Danish Energy Agency

Electricity market reforms and integration of renewable energy in Denmark

丹麦电力市场改革与可再生能源的接入

Workshop on the Legislating for A New Electricity system – Integrating High Proportion of Variable Renewable Generation

新型电力系统立法研讨会

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Market reforms of the electricity sector introduced from year 2000
自 2000 年起，对电力部门进行市场改革

- **EU's electricity directive** was implemented in **Danish legislation in 1999**.
- The market reform **unbundled the Electricity sector** that previously had been vertically integrated. Distribution utilities owned the power and transmission companies. All companies were non profit.
- The market reform **liberalized power production and sale of electricity**.
- **Transmission system operation (TSO) and distribution** continued to be **monopoly**. An independent Regulator should secure efficiency using benchmarks and individual price caps.
- First phase was to **unbundle TSO from power production**. Next phase was to **unbundle ownership** of TSO and power production.
- The new **Electricity Supply Act** has been **amended every year** since 1999 to adjust to market conditions and new EU regulations.

- **1999年，欧盟电力指令在丹麦立法**中实施。
- 市场改革**拆分了**以前纵向一体化的**电力部门。**配电公司拥有电力和输电公司。所有公司都是非营利性的。
- 市场改革**放开了电力的产、销。**
- **输、配电系统运营**仍处于**垄断**地位。独立的监管机构应利用基准和个别价格上限来保证效率。
- 第一阶段是将**输电系统运营与发电分开。**下一阶段是**拆分**输电系统运营和发电的**所有权。**
- 自 1999 年以来，新的《**电力供应法**》**每年都要进行修订**，以适应市场条件和欧盟的新规定。

Market reform led to major shifts in ownership of power sector
市场改革导致电力部门所有权的重大转变

- The Danish electricity **utilities** were before market reforms **owned by municipalities and consumers**. They were **non profit** companies.
- After market reform there was a dispute about **who owned the equity capital** in the companies. The consumers or the companies?
- A political deal was made. The **equity capital was given free** to the owners in the electricity sector (2004). And the electricity companies transferred the overall transmission grid (400 kV) and the System Operator to the Danish State.
- An **independent, state owned TSO** (Energinet) for electricity and natural gas was established by the Danish State.
- The release of the free equity capital started **major changes in ownership**.
- The **Swedish** state owned **energy company** (Vattenfall) **bought 25%** of the generation capacity and the **Danish** state owned **oil and gas company** (DONG Energy) bought **75%**.

- 丹麦的**电力公司**在市场改革之前由**市政当局和消费者所有**。它们是**非营利**公司。
- 市场改革后，**电力公司股本所有权的归属**上出现了争议：属于消费者还是电力公司?
- 由此，达成了一项政治协议。电力部门的所有者**无偿获得了股本**（2004 年）。电力公司将整个输电网（400 千伏）和系统运营商转让给丹麦政府。
- 丹麦政府成立了一个**独立的国有**电力和天然气**输送运营商**（Energinet）。
- 免费让予股本引发了**所有权的重大变革**。
- **瑞典**国有**能源公司**（Vattenfall）**购买了 25%** 的发电装机容量，**丹麦**国有**石油天然气公司**（DONG Energy）购买了 **75%** 的发电装机容量。

