The role of nuclear plants in power systems – new challenges

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Behind ERRA involvement in nuclear energy (NERF, Warsaw 2024)

- Many countries are looking for stable energy sources of baseload power, ensuring security of supply and sustainability – growing interest in nuclear generation (PWR, SMR, MMR). RES are not enough to achieve those goals.
- Energy regulators are not at the forefront of nuclear energy deployment (international organizations, ministries, parliaments, gov. plenipotentiaries on nuclear, nuclear regulators & agencies)
- NRAs are market experts, dealing with energy costs, finances of energy companies, competition, long-term planning, natural monopolies, and security of supply.
- NRAs may be involved in nuclear power through general tasks (consultation of long-term plans, licensing) and/or dedicated tasks (preparing/consulting/managing support schemes for nuclear, regulation of nuclear energy companies with strong dominant position)
- Some questions: 1) sustainable and secure energy mix (nuclear/RES/other), 2) market issues (how to regulate the market with a high share of nuclear generation), 3) costs of nuclear and long-term planning, 4) the role of NRAs and ERRA.

Introduction

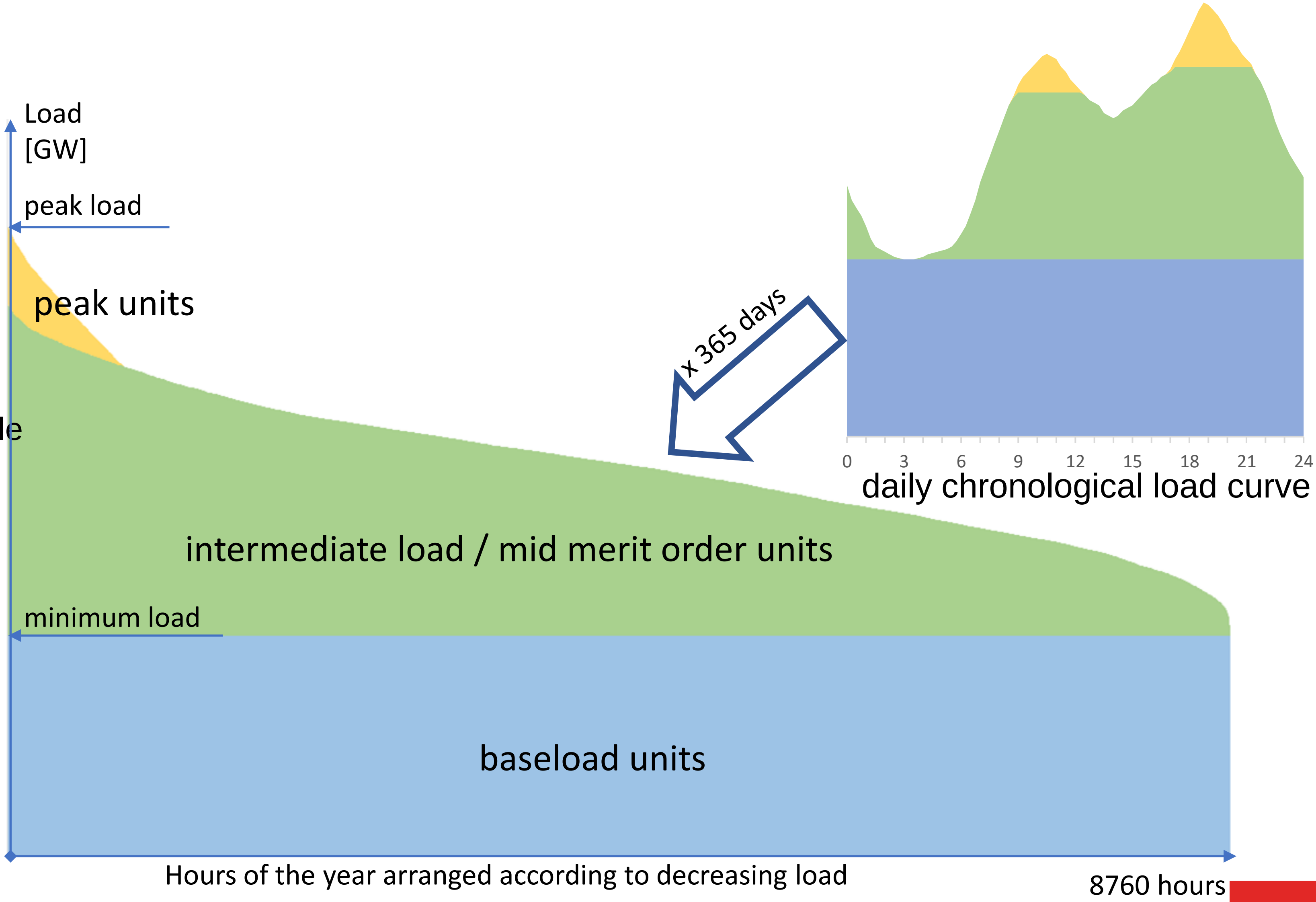
- From power system point of view nuclear plants operate in similar way as other conventional thermal plants:
  - Conventional part (turbine island) very similar (steam turbine, generator, step up unit transformer)
  - Main difference: source of steam – reactor (nuclear island) vs boiler (coal) or combustion chamber (gas)
- Nuclear plants specificities:
  - Nuclear safety – normal operation, emergencies:
    - need for decay heat removal (ca 1% of thermal power 2 hours after shut down)
    - back up supply of auxiliaries/house load important at any time – priority in restoration after blackout
  - Size of individual units – effect of scale as in all other generation technologies but largest units
  - CO_2 free power generation – full life cycle emissions even lower than for renewables
  - Very low variable costs – as intermittent renewables but fully dispatchable although with limited flexibility
- High safety culture, stimulate technological development of the whole supply chain (whole economy)

