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Future Of NTD Silicon In Manufacture Of High Power Semiconductors

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Welcome

NTD Silicon has been a **crucial material** for **manufacture** of **high power semiconductors** since its introduction in the 1970s. While wide bandgap (WBG) semiconductor materials such as Silicon Carbide (SiC) have started to take a growing share in high power semiconductor markets, the **overall growing demand for power devices** in general, largely driven by the energy transition and the urge to reduce carbon footprint, will result a significant and **growing demand for NTD Silicon over many more years**.

Having the perspective of a high power device maker, we present our informed view on the development of NTD Silicon consumption in future years, comment on required resistivity ranges and wafer diameters and back it up with the technical underpinning. We also consider typical product life cycles and transition periods to adapt new technologies (for instance a hypothetic future change from 200mm to 300mm wafer diameter).

We believe, our work contributes meaningfully to inform decision makers at research reactors and motivate further development and industrialization of production capabilities for NTD Silicon, and rises awareness that research reactors are a highly precious part of the high power semiconductor supply chain and inevitable to reach the goal of net zero carbon emissions.

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Introduction

Decarbonization / energy transition double demand for power semiconductor devices until 2030 [1]

Besides wide bandgap (WBG) materials, this will significantly push demand for NTD silicon

High power semiconductors, e.g. HVDC thyristors, used striation -free, homogeneously doped NTD silicon since 1970s [2, 3, 4, 5, 6, 7]

WBG materials, e.g. SiC, provide advantages for power semiconductors, particularly electric vehicles [8, 9, 10].

Also high power applications will benefit from SiC, nonetheless NTD silicon will prevail [11]

Efforts to align critical stakeholders along the value chain for NTD -based power semiconductors [12]

Calls for more capacity for 200mm ingots and possibly 300mm in future

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Review NTD Silicon Demand Forecast

- Potential demand of NTD silicon has been discussed since its establishment and continued ever since [4, 13, 14, 15, 16, 17, 18]
- Advancements in chemical dopants reduced demand for NTD silicon during 1990ies
- Increasing demand for power devices has driven growth of NTD silicon from 2000s onwards [18]
- Additional demand from hybrid & electric vehicles predicted massive increase by 2030 [17, 18]
- Future transition towards 300mm NTD silicon has been foreseen since some while [19]