Nordic electricity market is an efficient regional market
北欧电力市场是一个高效的区域市场

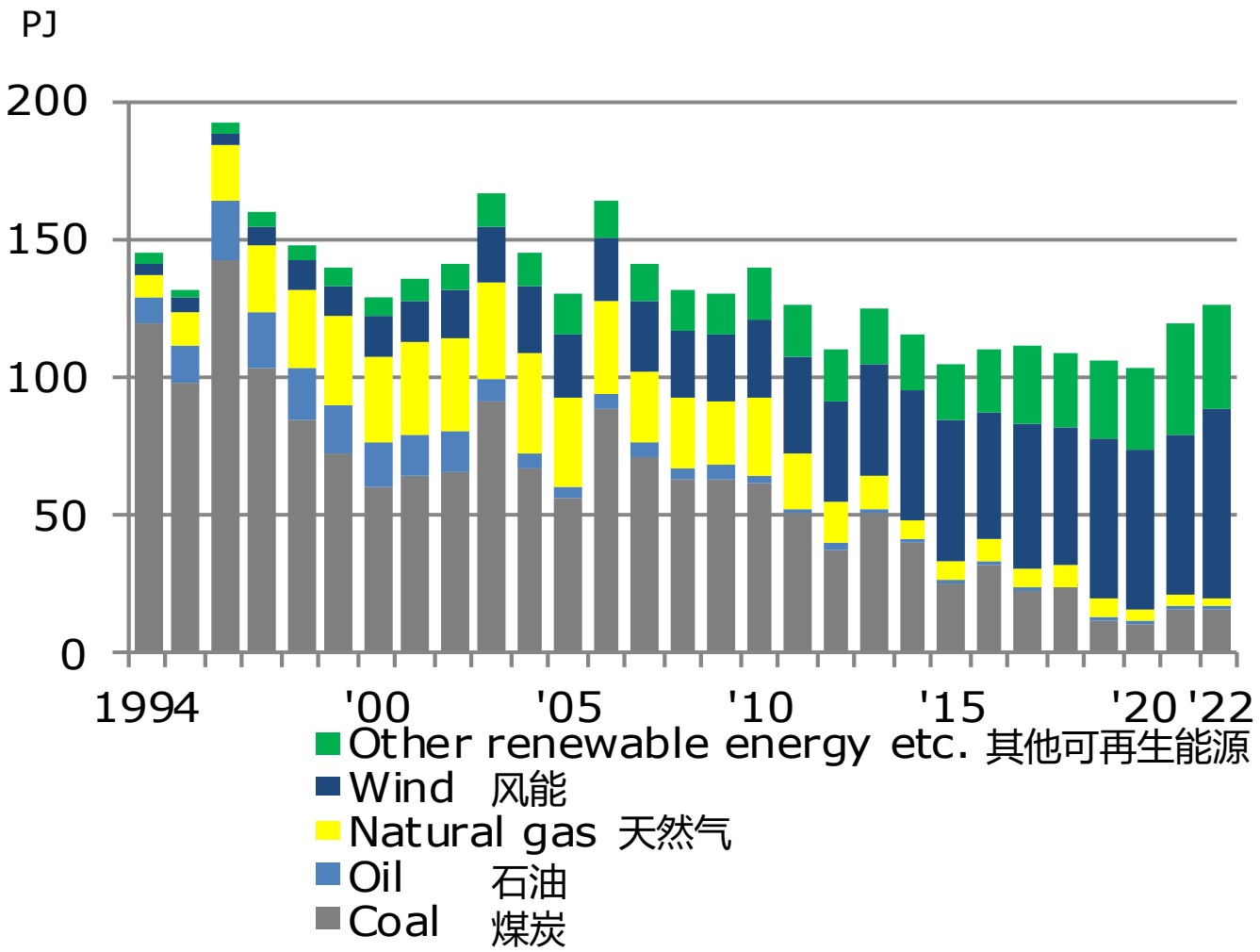
- Denmark has historically close **cooperation on electricity market** issues **with** neighbouring Nordic countries - **Norway, Sweden and Finland**.
- Strong **interconnectors** to **Norway** and **Sweden** for many years. Today also interconnectors to **Germany**, **Netherlands** and the **UK**. **Price zones** in Nordic countries.
- Norway has hydro power. Sweden has hydro and nuclear power. Denmark had primarily thermal power. So **exchange** of electricity was for **benefit of all three parties**. Today with a large share of wind and solar energy it is ever more important to have such neighbours.
- After market reform **Denmark joined the Nord Pool electricity exchange**.
- Nordic electricity market developed to be a very **efficient regional market**.
- Today **regional cooperation** with other regional TSO's in EU in **ENTSO-E** – established by the EU in 2009.