Operational features of nuclear plants

- Fully dispatchable with very high load factors (>90%):
  - load factor = energy actually produced in one year vs energy that could have been produced if generating unit operates at maximum power all the year around
- Cost structure (almost only fixed costs) justify baseload operation
- Highly predictable schedule of operation – very reliable source of electricity:
  - planned outages (refuelling) scheduled couple of years in advance
  - long fuel cycles (more than a year), ability to store fuel at plant site for several years
  - 60 years of lifetime, could be prolonged for another 20 years at least
- Load following capability:
  - technical minimums and ramping capabilities comparable with other thermal units, however less cycling
  - longer start up and minimum shut down times, practically only in emergencies
- Source of significant amount of inertia, short circuit and reactive power:
  - byproduct of producing active power in synchronous generator
  - important in systems with high penetration of inverter based resources (wind, PV, batteries, HVDC)
- Ability to be located in proper parts of power systems

Load duration curve (LDC) vs generation technologies

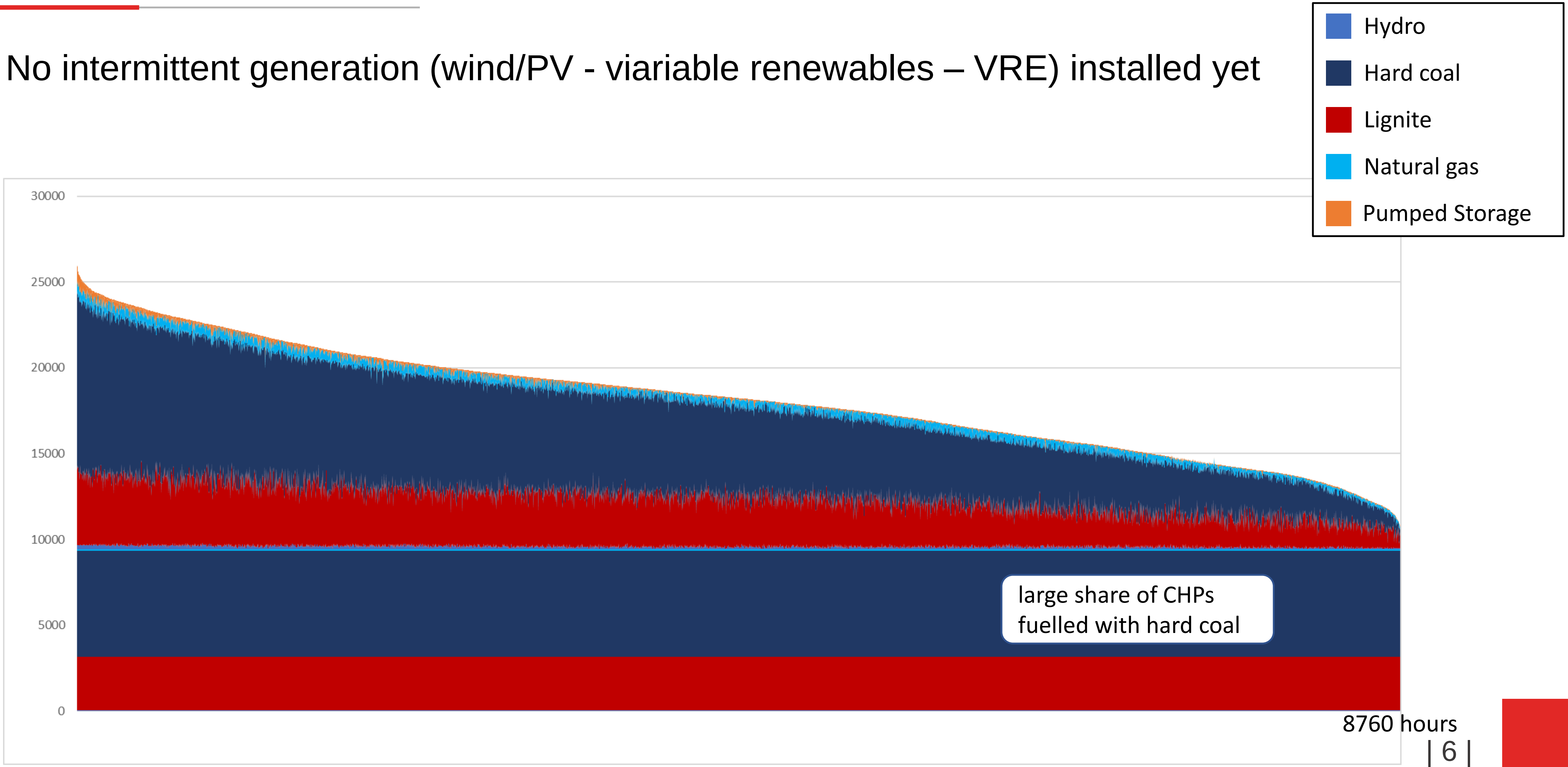
- Baseload units – low OPEX:
  - usually high CAPEX
  - high load factor > low MWh costs
  - run of river hydro, nuclear, lignite, all year must runs (e.g. cogeneration)
- Peak units – low CAPEX:
  - usually high OPEX
  - low load factor > MWh costs affordable
  - open cycle gas turbines,
  - Storage (hydro pumped / reservoir (high CAPEX)
- Mid merit order units:
  - other generation technologies able to follow the load easily
  - moderate CAPEX and OPEX
  - hard coal, combined cycle gas turbines, dispatchable renewables (biomass, biogas)