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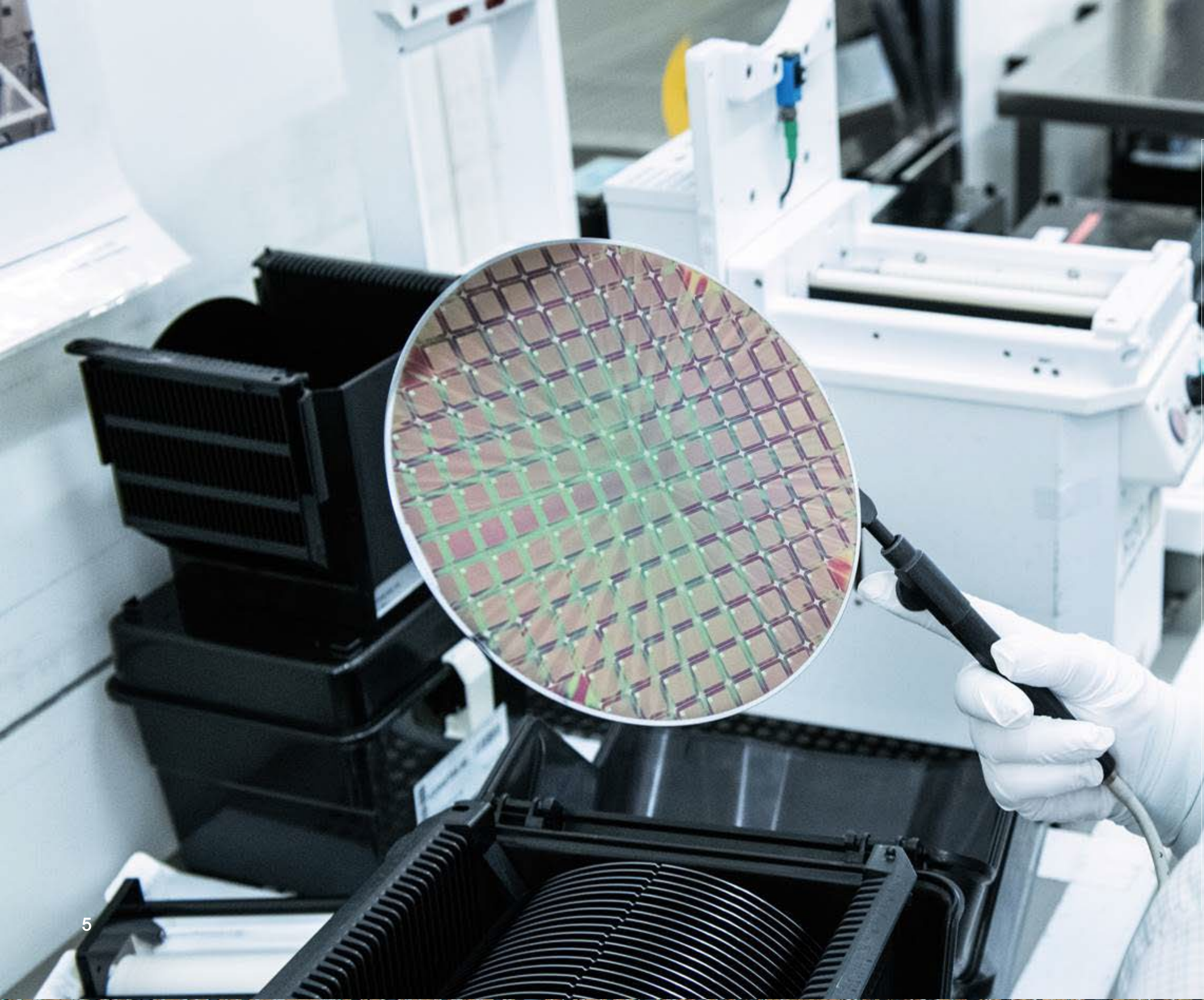
Method of generating Forecast of NTD Silicon Demand



- Forecast of NTD silicon demand only for Hitachi Energy
- Only **limited fraction** of entire demand, however, representative for demand **driven by energy transition**
- Based on **Energy's sales** and **production forecast**
- Fraction of and type of wafer associated with every forecasted product is considered
- **Tonnage of silicon undergoing NTD** process estimated from **wafer diameter and thickness**
- Adder of 130µm or 145 µm thickness, respectively, for etched or single side polished wafers, respectively
- Demand from **products manufactured from gas phase doped silicon** are **excluded**
- For **products qualified for both**, gas phase doped or NTD silicon, **half the demand is assumed** to be associated with NTD silicon
- Distinction between **100mm, 150mm and 200mm**
- **Two resistivity ranges** $\leq 200\Omega cm$ and $> 200\Omega cm$