- 丹麦历来**与**北欧邻国**挪威、瑞典和芬兰在电力市场**问题上合作密切。
- 多年来，丹麦一直与**挪威**和**瑞典**保持着紧密**互联**。如今还与**德国**、**荷兰**、**英国**和北欧国家的**计费区域**互联。
- 挪威有水力发电。瑞典有水力和核能。丹麦主要是火力发电。因此，电力**交易对三方都有利**。在当前风能和太阳能占比提高的情况下，拥有这样的邻国变得尤为重要。
- 市场改革后，**丹麦加入了北欧电力交易所**。
- 北欧电力市场已发展成为一个非常**高效的区域市场**。
- 如今，与欧洲输电系统运营商网络（欧盟于 2009 年成立）中的其他地区输电系统运营商开展**区域合作**。

Electricity production by fuel 不同燃料的发电量

Fossil fuels (coal, oil and natural gas) are being phased out and substituted by wind, solar and biomass

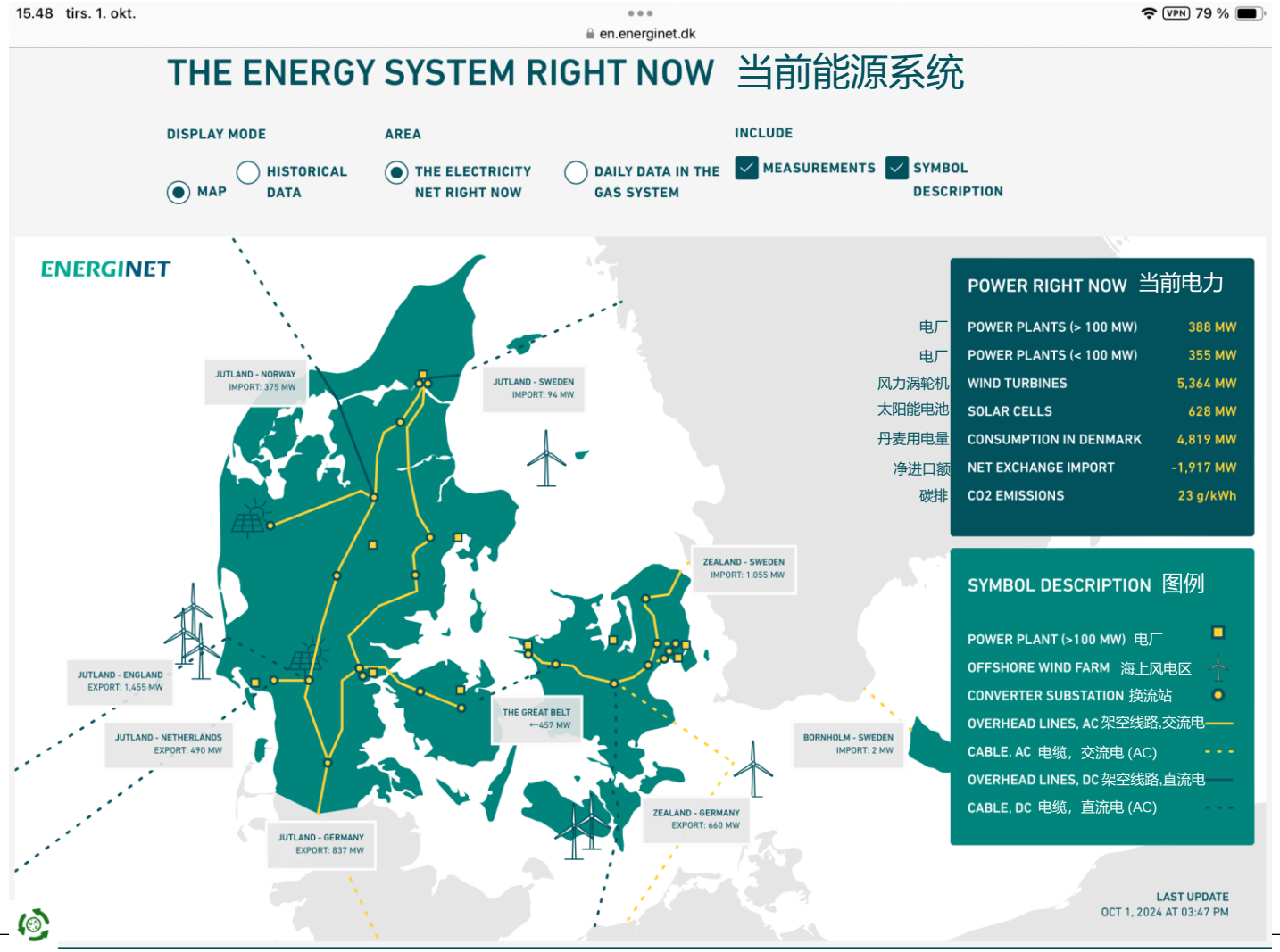
化石燃料（煤炭、石油和天然气）正在被淘汰，取而代之的是风能、太阳能和生物质能



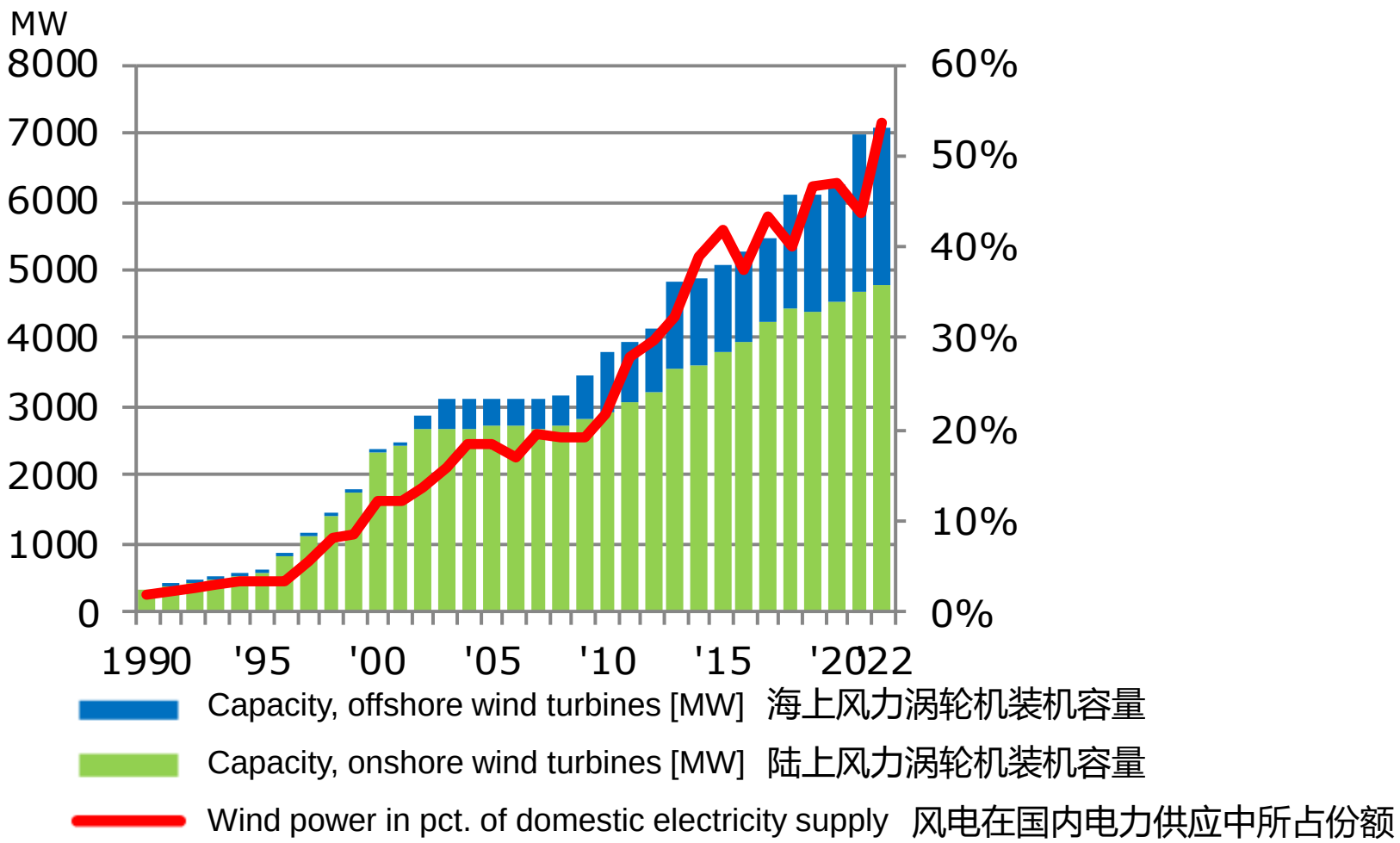
Denmark's electricity system 丹麦的电力系统

1 October 2024: Wind 5,364 MW + solar cells 628 MW exceeds total consumption in Denmark of 4,819 MW

2024 年10 月1 日：风力发电5,364 兆瓦 + 太阳能发电628 兆瓦，超过丹麦 4,819 兆瓦的总用电量



Wind power capacity and wind power's share of domestic electricity supply