- Historically relevant mix (allowing to satisfy demand of customers at minimum system costs) ensured by long term system planning (like IRP studies) ceased with implementation of competitive markets (unbundling) – now back in US

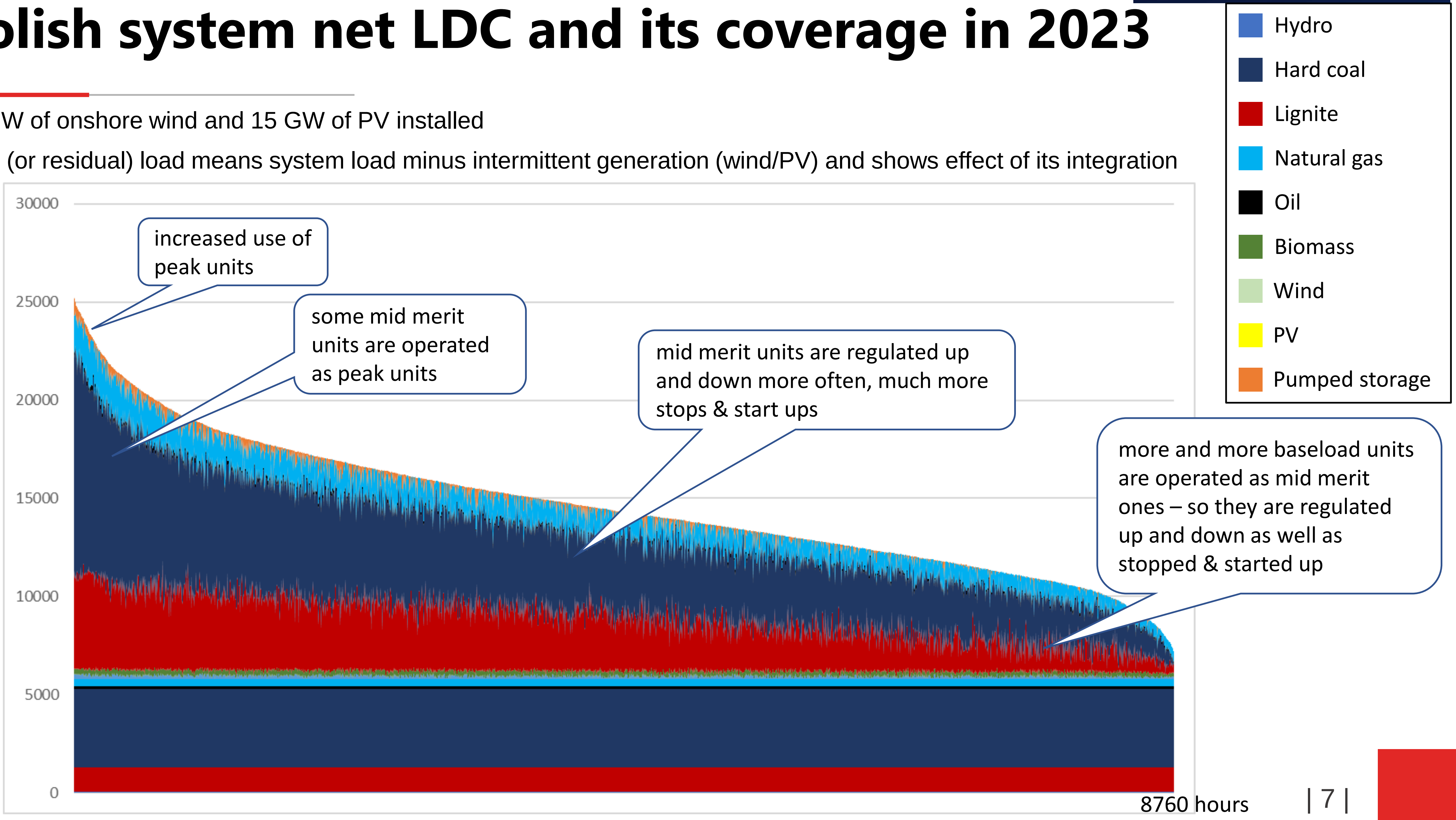
Example of Polish system LDC and its coverage in 2007

