* **Renewable Investment Pricing:** Gabriele discussed the challenges of correctly pricing renewable investments, particularly focusing on intermittent renewables like wind and solar, and their integration into traditional electricity markets.
  + **Challenges in Pricing:** Gabriele highlighted the difficulty in correctly pricing renewable investments due to the variability and intermittency of wind and solar power. He emphasized that these challenges are compounded by the need for these technologies to be competitive in the market without state support.
  + **Integration Issues:** Gabriele explained that integrating intermittent renewables into traditional electricity markets is challenging due to their unique characteristics, such as variability in output and the need for substantial deployment without significant state aid.
  + **Economic Viability:** Gabriele noted that wind and solar are among the cheapest sources of electricity, making their economic viability crucial for their deployment. He stressed that these technologies need to be competitive in the market to ensure their widespread adoption.
* **European Power Demand:** Gabriele highlighted that 30% of Europe's power demand is currently covered by intermittent renewables, with this percentage expected to double in the next 10 years.
  + **Current Coverage:** Gabriele stated that 30% of Europe's power demand is currently met by intermittent renewables, such as wind and solar. This figure is expected to increase significantly in the coming years.
  + **Future Projections:** Gabriele projected that the percentage of power demand covered by intermittent renewables in Europe will rise from 30% to 60% over the next decade, indicating a rapid growth in renewable energy deployment.
  + **Deployment Challenges:** Gabriele mentioned that achieving this increase will require substantial deployment of wind and solar technologies, which must be done without significant state support, highlighting the need for these technologies to be market-competitive.
* **Power Market Dynamics:** Gabriele explained the workings of the liberalized power market in Europe, where different actors bid their energy at optimal marginal prices, and the market algorithm accounts for cross-country energy flows.
  + **Liberalized Market:** Gabriele described the liberalized power market in Europe, where various producers bid their energy at optimal marginal prices. The market price is determined by the intersection of supply and demand.
  + **Cross-Country Flows:** Gabriele explained that the market algorithm considers the possibility of energy flows between countries, optimizing production and distribution based on cost-effectiveness. For example, cheaper nuclear energy from France can be transported to Italy to replace more expensive gas-generated power.
  + **Market Operations:** Gabriele noted that the European power market operates as a single coupled market, where each country has its own bid curve, but the overall optimization is done collectively to ensure efficiency and cost-effectiveness.
* **Challenges of Integrating Renewables:** Gabriele listed five main challenges in integrating intermittent renewables into the power market, including low capacity factors, cannibalization across countries, seasonal variability, curtailment, and forecast errors.
  + **Low Capacity Factors:** Gabriele highlighted that intermittent renewables like wind and solar have low and variable capacity factors, making it difficult to rely on them consistently for power generation.
  + **Cannibalization:** Gabriele explained the cannibalization effect, where wind generation in one country is correlated with wind generation in other countries, leading to simultaneous high output and low prices.
  + **Seasonal Variability:** Gabriele discussed the seasonal variability of wind and solar power, noting that while they may seem complementary on a monthly basis, their hourly resolution shows significant gaps that cannot be covered by current storage systems.
  + **Curtailment:** Gabriele pointed out the issue of curtailment, where excess renewable energy is wasted due to low demand and insufficient storage, leading to negative electricity prices and disincentivizing new investments.
  + **Forecast Errors:** Gabriele mentioned significant forecast errors in predicting wind and solar generation, which cause imbalances and stress on the grid, leading to increased intraday trading volumes.
* **Capacity Factor Variability:** Gabriele detailed the low and variable capacity factors of solar and wind power, emphasizing the impact of weather variability on renewable energy output.
  + **Weather Impact:** Gabriele emphasized that the output of solar and wind power is heavily impacted by weather variability, leading to low and inconsistent capacity factors. For example, solar power output varies significantly between summer and winter, and wind power output can fluctuate greatly from year to year.