风电装机容量和风电在丹麦国内电力供应中所占份额



Integrating renewable energy in the energy sector 能源部门接入可再生能源

Balancing electricity supply and demand requires several measures 平衡电力供需需要采取以下几项措施

- Political goal is **climate neutrality by 2045**. 110% green house gas reduction in 2050 compared to 1990.
- In **2030** at least **55%** of final energy demand **from renewables** and **100% green** electricity (wind, solar and biomass).
- Biggest concern is **balancing electricity supply and demand.** Measures to **integrate and balance the high share of variable renewable energy** (VRE) are:
  - Strong **integration of electric grid with neighboring grids** enables Denmark to balance its wind energy.
  - **System flexibility**: A large share of the country's electricity comes from **combined heat and power** plants, many of which are fueled by biomass. These feed into district heating systems and include thermal energy storage. Large heat pumps add further flexibility to the power system. Power-to-X might give further flexibility in future.
  - Sophisticated **day-ahead weather forecasting** by the TSO makes wind and solar energy quite predictable, ensuring efficient and reliable operations of the country's power system.
  - The TSO buys **balancing services**.
- 政治目标是**到 2045 年实现气候中和。**2050 年温室气体排放量与 1990 年的排放水平相比减少 110%。
- **2030 年**，**可再生能源**在最终能源需求中的占比至少为**55%**，**绿色**电力（风能、太阳能和生物质能）比例达到**100%。**
- 最大的问题是**电力供需平衡。整合和平衡高比例可变可再生能源**（VRE）的措施包括：
  - 与**邻国电网的强大整合**使丹麦能够平衡其风能。
  - **系统灵活性**：丹麦大部分电力来自**热电**联产厂，其中许多工厂以生物质为燃料。这些热电厂向区域供热系统供热，包括热能储存。大型热泵进一步增加了电力系统的灵活性。未来，“电到X（Power-to-X）"可能会带来更多的灵活性。
  - 输电系统运营商先进的**日前天气预报**使风能和太阳能具有相当高的可预测性，确保国家电力系统高效可靠运行。
  - 输电系统运营商购买**平衡服务**。

