CARBON FOOTPRINT AND ANTHROPOGENIC HEAT FLOW DUE TO THE ENERGY CONSUMPTION OF A LARGE CITY

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Abstract

It is well known the large city forms its own climate and significantly affects the climate of the region where it is located.

The main climatic factor of the large city is the emission of heat and greenhouse gases due to the energy consumption of the city economy.

In turn, the observed and projected climate change affects the needs for energy supply of the city and first for heat consumption during the heating season.

In this presentation, is analyzing the anthropogenic heat fluxes and carbon dioxide emissions of of a large city.

Climate and Energy of Global City

A global city (world city or alpha city) is an important node (hub) in the global economic system.

European global city elite in 2017 (according ATKearney 2017 report) consists of London, Paris, Berlin, Moscow and Amsterdam.

Urban climate dynamics and anthropogenic impact on the climate have a significant incomplete and fragmentary nature. The dynamics of Moscow's climate is similar to the dynamics of the climate in European cities and it investigation has similar problems.

An impact of climate change on the urban energy consumption of the city economy and carbon footprint even less studied than urban climate changes itself.

Scale of urban and atmospheric processes

Urban effects are in the middle of the characteristic time and horizontal length scales of atmospheric processes.

The main factor of urban influencing on mesoscale atmospheric and climatic processes are anthropogenic heat fluxes (AHF) caused by all types of sources of thermal energy in urbanized areas - from industry to residents' metabolism.

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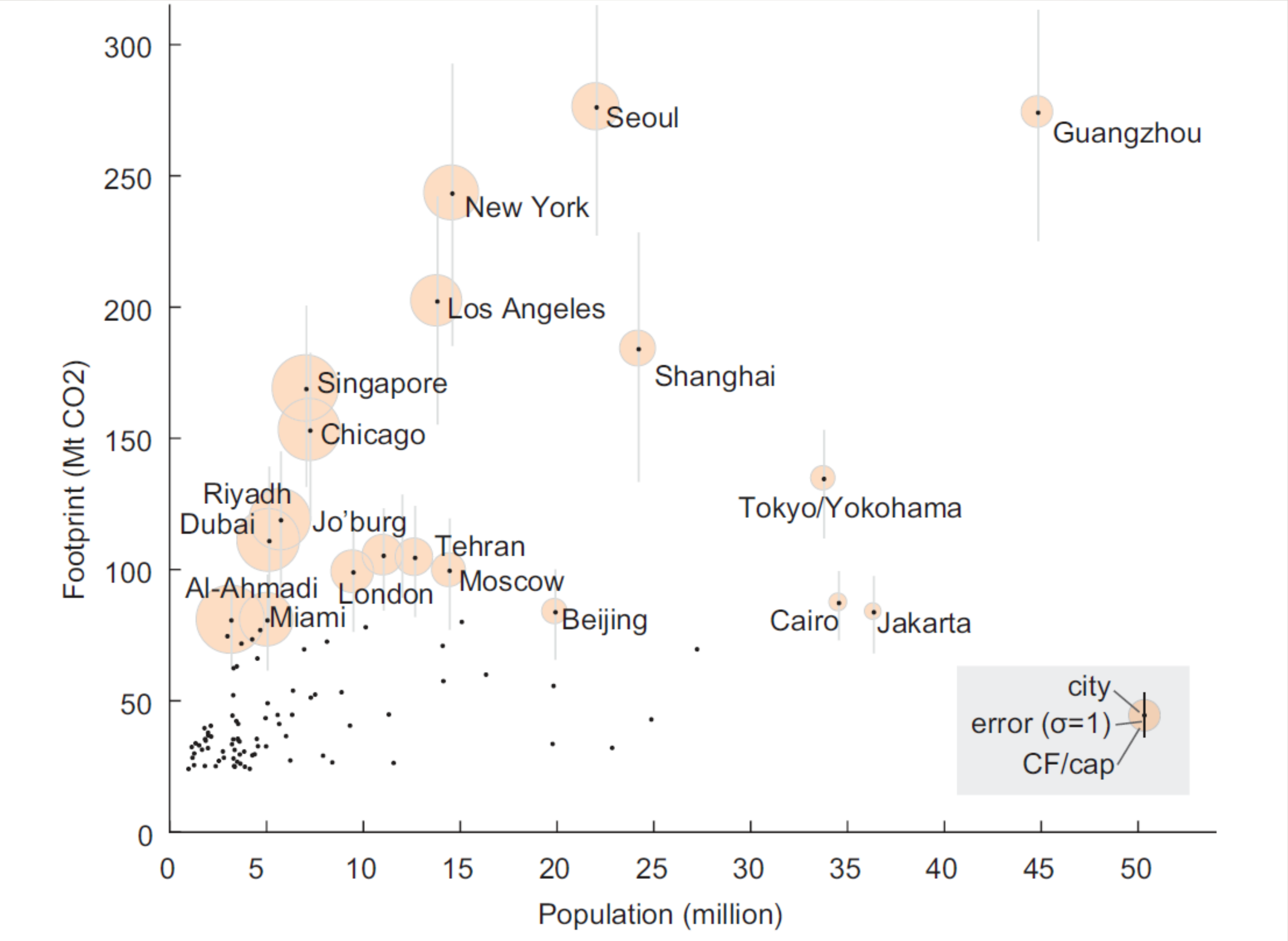
Carbon footprint

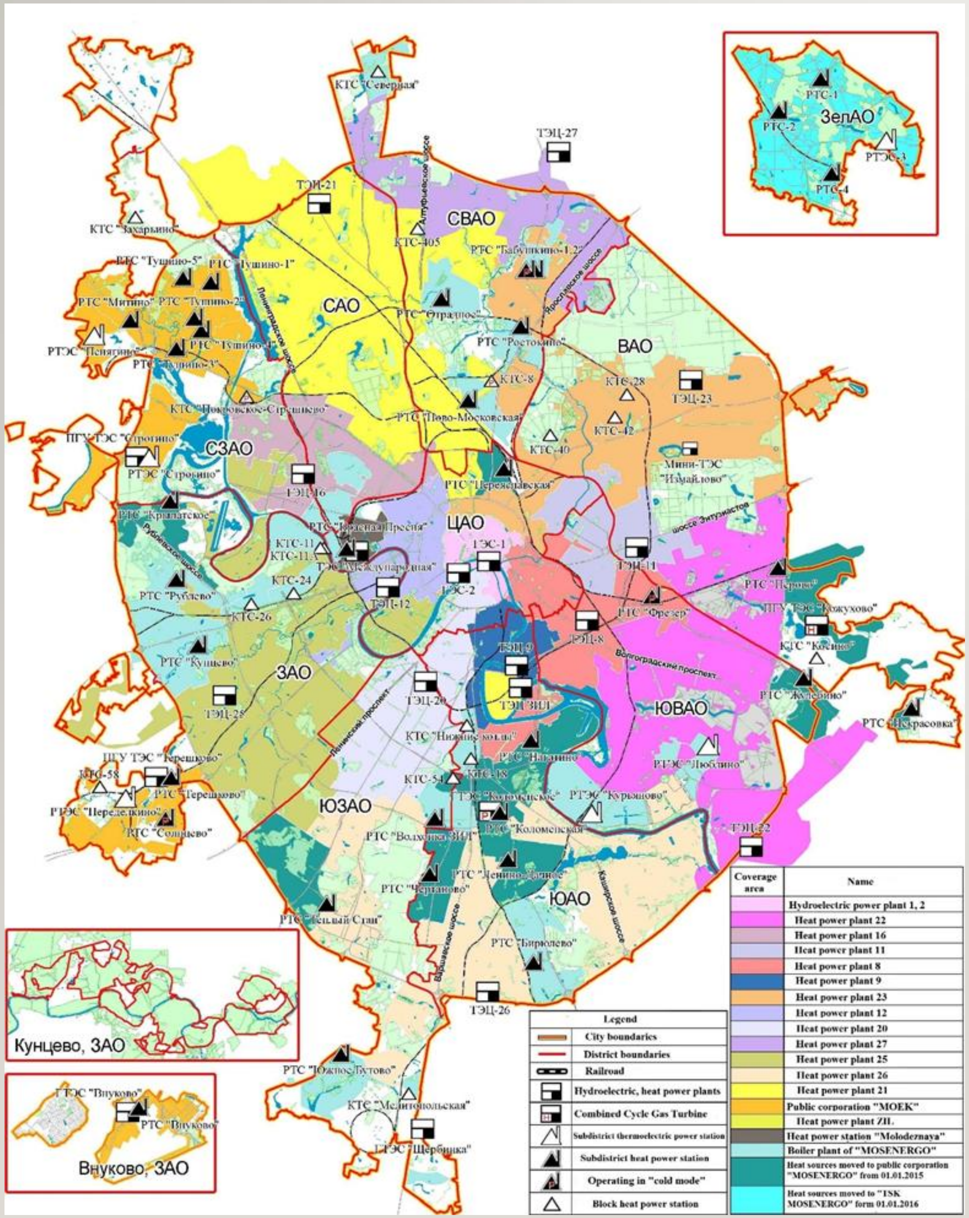
Urban areas generate most carbon emissions. The anthropogenic carbon footprint is the total greenhouse gas (GHG) emissions caused by an individual, event, organization, or product, expressed as carbon dioxide equivalent. Greenhouse gases, including the carbon-containing gases carbon dioxide and methane, can be emitted through the burning of fossil fuels, land clearance and the production and consumption of food, manufactured goods, materials, wood, roads, buildings, transportation and other services.

