



WÄRTSILÄ

**POWER SUPPLY CHALLENGES**  
**SOLUTIONS FOR INTEGRATING RENEWABLES**  
BY JACOB KLIMSTRA



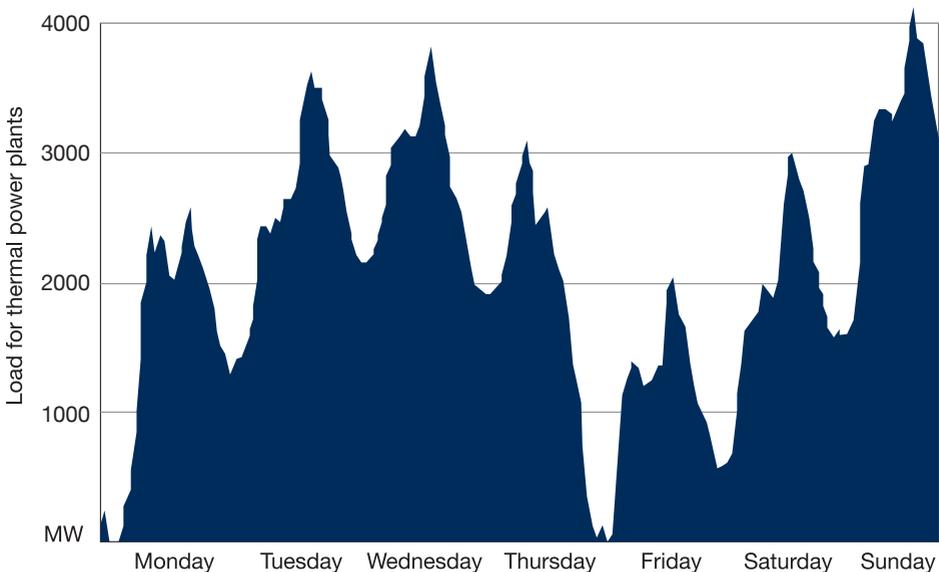
# HOW TO INTEGRATE RENEWABLES TO MEET FUTURE ENERGY DEMAND?

Wind and solar energy are crucial to meet future energy demand and to cut CO<sub>2</sub> emissions. But we are just beginning to understand the technical challenges of integrating them into decades-old power systems. With a large share of variable renewable energy, baseload will disappear. Gigawatts of backup power need to be pushed online in a very short time due to changing weather and forecast errors.

It is becoming widely understood that future power systems must be extremely flexible. What remains under debate is the best means for flexibility. Much-hyped electricity storage, super-grids and demand response may play a role in the future. With compelling scientific evidence, **Power Supply Challenges** proposes, however, that fast-reacting gas-fired power plants based on combustion engines are often the most credible solution.

The book combines empiric data with theory of power engineering. It reaches from detailed electrotechnical analysis to system-level political and economical issues.

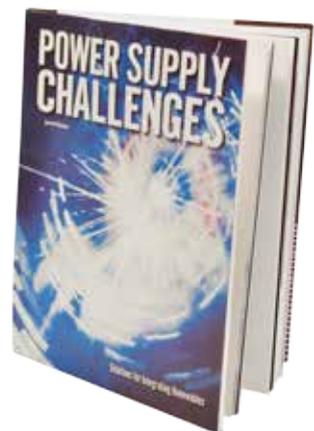
## What happened to the baseload?



- **Avoid double energy costs.** Renewables can easily raise the cost of electricity by 100%. This is due to reduced use and hiking capital costs of the remaining thermal power plants. With flexible generation based on combustion engine technology, the cost rise can be prevented. Agile power plants can reduce electricity costs by upto 50%, compared to business-as-usual gas turbine scenarios.
- **Reduce CO<sub>2</sub> emissions by 80%.** Building more slow-reacting, inflexible gas turbine-based generation will lock in huge future CO<sub>2</sub> emissions. By contrast, investing in flexible generation can reduce emissions to a fifth. This is possible as flexible power plants facilitate more renewable capacity. In fact, they seem to be the best means to increase the share of renewables.
- **Ensure reliability of power supply.** Because renewable-based power systems are instable, it is crucial to have reliable back-up power. Modular plant design with multiple generation units in parallel offer reliability – if one of twenty units trips, there are still nineteen fully available. This is not the case with traditional single-unit power plants.
- **The operation of power plants will change dramatically.** Even with high shares of wind and solar energy in the system, almost the same amount of thermal power generation is needed than without renewables. But running the power plants will be very different. Baseload will disappear. Only sharp demand spikes are left for thermal plants. Only power plants with very fast start and and ramp rates can do this.

*“Through his profound insight to energy issues, the author succeeds to explain in an easy and understandable way the science and facts behind integrating large amounts of variable renewables into energy systems. He explains in an elegant way the underlying physics and provides a lot of useful data.”*

**Peter Lund**  
Professor in Advanced Energy Systems  
Aalto University  
Finland



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# WÄRTSILÄ

Wärtsilä Power Plants is a leading global supplier of flexible baseload power plants of up to 700 MW operating on various gaseous and liquid fuels. Our portfolio includes unique solutions for peaking, reserve and load-following power generation, as well as for balancing intermittent power production. Wärtsilä Power Plants also provides LNG terminals and distribution systems for the entire value chain of LNG industry. As of 2014, Wärtsilä has 55 GW of installed power plant capacity in 170 countries around the world.

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*"The author does a nice job to describe the changing character of electric power generation while respecting the fundamentals and working principles of an integrated grid."*

**Thomas Key**

Senior Technical Executive  
Electric Power Research Institute EPRI  
USA

*"A timely book to demonstrate how to balance the power supply and demand under very complex conditions, such as renewables integration, temperature variation and demand uncertainty."*

**Chongqing Kang**

Professor in Electrical Engineering  
Tsinghua University  
China

*"The book addresses both the challenges and possible solutions for future power systems, using clever illustrations and examples from around the world. This book is a great reference for anyone involved in the energy industry."*

**Michael Walsh**

Director of Future Grids  
Eirgrid  
Ireland