Nord Pool is well functioning electricity market in Europe
北欧电力市场是欧洲运作良好的电力市场

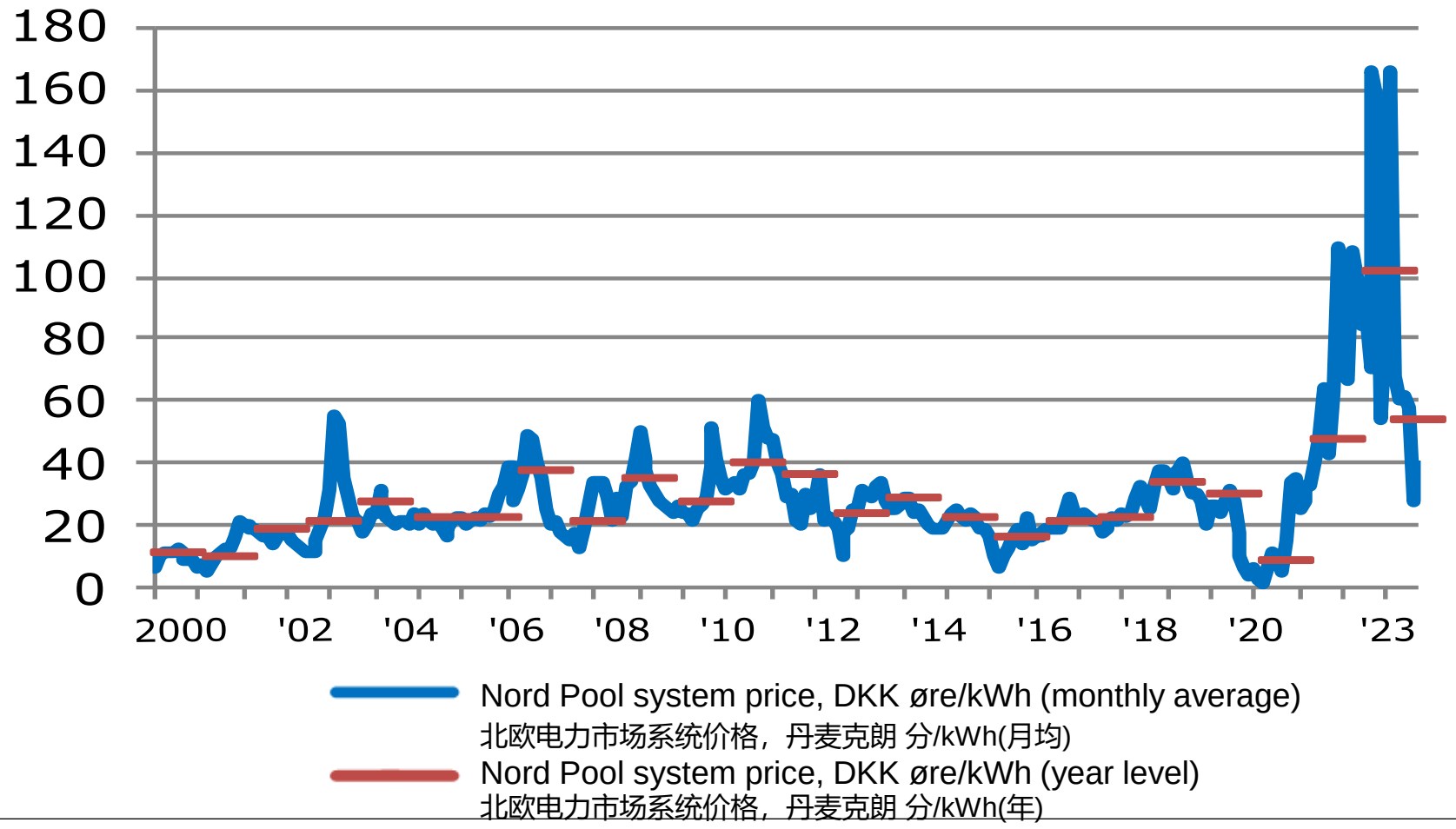
- The **electricity market** is an **hourly-based market** where electricity-producing companies can bid to sell electricity, i.e., how much electricity they are capable of producing and at what price. Conversely, the demand bids are also placed.
- Nord Pool ranks the production **bids from cheapest to most expensive to ensure the electricity demand is met.** The **electricity price** is determined by the **electricity production capabilities** (such as solar energy, wind energy, nuclear, coal, biomass and gas) and **market demand**. The price is equal to the marginal cost.
- Nord Pool is a well functioning **electricity market in Europe** and allows electricity to be sold between countries.
- However, **not all countries (or price zones) have the same electricity price**, which is determined according to the interconnection capacity between countries.
- Denmark has 2 price zones, Norway 5 and Sweden 4.