Carbon footprints of large cities around the world



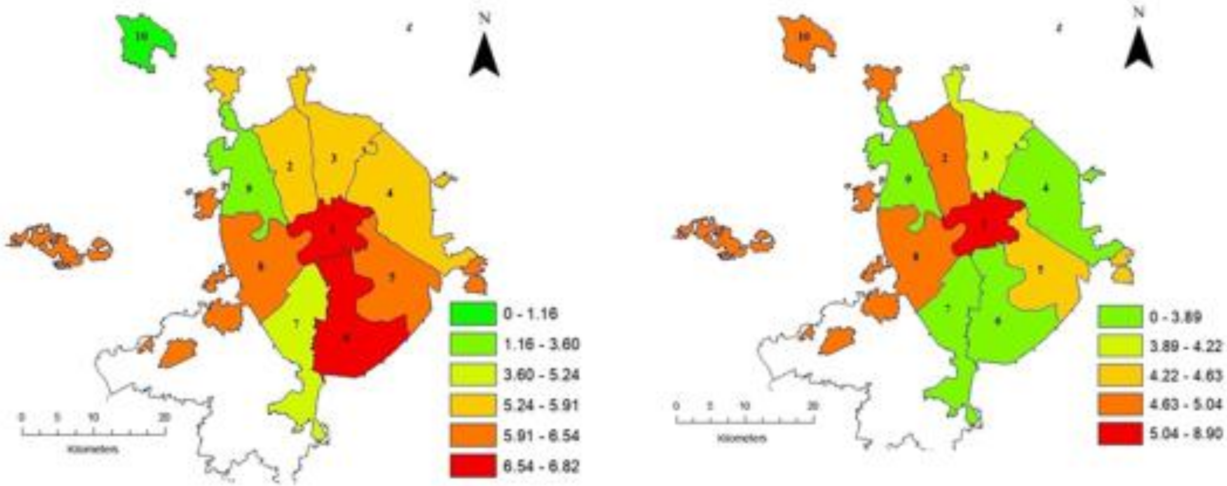
European carbon footprint map

Moscow district heating sistem



Moscow DHS Carbon Footprint

$$C_{DH} = C \cdot \frac{G_{DH}}{G_t}$$



DHS – district heating system

Anthropogenic heat flux

The anthropogenic heat fluxes (AHF) above urbanized territories around the world very strongly affects mesoscale atmospheric processes.

AHF within the largest urban agglomerations of the world could be estimated by empirical assessment, based on the use of the most reliable data on the population and energy consumption of the urban economy of megacities.

Regional atmospheric advection significantly affects the intensity of the urban heat island, strengthening or weakening the feedback between the temperature regime and the energy consumption of urbanized territories.

The main methods of AHF estimation:

1. direct (in-situ) measurements of the heat fluxes at the level of roofs;
2. inventory and summing of all consumers of the heat and electric energy in the city with account for the population size and means of transport, length of roads, and engineering communications;
3. remote satellite measurements of the heat radiation fluxes and separation of the anthropogenic fluxes based on the local meteorological data.

The most popular method for AHF estimating is the inventory of heat sources:

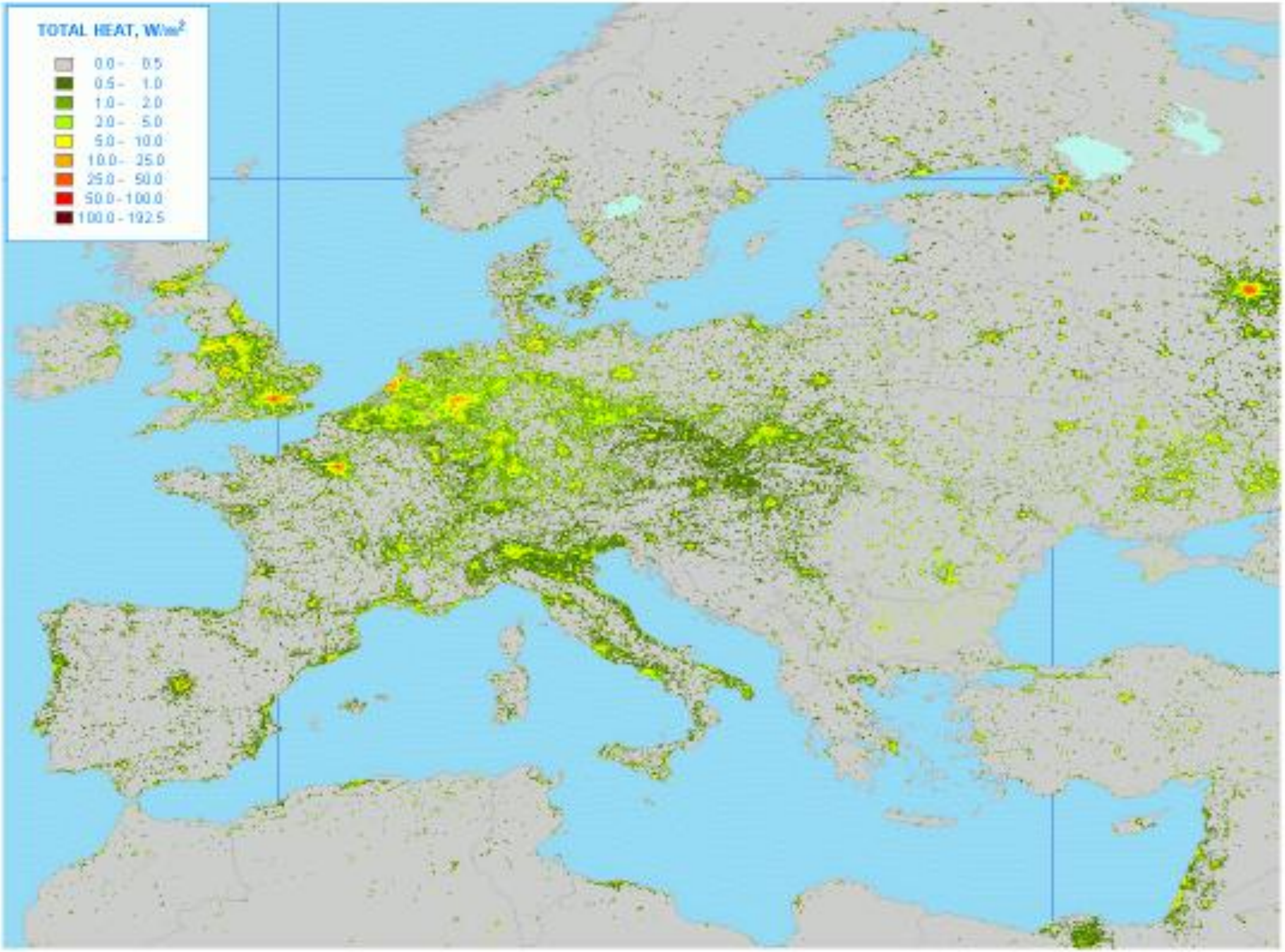
$$Q_a = Q_v + Q_b + Q_m \, ,$$

were Q_a is total AHF, Q_v – heat generated by vehicles, Q_b - heat from buildings, and Q_m - human metabolism.

The alternative method was proposed by author and his co-authors. It based on the use of the most reliable data on the population and energy consumption of the urban economy:

$$Q_a = k \cdot PD \cdot EC$$

where PD is the population density within the urban administrative boundaries, EC is the energy consumption per capita in the country. If Q_a is describing in W/m^2, PD in people per sq. km, and EC in kg o.e., the coefficient will be k = 1.325.