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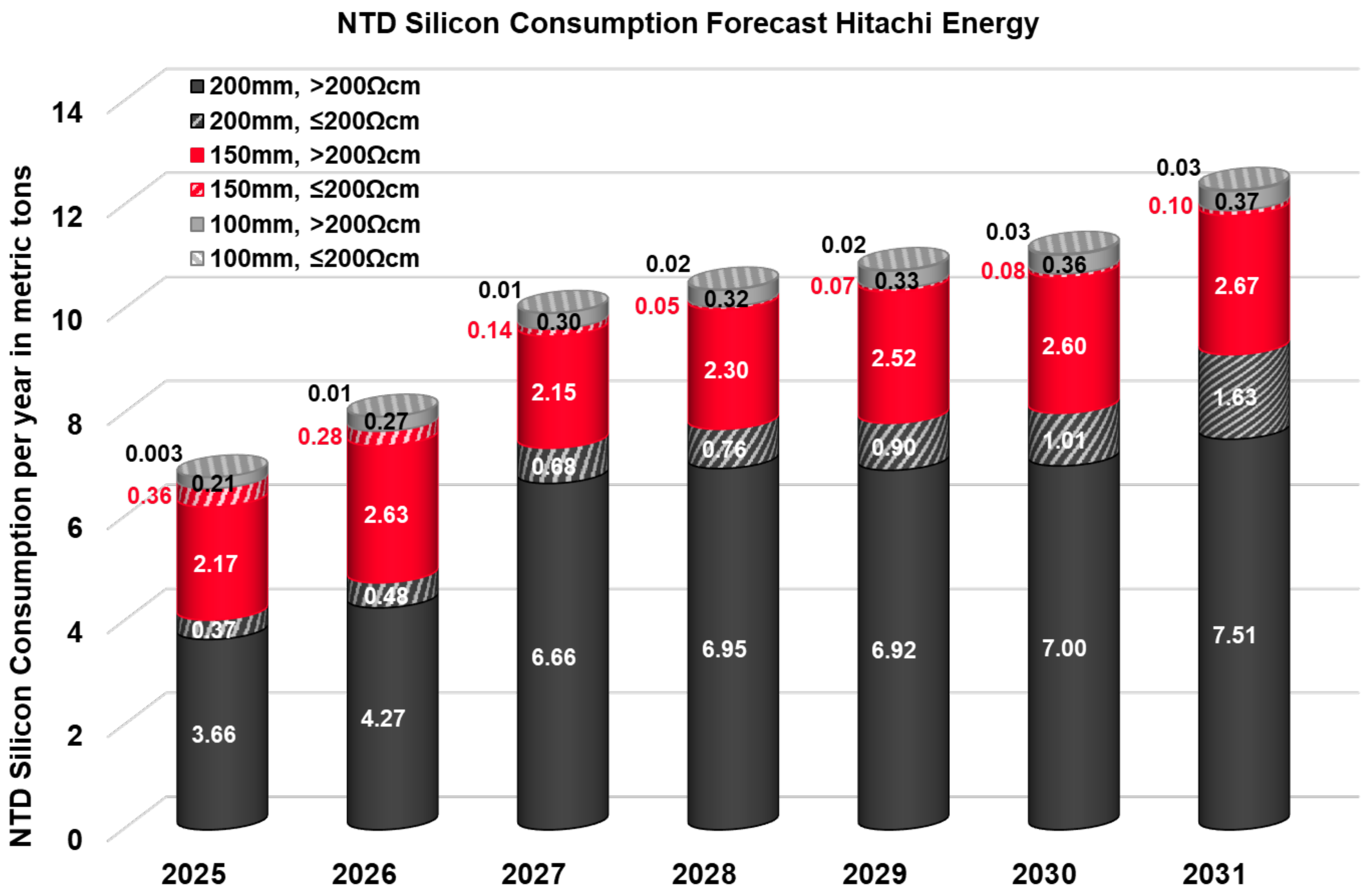
Forecasted Annual Consumption

- **Almost doubling of total amount from 2025 to 2031**
- Resistivities >200Ωcm fluctuate between 86% and 92%
- Share of 100mm almost constant at 3% to 4%
- **Shift from 150mm (37% ↘ 23%) towards 200mm (59% ↗ 74%)**
- Overall growth mainly due to increasing demand on 200mm
- 150mm stable at constant absolute figures
- **100mm demand doubles at low absolute numbers.**