- **电力市场**是一个**以小时为单位的市场**，发电公司可以竞价售电，即他们能够发多少电以及以什么价格出售。反之，需求方也可以进行竞价。
- 北欧电力市场将发电商报价**从最低到最高**排序，**以满足电力需求。电价**由**发电能力**（如太阳能、风能、核能、煤炭、生物质能和天然气）和**市场需求**决定。电价等于边际成本。
- 北欧电力市场是**欧洲**运作良好的**电力市场**，允许各国之间进行电力交易。
- 然而，**并非所有国家（或计费区域）的电价都相同，电价**是根据国家间的互联能力确定的。
- 丹麦有2个计费区域，挪威有5个，瑞典则有4个。

Spot market prices for electricity 电力现货市场价格

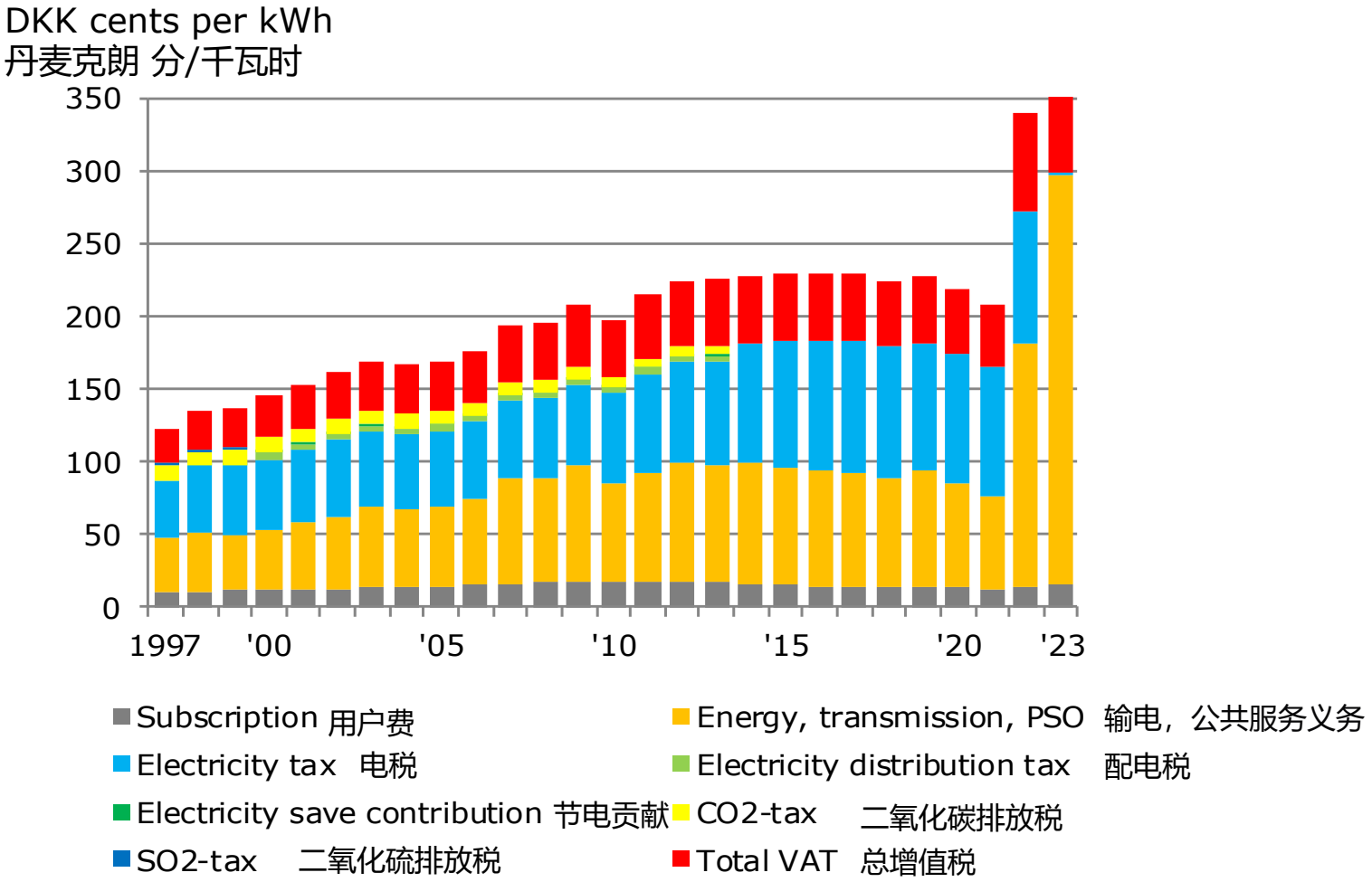
From 2000 to 2021 the price varied on an annual basis from 0.10 DKK/kWh to 0.40 DKK/kWh. 1 DKK /kWh in 2023