TOTAL HEAT, W/m²
0.0 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 5.0
5.0 - 10.0
10.0 - 25.0
25.0 - 50.0
50.0 - 100.0
100.0 - 192.5

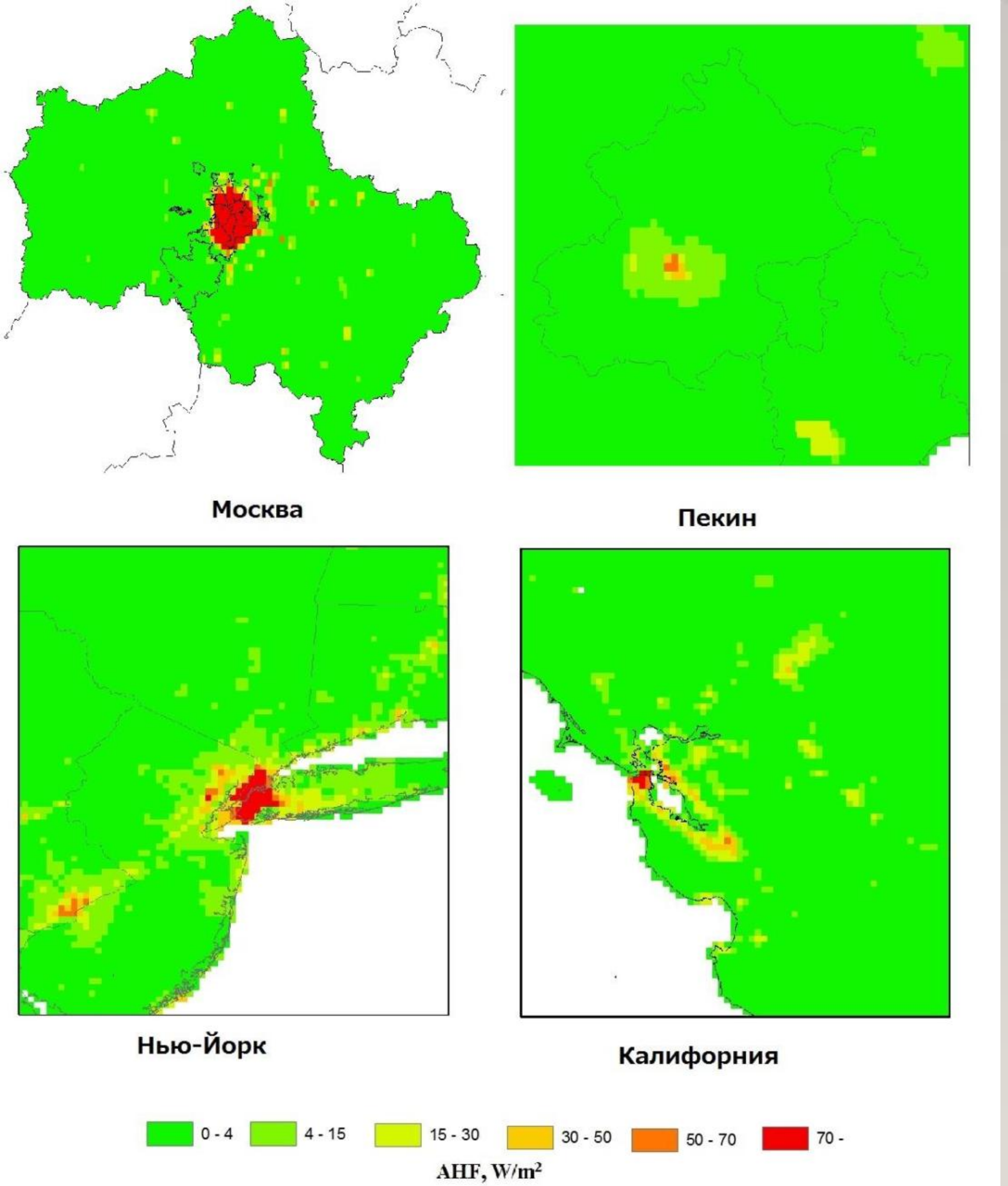
AHF and Urban Climate

Calculation of the influence of energy consumption in urban areas on mesoscale atmospheric processes was carried out from the COSMO-CLM model with the TERRA_URB scheme.

It is shown, that anthropogenic heat fluxes have a noticeable effect on the wind regime of the megalopolis. In the case of the Moscow agglomeration, the average wind speed increases by more than 1 m/s, while the prevailing wind direction changes slightly.

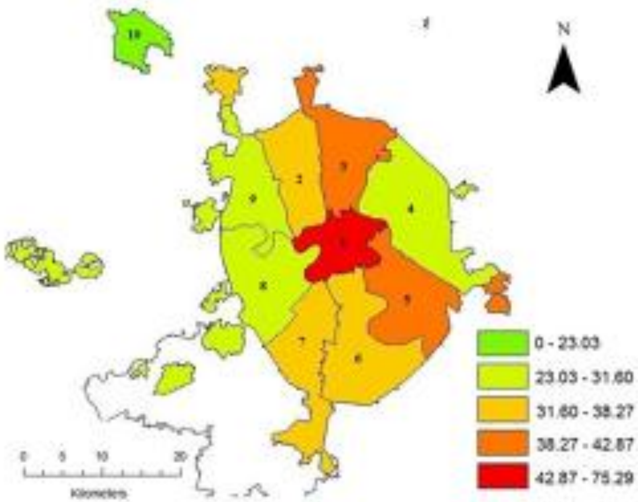
AHF maps within different largest urban agglomerations around the world

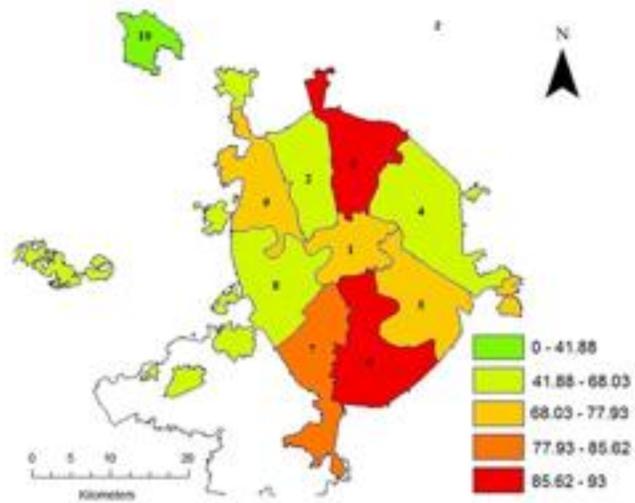
Moscow, Beijing, New-York, California.