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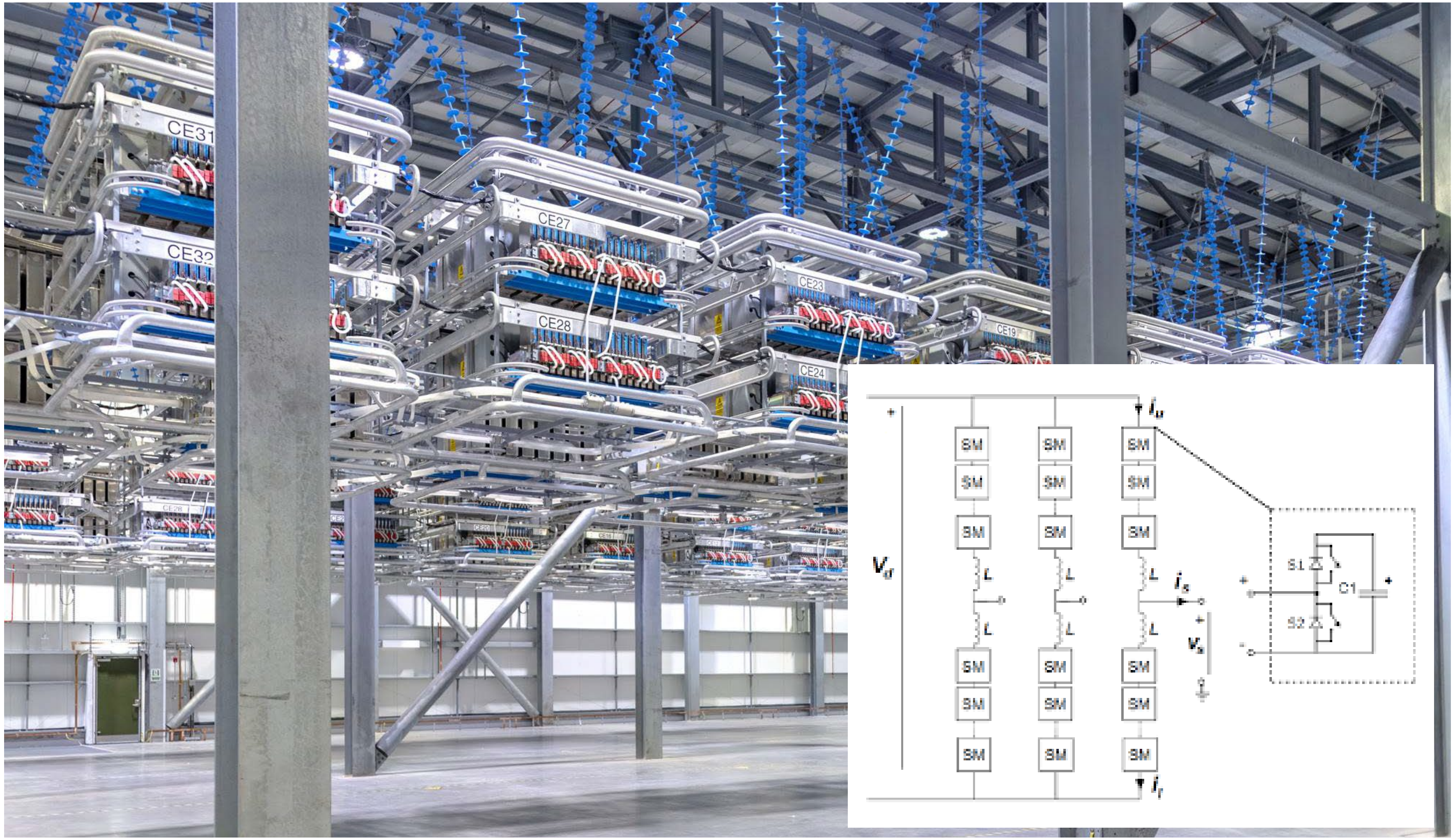
Applications - HVDC



- **High Voltage Direct Current Transmission** (HVDC) links reduces the **transmission losses** by approximately **50 %.**
- Use of **high voltage** (5200 V, 6500 V) and **high current** (up to 5000 A) **power semiconductors**
- Use of in **Modular Multilevel Converters** (MMC)
- Design **Lifetime 30-40 years**.