- No intermittent generation (wind/PV - viariable renewables – VRE) installed yet



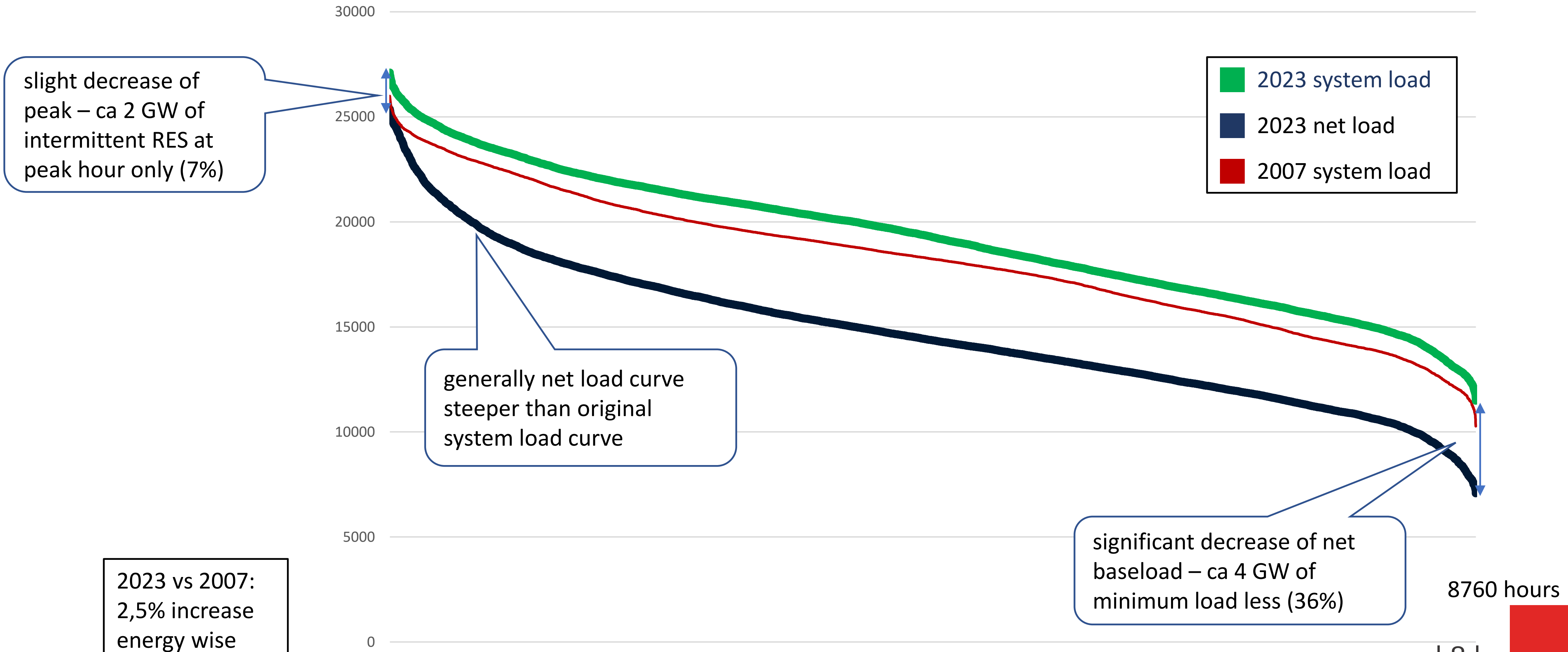
Polish system net LDC and its coverage in 2023