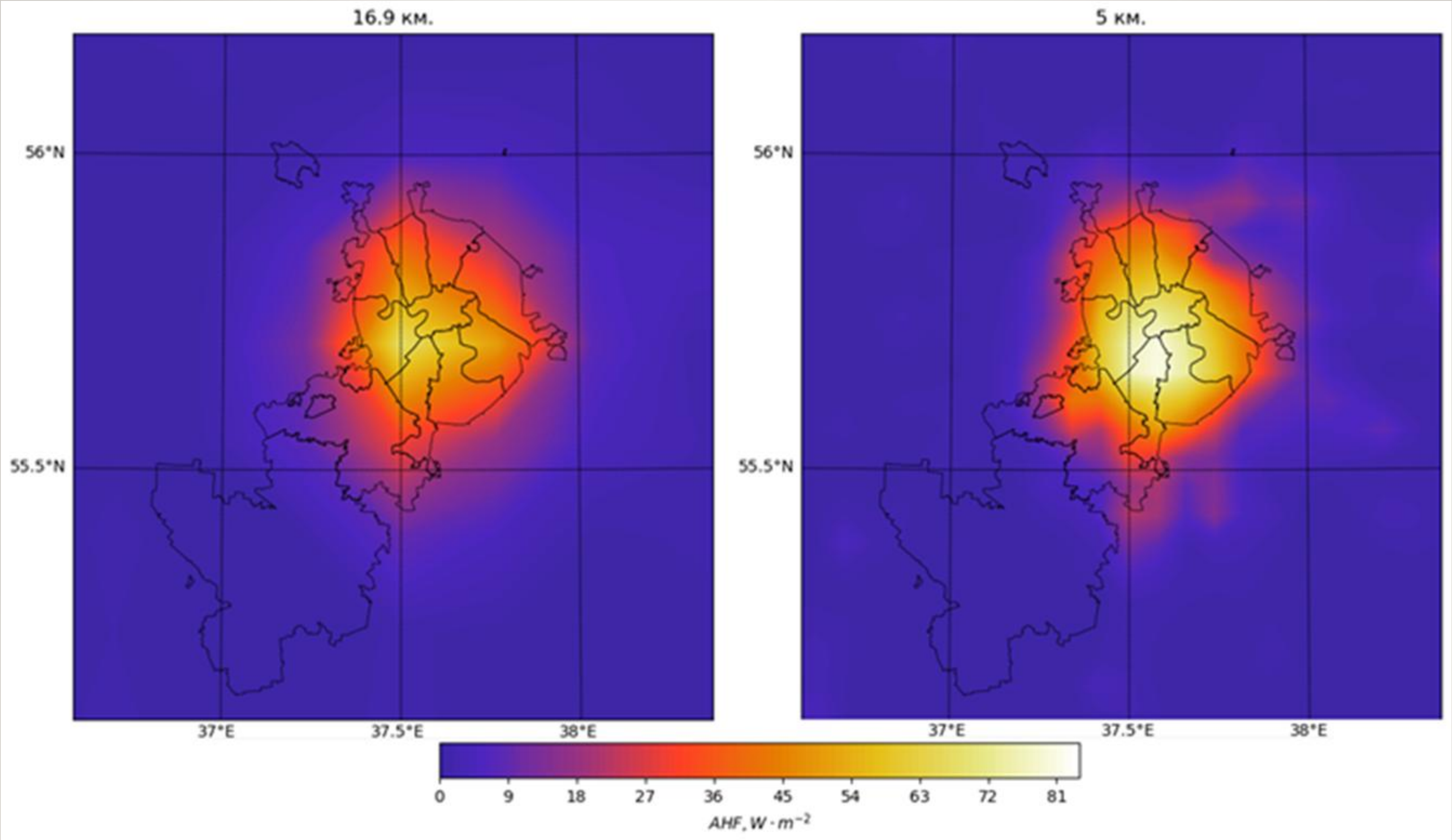


Anthropogenic heat fluxes

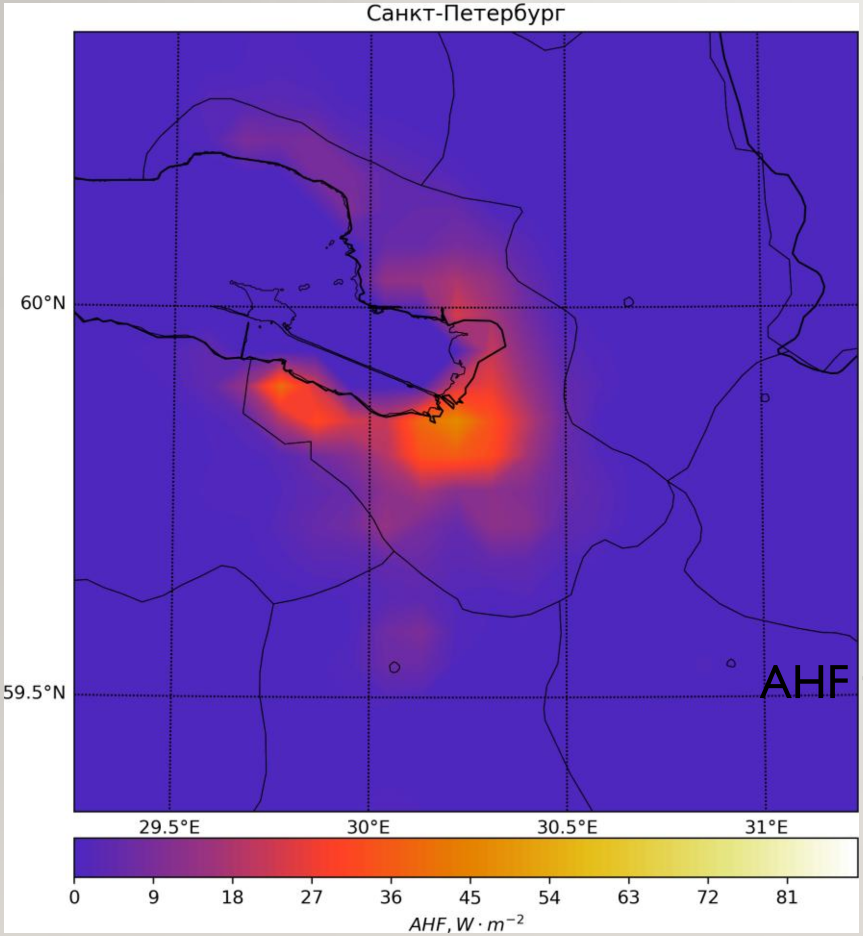
$$Q_a = k \cdot PD \cdot EC \qquad AHF = G \cdot \frac{C_{GW}}{S}$$



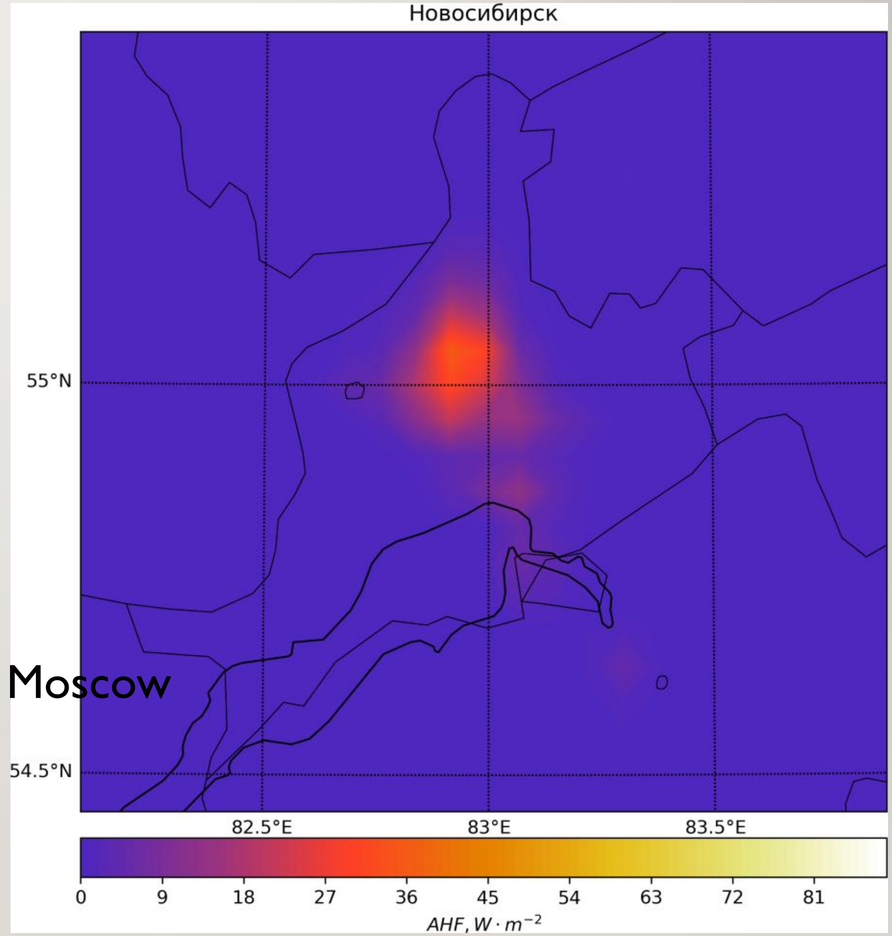




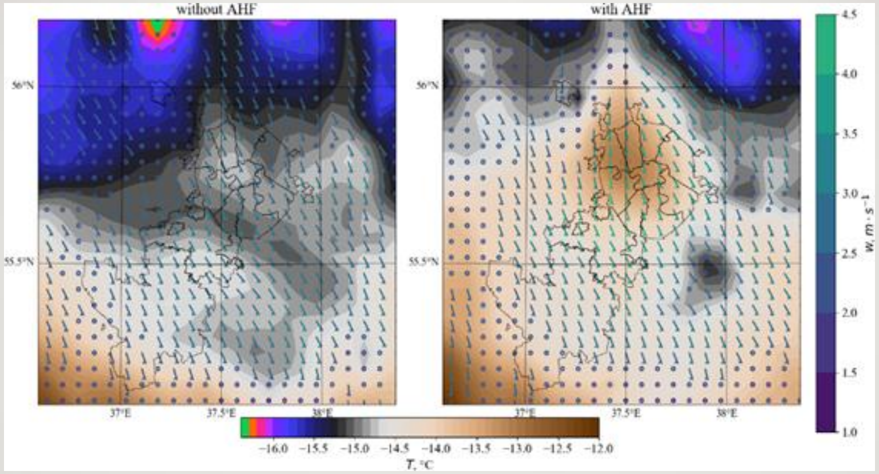
AHF for Moscow area (COSMO-CLM model with different sell size: left – 16.9x16.9 km, right – 5x5 km)