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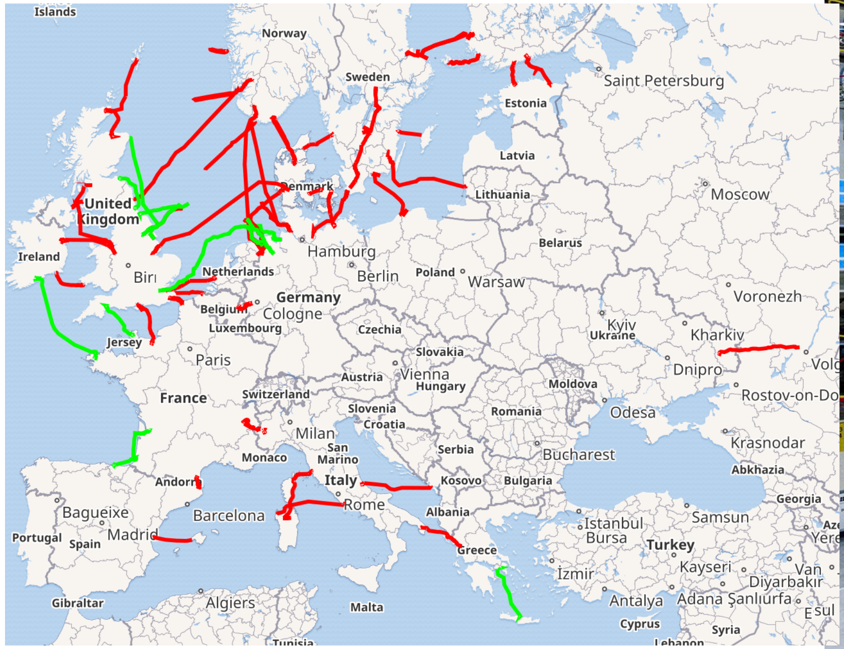
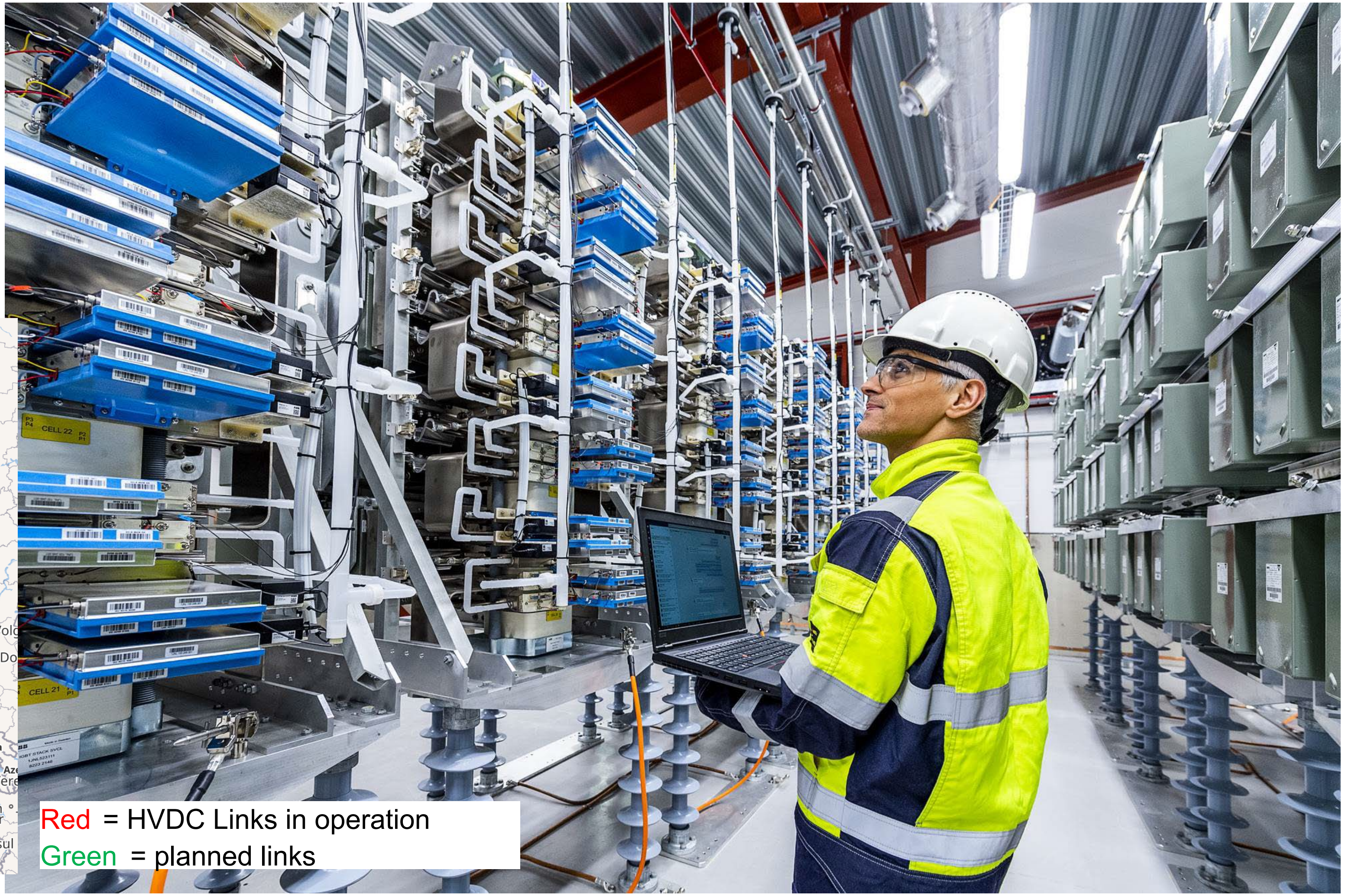
Applications - HVDC