- 9 GW of onshore wind and 15 GW of PV installed
- Net (or residual) load means system load minus intermittent generation (wind/PV) and shows effect of its integration



Polish LDC 2023: system vs net

- Net (or residual) load means system load minus intermittent generation (wind/PV) and shows effect of its integration



2023 vs 2007: 2,5% increase energy wise

Future outlook

- Decarbonisation of Polish power system urges for introduction of nuclear power:
  - combination of intermittent RES only with relevant storage not feasible yet – no large scale storage is technically available so far to move massive amounts of energy between seasons
  - hydrogen is the only potential technology for that but require at least a decade of developments – outcome uncertain, also cost wise,
  - combination of intermittent RES with currently available storage (limited hydro and batteries) in baseload operation according to PSE studies is three times more expensive (MWh wise) than nuclear power
  - thus the only currently available non CO_2 emitting technology able to replace baseload fossil generation is nuclear power,
- Degradation of system baseload does not help decarbonisation:
  - increases intermediate load – for that no CO_2 free alternative to combination of intermittent RES and storage,
  - might be kept with large scale electrification – long term proces, plenty of uncertainties and even potential detrimental effects (increase of peak load as well)
- How to ensure nuclear power can find its natural place in power system (baseload) ?
  - nowadays (with CO_2 payments) nuclear is the cheapest baseload technology
  - yet new nuclear projects in competitive market jurisdictions seek for out of market financial suport (CfDs, RAB, etc.) to complete financing, **why ?**

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Ensuring baseload operation of nuclear units

- Reasons for degradation of system baseload:
  - intermittent RES (VRE) has enjoyed priority dispatch at least in first years of their deployment,
  - even after its formal end in 2019 VRE usually continued to be heavily subsidized:
    - 2019 EU market regulation requires all 400 kW+ resources to participate in market (200 kW+ from 2026)
  - 1 nuclear unit x 1 GW x 8000 h = 8 TWh/year = 800k rooftop PV panels (out of market) x 10 kW x 1000 h = 200 offshore windmills (heavily subsidized) x 10 MW x 4000h – why different regulatory approach to these resources ?
  - no level playing field for other CO2 free technologies, like nuclear
  - the above hide intermittency of VRE and make them artificially competitive
  - fair competition require combining VRE with relevant storage
- Solution – ensure level playing field for all producers regardless of their size and technologies:
  - all producers, who sold electricity to customers operate subject to network constraints (baseload kept),
  - precondition for setting prices properly incentivizing development and operating storages and demand side response – necessary for efficient usage of VRE surplus at any time,
  - the above ensures overall efficiency of system development (CAPEX) and operation (OPEX)
- To be extended also for all ancillary services:
  - some of them not remunerated at all nowadays (e.g. inertia, short circuit power) are provided for free as a byproduct in all synchronous generators (also by nuclear units)
  - VRE have not provided them at all so far – investments in grid forming capabilities needed

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Post conference report on TSO session

Nuclear Energy Regulatory Forum

The Role of Nuclear Power in the Energy Transition

June 12–13, 2024 | Warsaw, Poland

Session 3:

Nuclear Energy and the Transmission Grid – Challenges of System Planning

Session Moderator:

- **Prof. Klaus KLEINEKORTE**, Institute for Power Economics, RWTH Aachen University

Panel Members:

- **Mr. Mattias JONSSON**, Technical Director, Svenska Kraftnät, Sweden
- **Mr. Robert PAPROCKI**, Representative of the Board for Nuclear Integration, Polskie Sieci Elektroenergetyczne S.A., Poland
- **Mr. Dimitar ZARCHEV**, Director, National Control Centre, Electricity System Operator EAD, Bulgaria

June 2024

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In cooperation with: Ministry of Climate and Environment Republic of Poland

Hosted by: Energy Regulatory Office

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THANK YOU FOR YOUR ATTENTION!