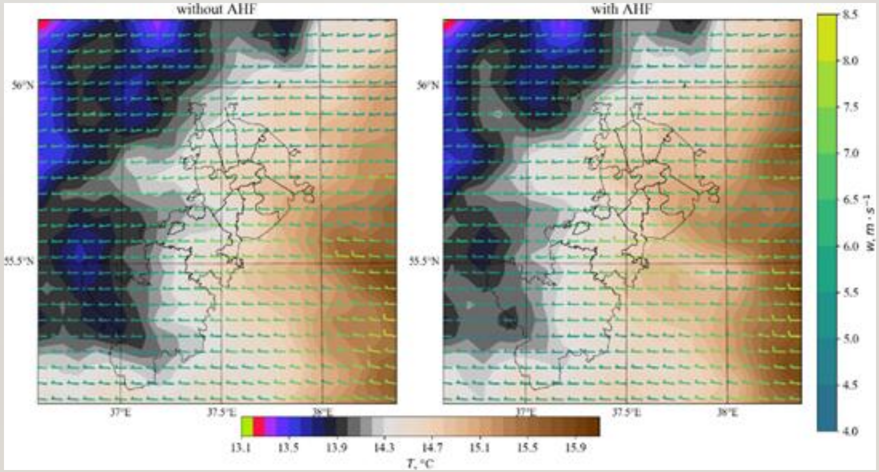
AHF for Moscow



AHF for Saint-Petersburg (left) and Novosibirsk (right) areas

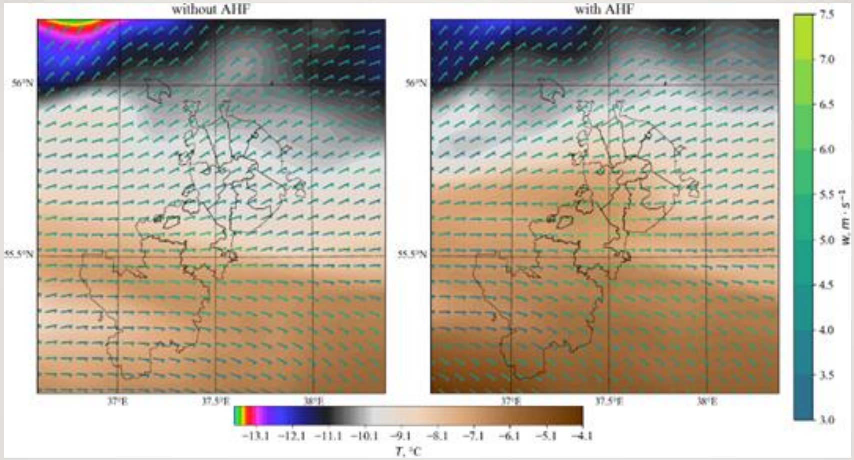


January 5, 2016

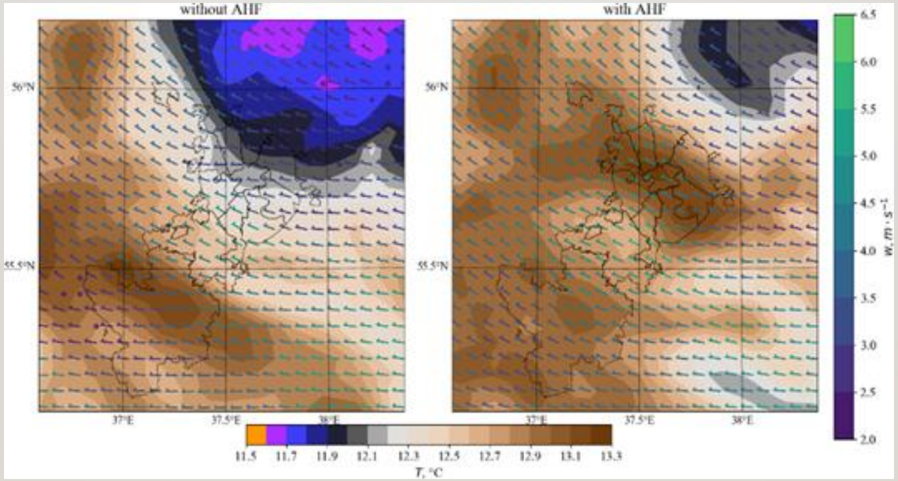


July 5, 2016

Temperature and wind fields modeling left – without AHF, right – with AHF



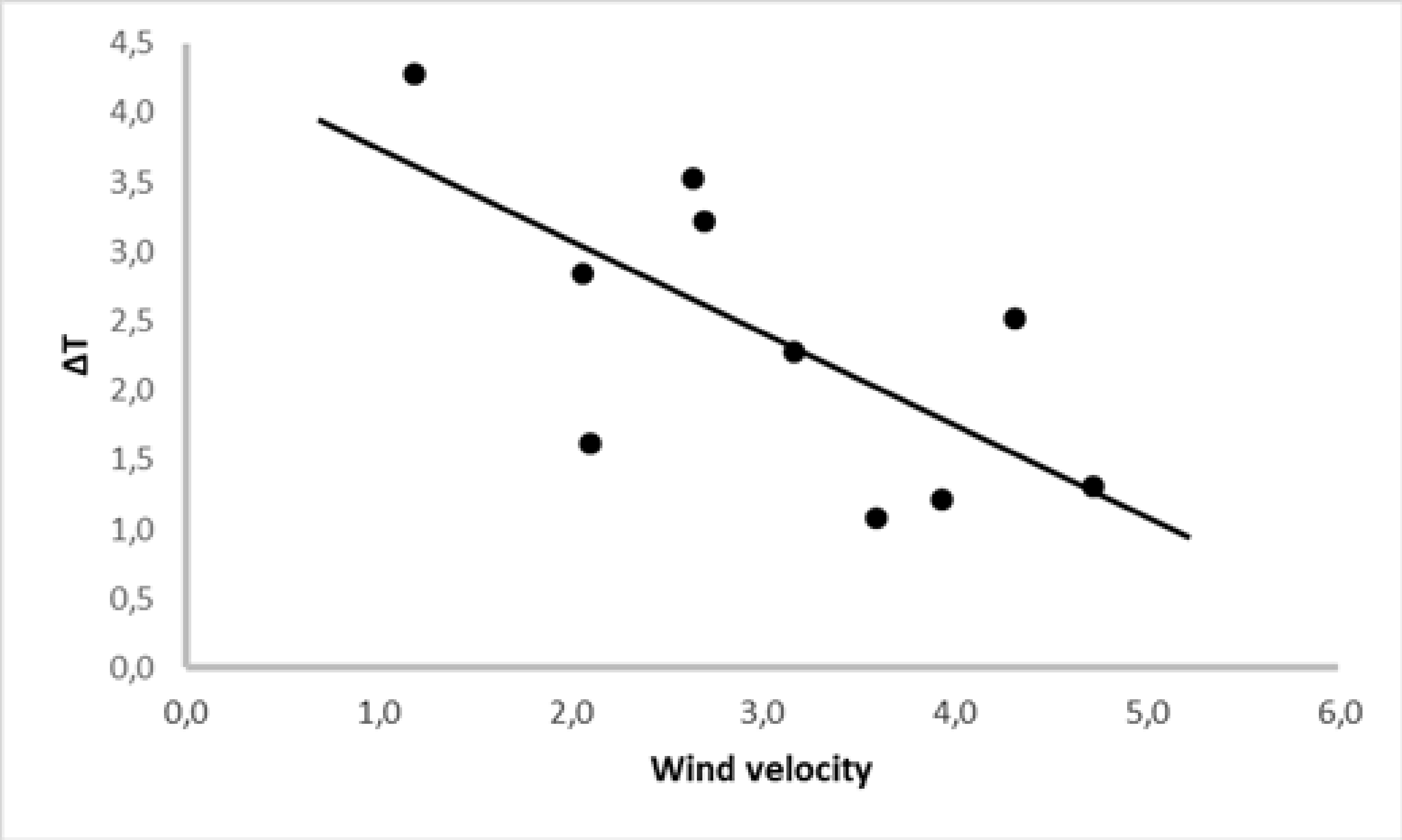
January 5, 2017



July 6, 2017

Temperature and wind fields modeling left – without AHF, right – with AHF

AHF influence depends on wind speed



Heating and Cooling Periods and Degree-Days

The duration of indoor heating periods in various countries and regions of the world is defined in different ways.

In Russia, the heating season generally starts on the date when average daily air temperature stably (for 5 days) falls below the level of +8°C in autumn and ends on the date when it stably (for 5 days) rises above this level in spring.

Due to climate warming several last winters in Moscow region had the 2-3 weeks periods with mean daily air temperature above +8°C and Moscow city authority switched off city district heating system for about a week.

Heating degree day (HDD) is the parameter, which is applied to estimate the energy amount needed to heat indoor living and public spaces.

HDD is calculated as follows:

$$HDD = \sum_{i=1}^{N} (t_c - t_{ai})$$

where N is the number of days within heating period, when ta bellow 8 °C.

City	Average heating season length (days)	Average HDD
Moscow	201	4129
Samara	198	4502
Novosibirsk	223	5768
Saint Petersburg	210	4088
Krasnodar	143	2270
Vladivostok	193	4808

HDD online calculator

$$HDD\_CDD = \sum_{i=1}^{N} |18 - T_i|$$

21 декабря	-2.0 °C
22 декабря	-4.0 °C
23 декабря	-4.5 °C
24 декабря	-4.5 °C
25 декабря	-3.0 °C
26 декабря	-4.0 °C
27 декабря	-2.5 °C
HDD_CDD	150.5

Moscow, December 2017

Thank you for your attention!