- Ideal to **interlink renewable power sources** with the **existing loads**
- Typical HVDC **DC link** operation Voltage **+/ - 525’000 V**
- **Transmission power several Gigawatt**





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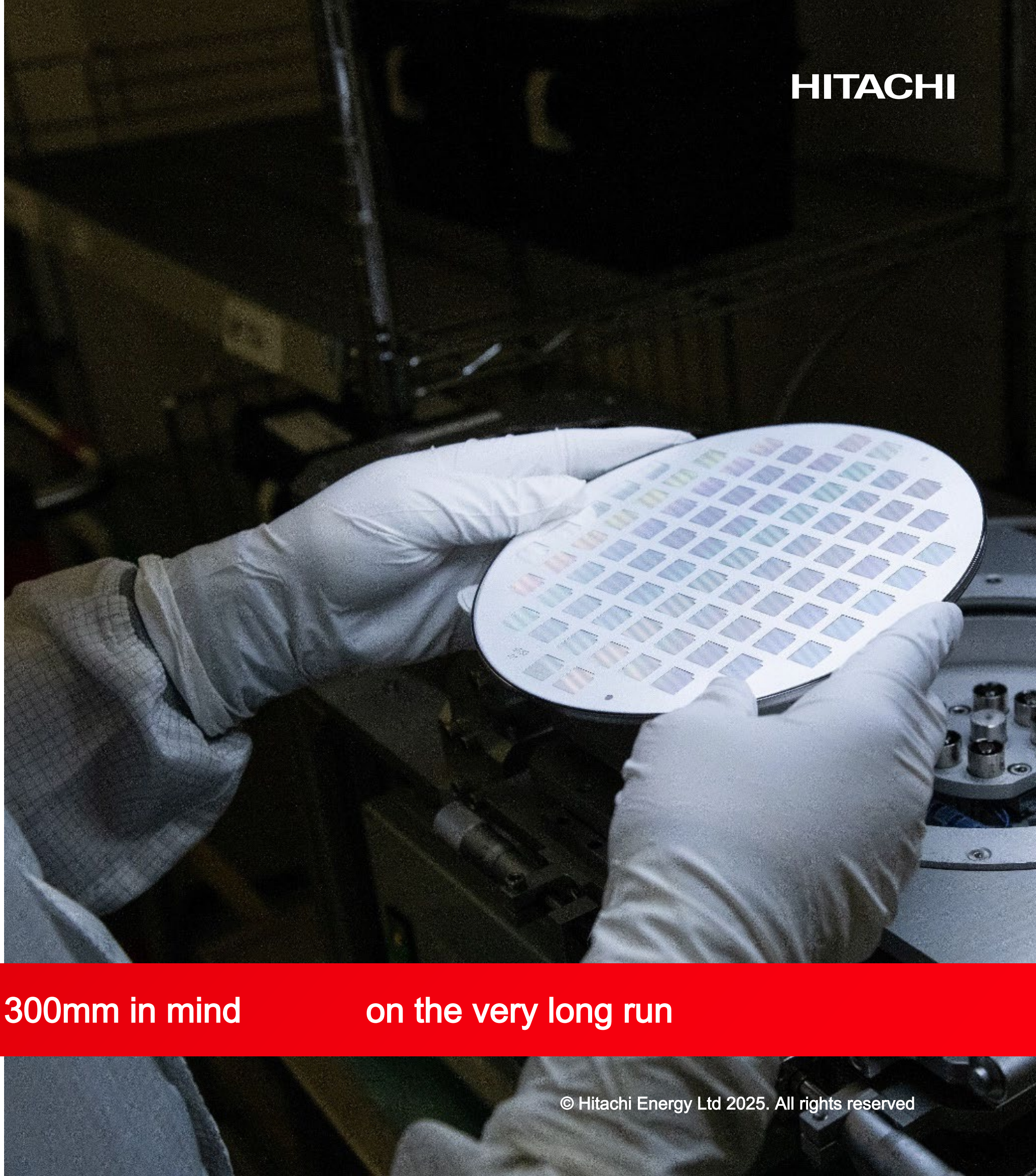
Outlook Towards 300mm