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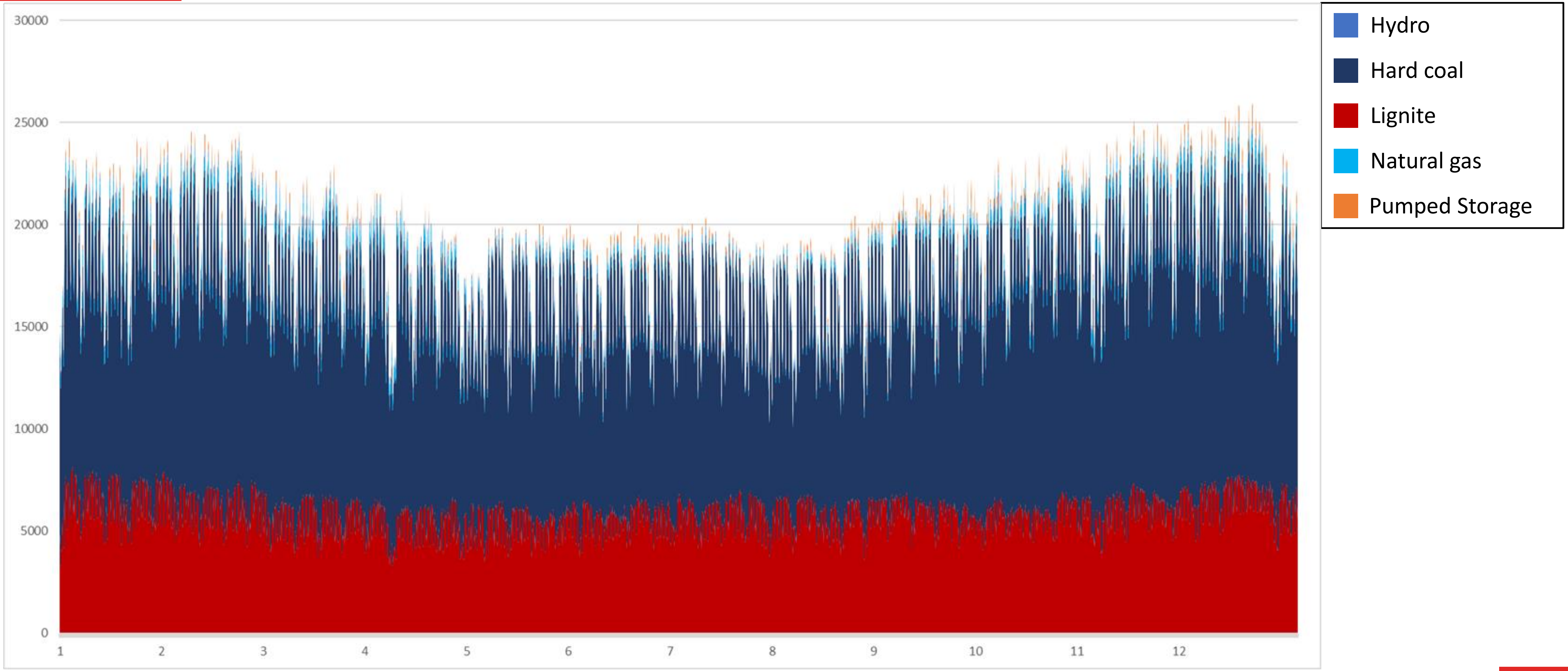
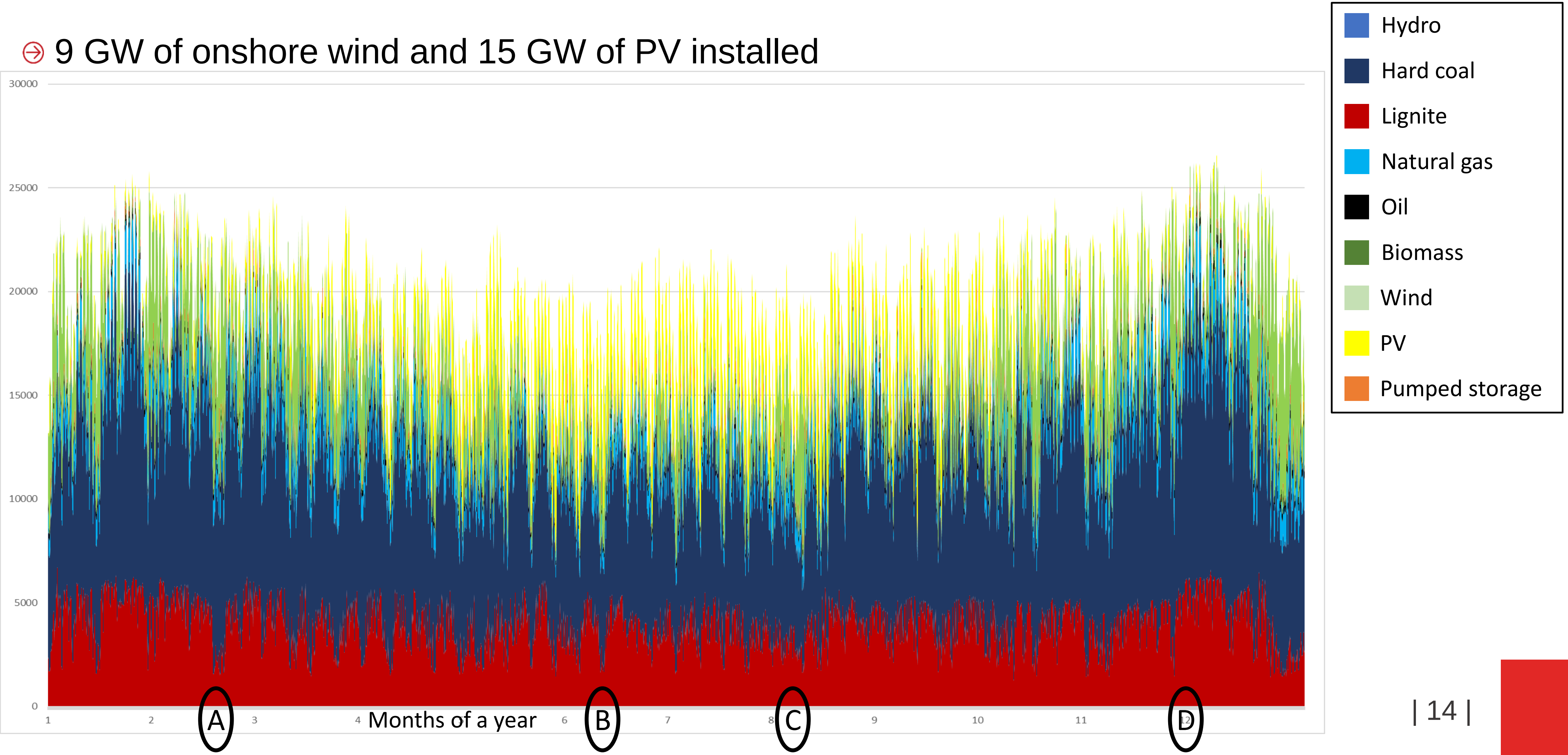
Chronological Polish system load and its coverage in 2007