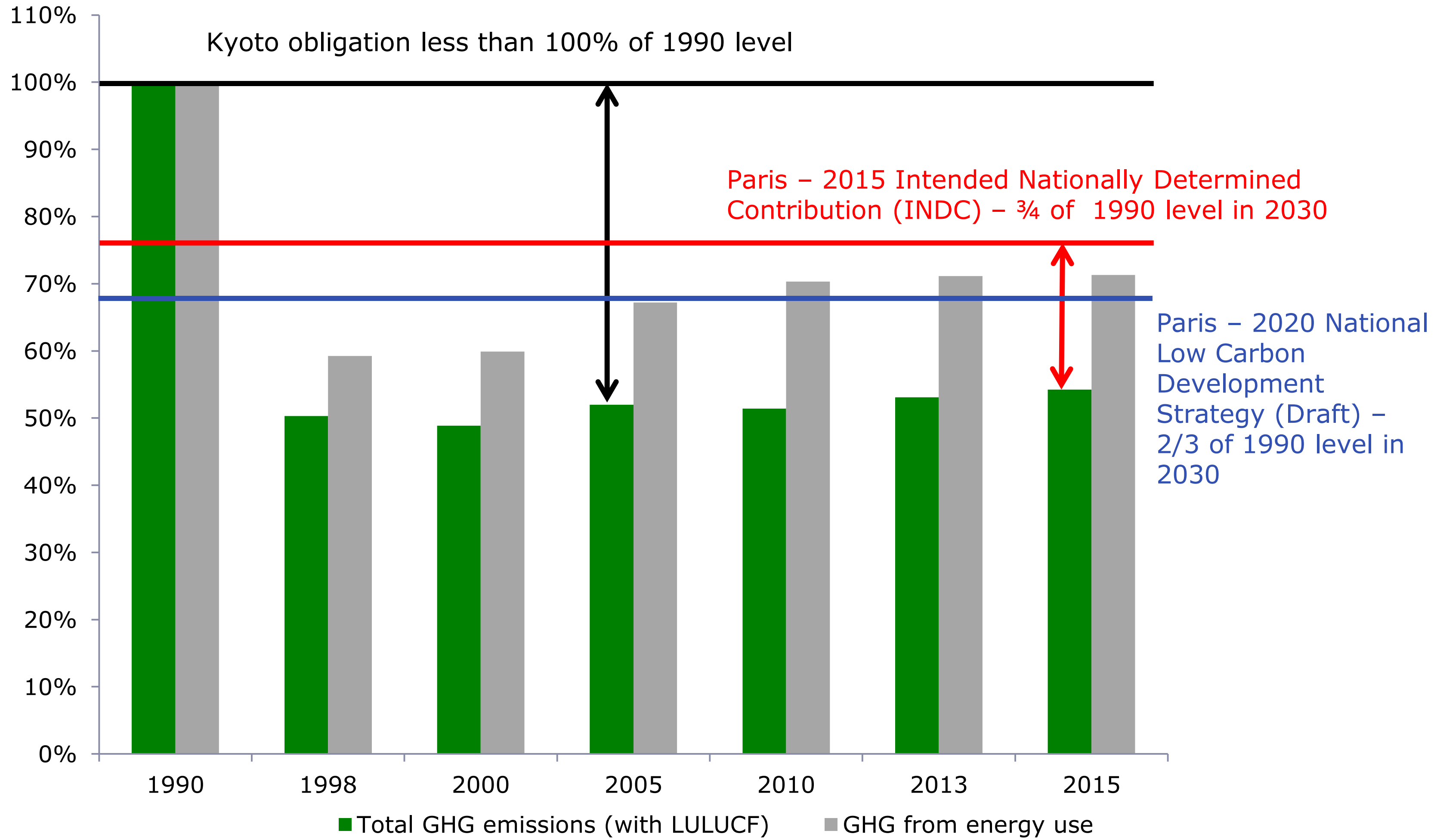
Competitiveness of nuclear power plants in the context of decarbonization strategies

Fedor Veselov, Energy Research Institute of RAS

NICE Future webinar

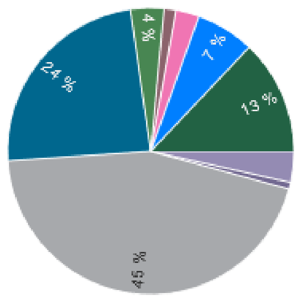
Moscow, June 2020

From Kyoto to Paris - strengthening of the national GHG obligations



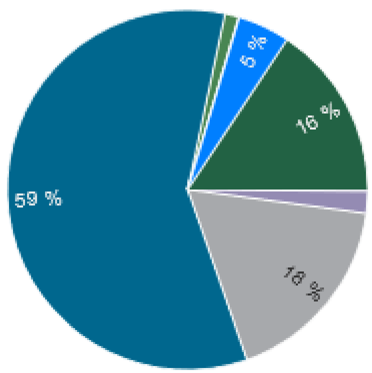
Russian electric power sector.

World (2017)
Total: 5 313 Mtoe



	Oil products	185 Mtoe
	Oil	41 Mtoe
	Coal	2 374 Mtoe
	Natural gas	1 264 Mtoe
	Biofuels and waste	200 Mtoe
	Geothermal	72 Mtoe
	Solar/tide/wind	139 Mtoe
	Hydro	351 Mtoe
	Nuclear	687 Mtoe

Russian Federation (2017)
Total: 339.6 Mtoe



	Oil	0.5 Mtoe
	Oil products	6.7 Mtoe
	Coal	59.6 Mtoe
	Natural gas	199.2 Mtoe
	Biofuels and waste	4.2 Mtoe
	Geothermal	0.1 Mtoe
	Solar/tide/wind	0.1 Mtoe
	Hydro	15.9 Mtoe
	Nuclear	53.3 Mtoe

Russian power sector is one of largest in the world

- 4th place in the total generation of electricity (1092 TWh in 2017)
- Gas-fired plants forms 48% of total capacity (264 GW)
- CHP forms 50% of thermal plants' capacity

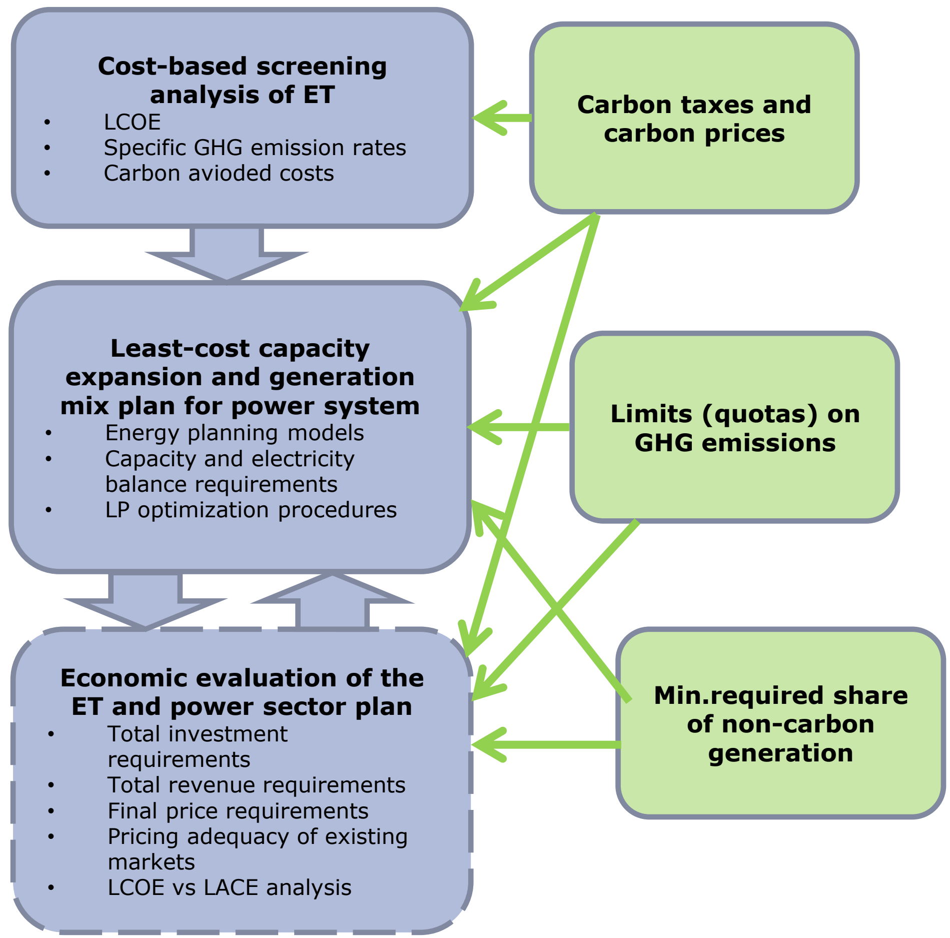
Russia has 29 GW of nuclear plants (11% of total installed capacity) and takes 5th place in world (203 TWh in 2017)

Assessment of the non-carbon energy technologies (ET) competitiveness in the multistage energy planning procedure

Diversity of energy technologies for the low-carbon transformation of the national power sector

