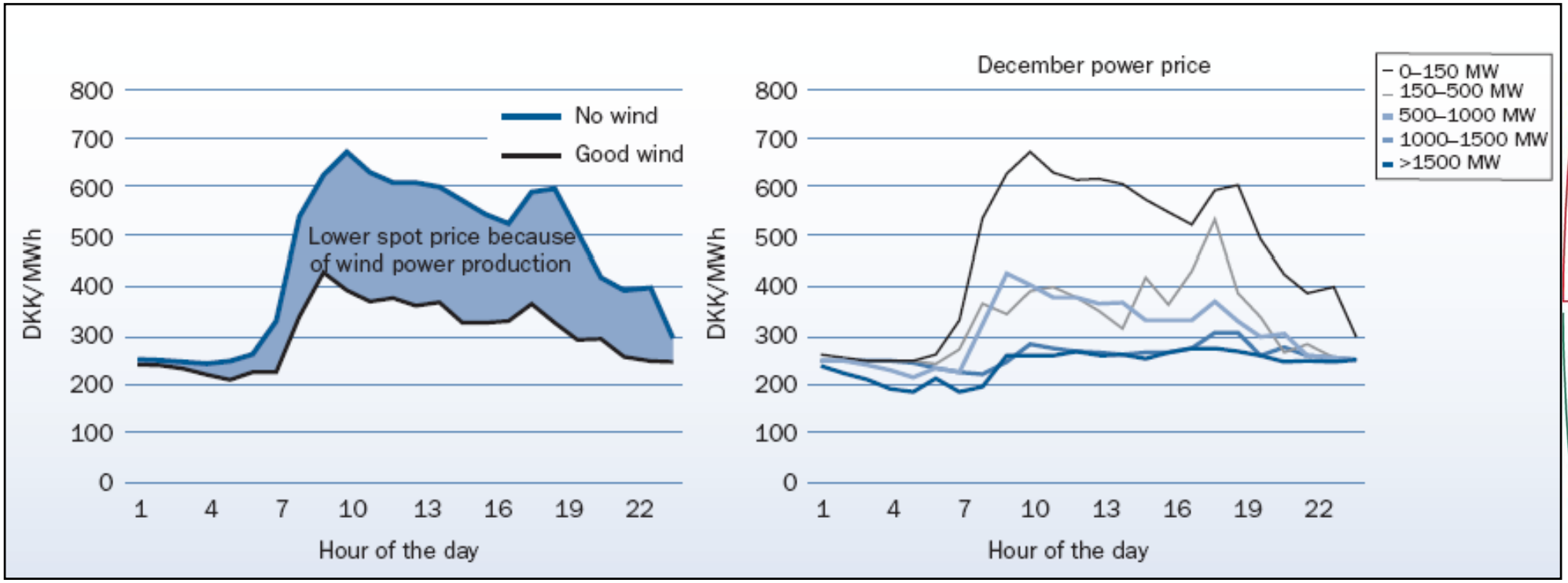
优势排序效应总值（2006年）：49.8亿欧元

Summary of relevant studies and their estimated merit order effects
相关研究结论以及各种研究估算的优势排序效应



Source: EWEA 2010

The impact of wind power on the spot power price in the western Denmark power system in December 2005 在2005年丹麦西部电网中风电对实时电力价格的影响



Source: EWEA 2010

Summary结论

- Value vs. cost perspective

  定价和成本

- Levelised electricity costs is central for determining appropriate tariffs

  平准化发电成本是确定合适电价的核心

- Benefits of renewable power e.g. due to merit order effects may exceed the total costs

  可再生能源电力的收益（例如由于优势排序效应）可能会超过总成本