Chronological Polish system load and its coverage in 2023

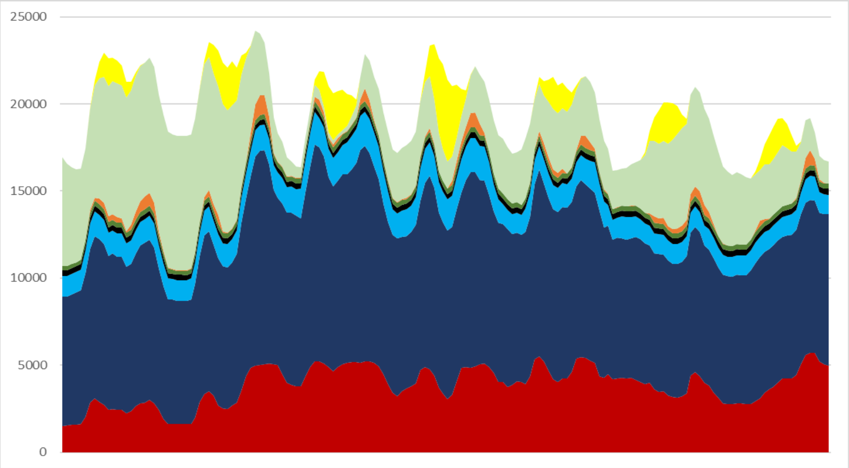
- 9 GW of onshore wind and 15 GW of PV installed