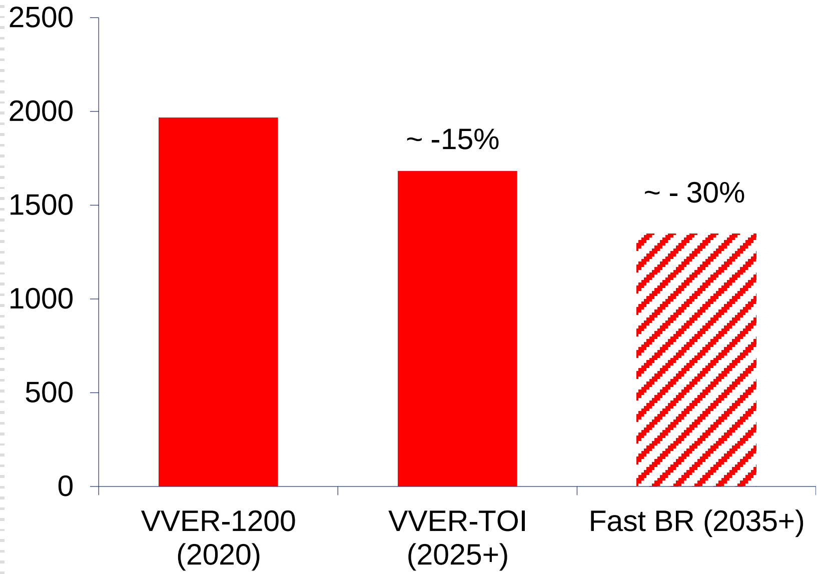
	Low carbon emissions	Zero carbon emissions
Use depletable resources	CCGT Gas-fired CHP CCGT+CCS Coal+CCS	**Nuclear (all types)**
Use renewable resources	Biomass/biogas plants, incl. CHP	Hydro **Wind on/offshore** **Solar PV/CSP**

Multistage energy planning procedure with detailed GHG abatement options

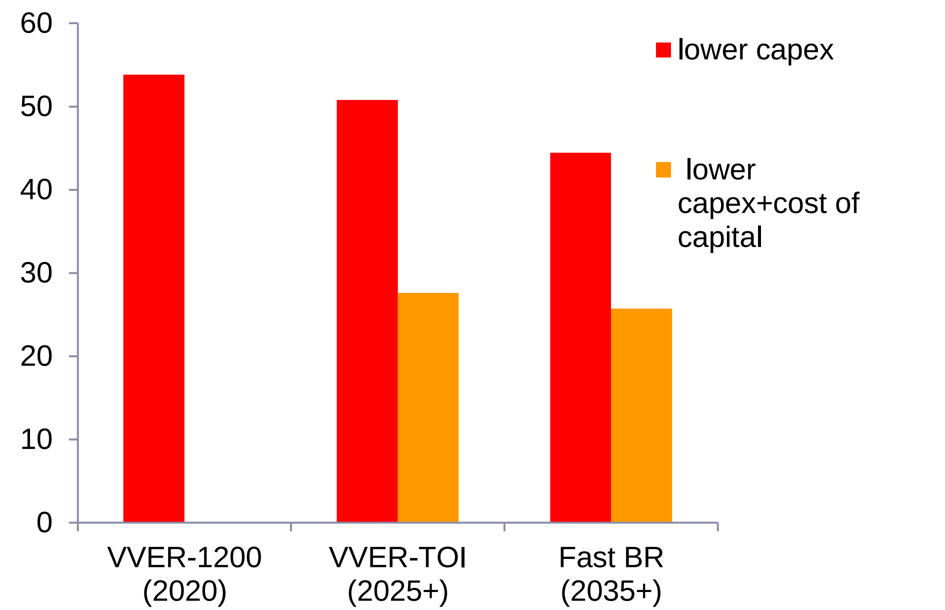


Nuclear plants – technological improvements as a key factor of their competitiveness

Impact of technological improvements on the NPP capex (local projects), $/kW



Impact of lower NPP capex and cost of capital on the LCOE, $/MWh (2018)

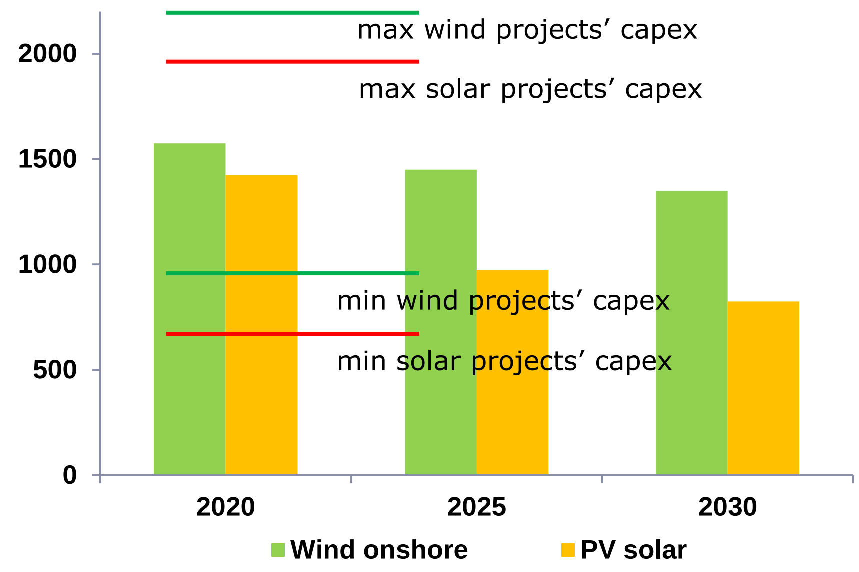


Additional factors:

- Lower O&M costs
- Lower fuel costs
- Higher Capacity factor
- Lower cost of capital

RES plants – rapid technological improvements will be accompanied by the high system integration costs

Impact of technological improvements on the wind and solar capex (local projects), $/kW

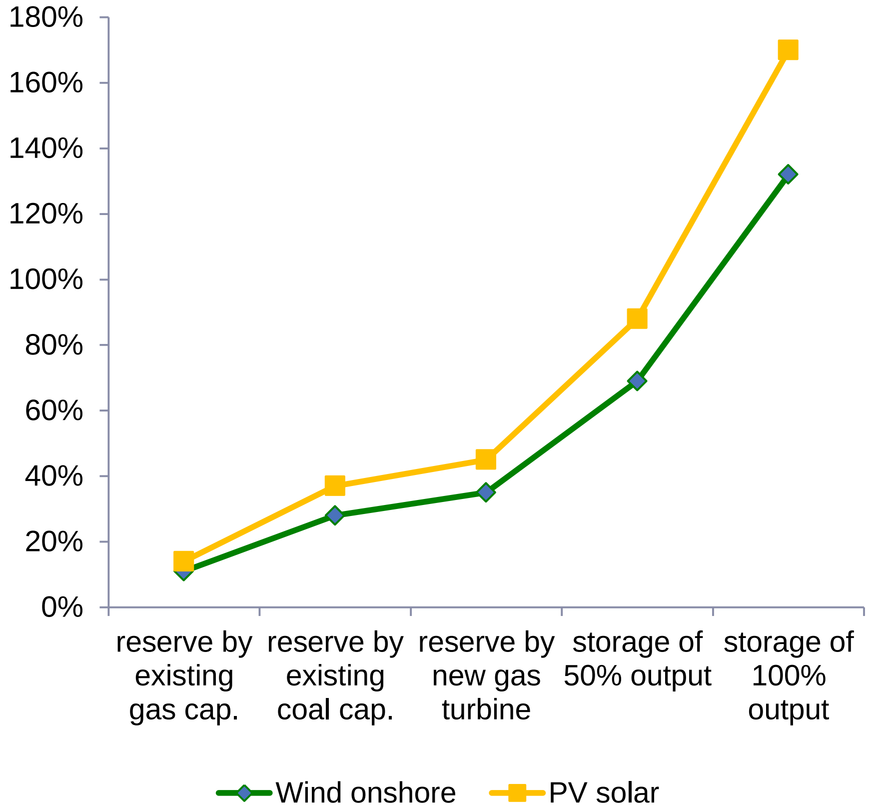


Wind and solar plants generate electricity stochastically, depending on the weather current conditions

For the proper screening analysis of ET it is important to take into account additional costs to enhance the availability of their capacity through:

- Maintaining of the additional reserves at existing of new thermal plants
- Their combination with storage capacities

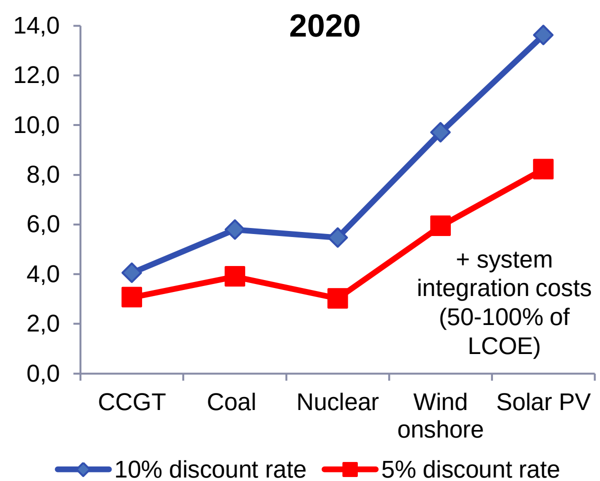
Impact of RES availability costs on the LCOE of RES plants (in % of RES LCOE)