2000 年至 2021 年，年价格在0.10丹麦克朗/千瓦时到0.40丹麦克朗/千瓦时之间变动。2023 年为 1 丹麦克朗/千瓦时



Electricity prices for households 1997-2022 (1 January – 4,000 kWh/year)
1997-2022 年家户电价（1 月 1 日-4,000 千瓦时/年）

Prices for households have not decreased after market reforms. But prices for industry have decreased 市场改革后，家庭电价未下降；工业电价却下降了



Electricity prices hour by hour for households 家庭逐时电价

1 October 2024 at 16-17 household price was 2.08 DKK/kWH. Price for energy was 0.54 DKK/kWh. Rest is tax and transport

2024 年 10 月 1 日16-17 时，家庭电价为 2.08 丹麦克朗/千瓦时。能源价格为 0.54 丹麦克朗/千瓦时。其余为税和运输费用

Electricity prices hour for hour with TimeEnergi

TimeEnergi逐时电价

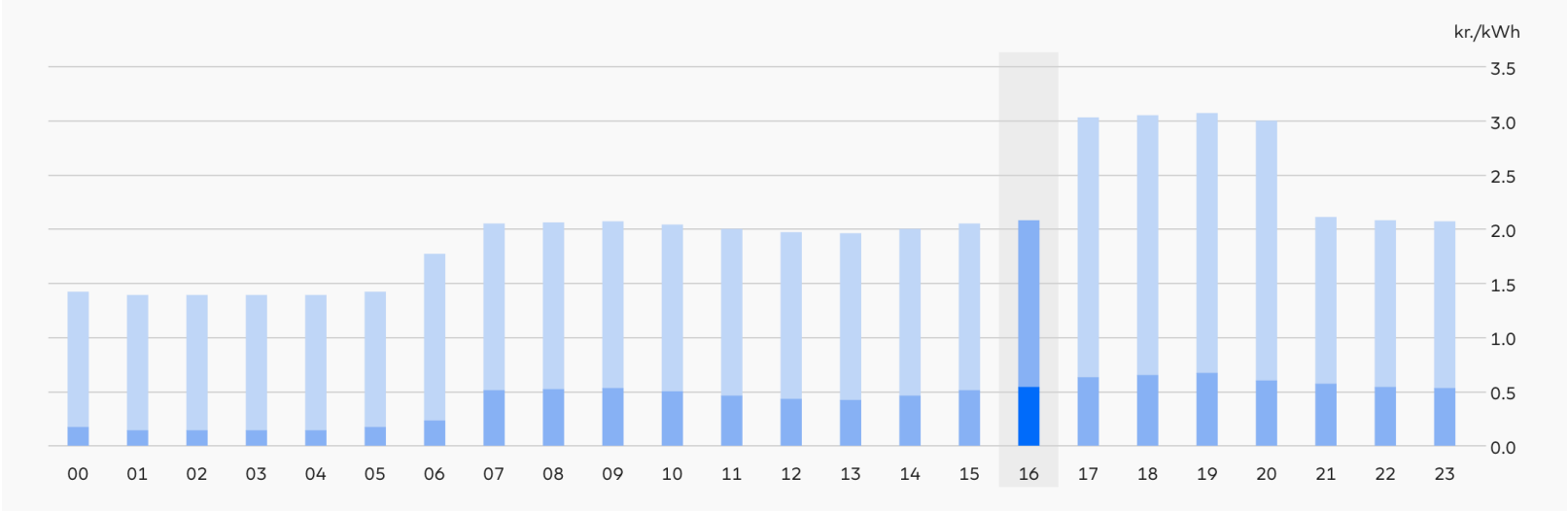
4-5 PM, Tuesday October 1st the price is

周二，十月一日，16-17时的电价为

2,08 DKK/kWh 丹麦克朗/千瓦时

Do you live east or west from Storebælt? West East

Show prices incl. transport and duties for Radius Elnet's area No Yes



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Thank you
感 谢