  + **Geographical Differences:** Gabriele noted that the capacity factor for solar power varies by location, with higher output in southern countries like Spain and lower output in northern countries like Germany. Similarly, wind power output varies by region and is subject to significant annual variability.
  + **Investment Risks:** Gabriele highlighted that the variability in capacity factors introduces significant risks for investors in renewable energy projects, as the actual output can differ substantially from year to year, impacting the financial viability of these projects.
* **Cannibalization Effect:** Gabriele discussed the cannibalization effect, where wind generation in one country is correlated with wind generation in other countries, leading to simultaneous high output and low prices.
  + **Correlation of Wind:** Gabriele explained that wind generation in one country is often correlated with wind generation in neighboring countries. For example, wind in Germany is correlated with wind in France, Sweden, and even Italy and Spain, leading to simultaneous high output across multiple countries.
  + **Price Impact:** Gabriele noted that this correlation leads to the cannibalization effect, where high wind output in multiple countries simultaneously drives down electricity prices, reducing the revenue for wind power producers.
  + **Market Dynamics:** Gabriele highlighted that the cannibalization effect complicates the integration of wind power into the market, as it reduces the financial incentives for new investments in wind energy due to the lower prices during periods of high output.
* **Seasonal Variability:** Gabriele explained that while wind and solar generation may seem complementary on a monthly basis, their hourly resolution shows significant gaps that cannot be covered by current storage systems.
  + **Complementary Generation:** Gabriele mentioned that wind and solar generation appear complementary on a monthly basis, with wind power peaking in winter and solar power peaking in summer. However, this complementarity does not hold at an hourly resolution.
  + **Hourly Gaps:** Gabriele emphasized that significant gaps exist in the hourly generation profiles of wind and solar power, leading to periods where neither source can meet the demand. This is particularly problematic during night hours or periods of low wind.
  + **Storage Limitations:** Gabriele pointed out that current storage systems are insufficient to cover these hourly gaps, as they can only store power for a few hours rather than the extended periods needed to balance the variability in renewable generation.
* **Curtailment Issues:** Gabriele highlighted the issue of curtailment, where excess renewable energy is wasted due to low demand and insufficient storage, leading to negative electricity prices and disincentivizing new investments.
  + **Excess Generation:** Gabriele explained that curtailment occurs when there is excess renewable energy generation during periods of low demand, leading to wasted energy. This is particularly common during weekends and holidays when demand is lower.
  + **Negative Prices:** Gabriele noted that curtailment leads to negative electricity prices, as the excess energy drives prices down. This disincentivizes new investments in renewable energy, as producers are concerned about the financial viability of their projects.
  + **Storage Deficiency:** Gabriele highlighted that the lack of sufficient storage capacity exacerbates the curtailment issue, as there are not enough batteries or other storage systems to absorb the excess energy during periods of high generation.
* **Forecast Errors:** Gabriele pointed out the significant forecast errors in predicting wind and solar generation, which cause imbalances and stress on the grid, leading to increased intraday trading volumes.
* **Long-Term Power Market Modeling:** Gabriele described their team's efforts to extend power market modeling to longer horizons, using historical weather data to simulate future scenarios and understand the dynamics of a renewable-dominated system.
* **Capture Prices and Rates:** Gabriele introduced the concept of capture prices and rates, which reflect the actual value of renewable generation based on the timing of production and market prices, and their importance in evaluating renewable investments.
* **Financing Renewable Investments:** Gabriele discussed different financing forms for renewable investments, including contracts for difference and power purchase agreements (PPAs), and their implications for wind and solar projects.
* **Storage Opportunities:** Igor inquired about storage opportunities for solar and wind, and Gabriele explained that while storage is being developed, it is still far from sufficient to meet the needs of the rapidly growing renewable capacity.
* **Impact of Climate Change:** Andreas asked about the impact of climate change on wind scenarios, and Gabriele acknowledged that while they currently do not account for it, they plan to incorporate climate change corrections in future models.