– 300mm NTD Silicon would provide huge leverage regarding economies of scale

– Transition 200mm → 300mm is costly, risky and, thus, may occur only on long-term

– Higher effort in terms of cost and manpower than any earlier transitions in wafer diameters [20, 21]

– Today's 200mm usually occupy profitable niches, optimization of current 200mm may pay off better an/or bear less risk than huge investment into a 300mm [22, 23]

– May first involve already existing 300mm fabs manufacturing power semiconductors at lower voltage and/or current ratings from 300mm magnetic Czochralski (MCZ) silicon, rather than established high power device manufacturers

Recommendation: Focus on 200mm, now, with 300mm in mind on the very long run

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Biographies

Magnus Kunow obtained a PhD in Chemistry from University of Münster in 2004, where he studied the ion dynamics of solid ion conductors using computer simulations. He also obtained an MBA from University of Cumbria in 2020 for his master dissertation "Business Model Innovation and its Underpinning Dynamic Capabilities", and is a certified SixSigma BlackBelt since 2016. He joined Hitachi Energy Ltd, Semiconductors (then ABB Switzerland Ltd, Semiconductors) in 2006, where he held several engineering and managerial positions in process engineering, product engineering and operations in BiMOS and Bipolar production lines in Lenzburg, Switzerland, and Prague, Czech Republic. Since 2023 he serves as Operations Manager of the BiMOS Frontend. He represents Hitachi Energy within the GMM Fab Manager Community, the SEMI Fab Owners Alliance and at the SEMI Europe Fab Management Forum.

Tobias Keller graduated in 2004, from University of applied science Aargau, the Electrical Engineering Faculty, with a degree in power electronics, thermodynamics and electrical machines. At the end of 2004, he joined ABB Excitation systems and Synchronizing equipment business (Turgi, Switzerland) and held various engineering position until 2008. He holds the first patent on MEGATROL, ABB's smart power package solution for reliable starts of gas turbines or any synchronous machine and another patent quenching arc faults in excitation systems. In 2008 he became the Head of global Technology and Support for ABB's Excitation systems and Synchronizing equipment business. Between 2009 and 2015 he was the Vice President global Products and Marketing at ABB Excitation systems and Synchronizing equipment and High Power Rectifier business. Starting from 2016 until 2019 he held the Vice President position for Vehicle Integration Engineering business. Since April 2019, he is the Vice President of global Product Management, Portfolio and Marketing in ABB Semiconductors (Lenzburg, Switzerland) now HITACHI Energy Semiconductors. Tobias Keller is a senior member of IEEE (20127) and co-author of various papers.

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