Examples of weekly patterns in 2023

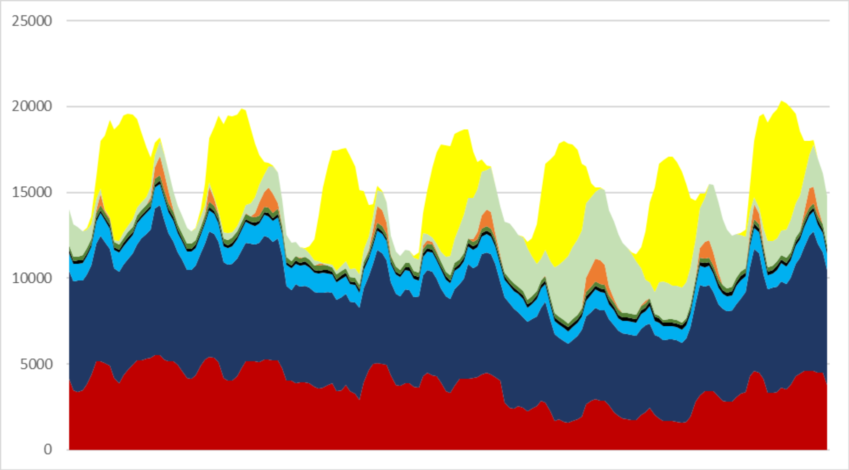
- Hydro
- Hard coal
- Lignite
- Natural gas
- Oil
- Biomass
- Wind
- PV
- Pumped storage

A
Feb 20th/26th windy winter week (low sun)



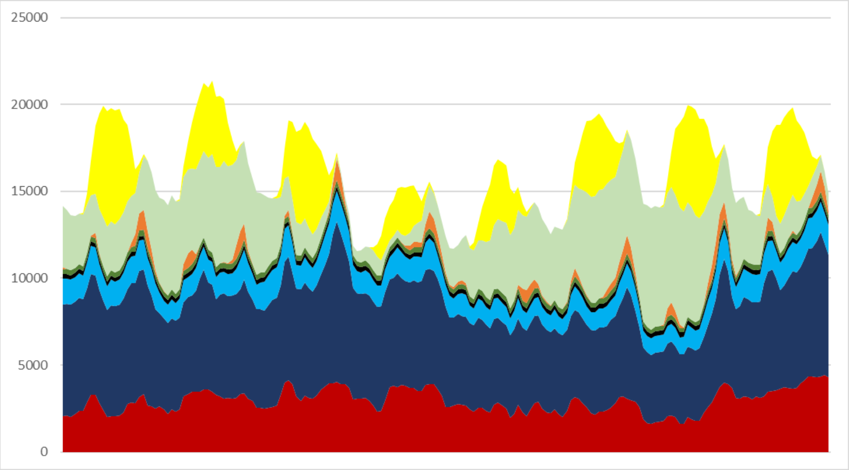
7 days of a week

B
June 6th/13th sunny summer week (low wind)

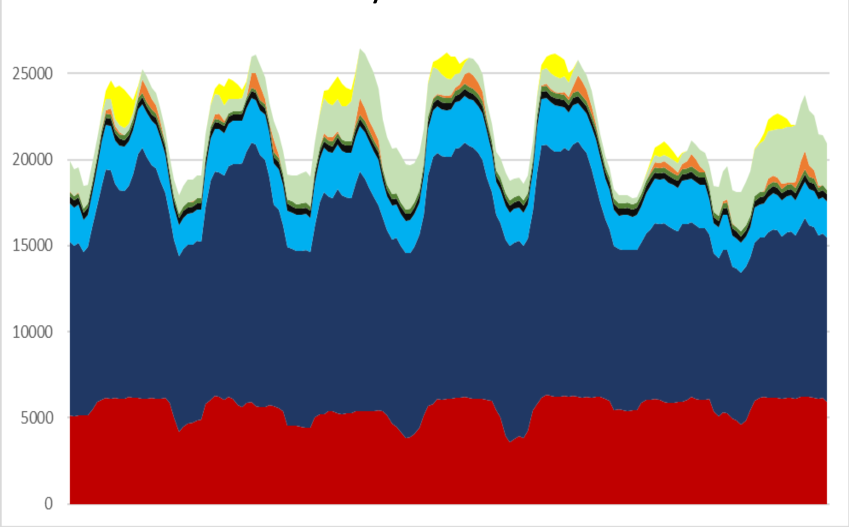


7 days of a week

C
August 2nd/8th sunny & windy summer week



D
Nov 27th Dec 3rd typical winter week (low sun, low wind, high load), however normal winter weather (no extreme cold spells, e.g. stable high pressure systems in Europe – so called Omega configuration)



Wind and PV generation duration curves 2023

- 9 GW of wind + 15 GW of PV = 24 GW almost equal to peak system load (27 GW)
- covered only 21% of PL energy demand due to intermittency with low load factors
- equivalent baseload plants would have 2,5 and 1,5 GW of generating capacity respectively