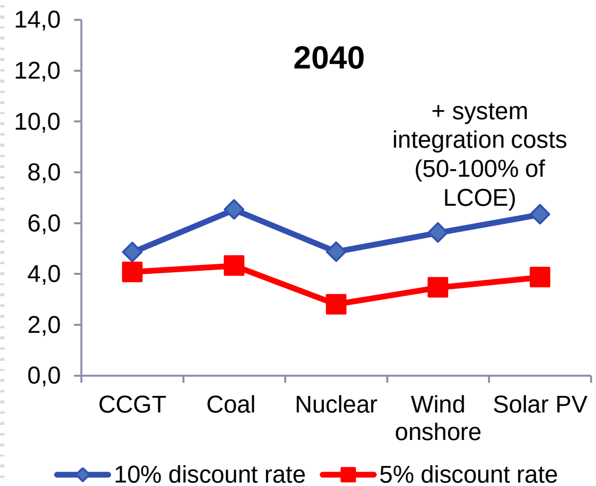


Source: ERI RAS analysis

Cost-based analysis of non-carbon energy technologies and the role in the future capacity mix

LCOE of greenfield plants in the Central Russia, 0.01$/kWh





Nuclear and modern gas plants will be the most important options for GHG emissions abatement in the Russian power sector

	2017	2040								
		1	2	3	4	5	6	7	8	9
Total capacity, GW.	239.8	289.2	289.6	288.9	297.0	289.6	294.9	291.0	298.1	258.2
Hydro	48.4	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3
Wind and solar	0.7	6.1	6.1	6.1	13.8	6.6	13.0	7.4	15.3	6.1
Nuclear	**27.9**	**65.0**	**61.3**	**60.5**	**70.1**	**62.5**	**51.6**	**70.5**	**72.9**	**53.9**
Thermal	162.8	162.8	166.9	167.1	157.8	165.3	175.0	157.8	154.6	142.9
Total capacity, %	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Hydro	20.2	19.1	19.1	19.1	18.6	19.1	18.7	19.0	18.5	21.4
Wind and solar	0.3	2.1	2.1	2.1	4.6	2.3	4.4	2.5	5.1	2.4
Nuclear	**11.6**	**22.5**	**21.2**	**20.9**	**23.6**	**21.6**	**17.5**	**24.2**	**24.5**	**20.9**
Thermal	67.9	56.3	57.6	57.8	53.1	57.1	59.3	54.2	51.9	55.3
Total fuel demand, Mtce	274.6	278.1	285.2	291.2	261.2	284.0	302.6	259.9	250.0	254.7
Gas, % of total	**71.4**	**62.8**	**69.4**	**68.5**	**62.0**	**63.0**	**64.0**	**69.2**	**70.9**	**63.9**
Total CO_2 emissions, $MtCO_2$	545.8	583.0	574.4	589.5	550.3	594.6	629.6	524.1	498.8	530.4
In % to 2017 level		7%	5%	8%	1%	9%	15%	-4%	-9%	-3%

Source: ERI RAS analysis

The research was supported by RSF (project No. 17-79-20354)

Energy Research Institute of the Russian Academy of Sciences

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Thank you for attention!

State atomic energy corporation “Rosatom”

2050 LOW-CARBON AGENDA & SUSTAINABLE ENERGY MIX

Polina Lion

Chief Sustainability Officer,
State Atomic Energy Corporation Rosatom

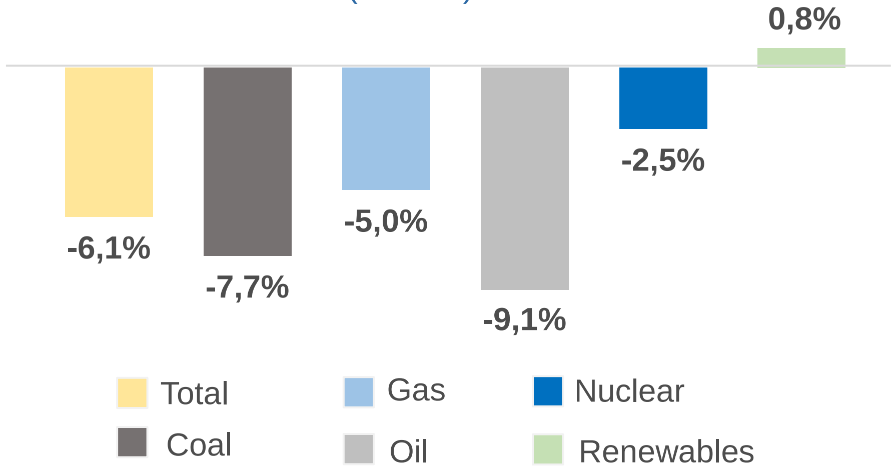
17.06.2020

Webinar for NICE Future

ENERGY MIX: CURRENT OBSERVATIONS

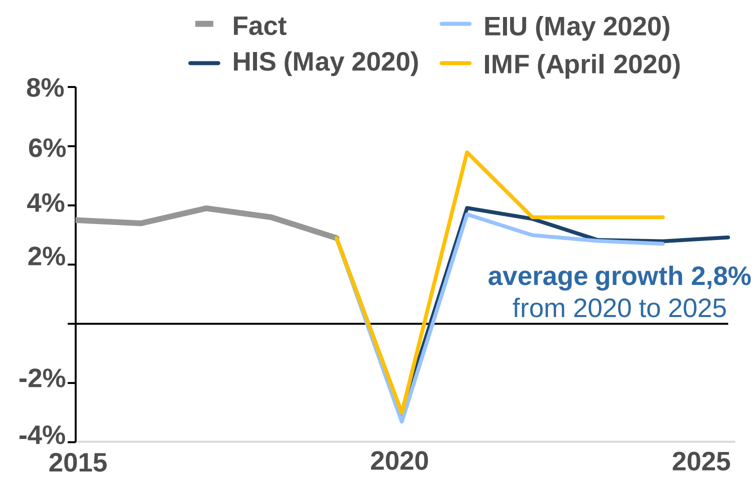
ROSATOM

PROJECTED CHANGE IN ENERGY DEMAND BY FUEL
(in 2020)



Source: IEA

WORLD GDP GROWTH



Source: IHS Markit, EIU Global Outlook, IMF World Economy Outlook

In Europe electricity demand decreased by 27% between the first week of February and the last week of March. In Italy and Spain electricity demand decline was reaching 30-40%

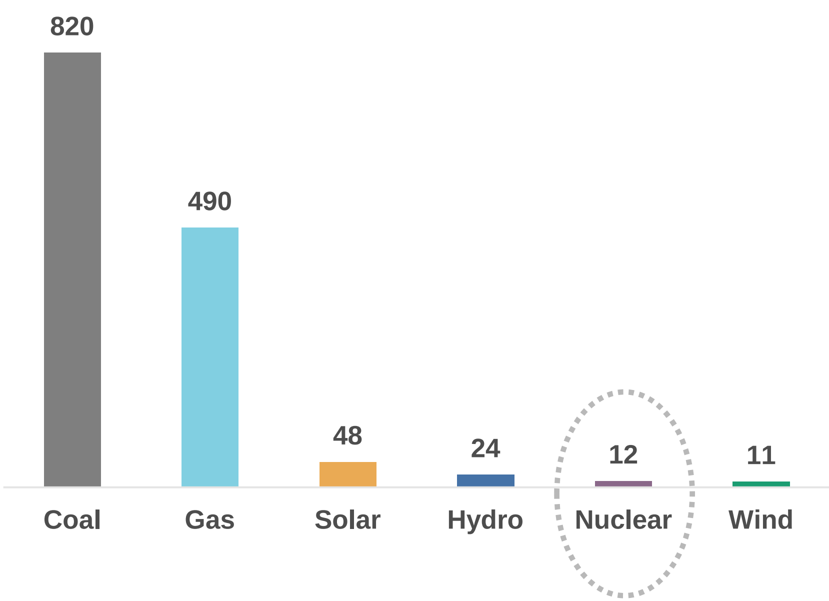
Consensus-forecast assumes that the world economy will return to growth rates of more than 3% per year from 2021

Despite the Covid-19 lockdown and economic disruption, the Sustainability and Green Deal are still top priority for the European strategic agenda

LOW-CARBON AGENDA KEEPS THE PRIORITY

Jun.19	Dec.19	Mar.20	Jun.20	Dec.20	2021
Taxonomy first release	Green Deal announcement at COP 25	Taxonomy final release	Taxonomy official adaptation	Delegated Act adaptation	Delegated Act enters into application

EMISSIONS OF SELECTED ELECTRICITY SUPPLY TECHNOLOGIES (gCO2eq / kWh)



Source: IPCC

- **Screening criteria** for 67 activities across **6 sectors** that can make a substantial contribution to climate change mitigation
- **2 dimensions** of assessment:
  - **(+)** Environmental effects
  - **(–)** DNSH criteria

Do no significant harm criteria (DNSH):

- No pollution **(CO_2 emissions up to 100 g / kWh)**
- Min water consumption
- Circular economy
- Ecosystems

LCOE TO COMPARE ENERGY SOURCES EFFICIENCY

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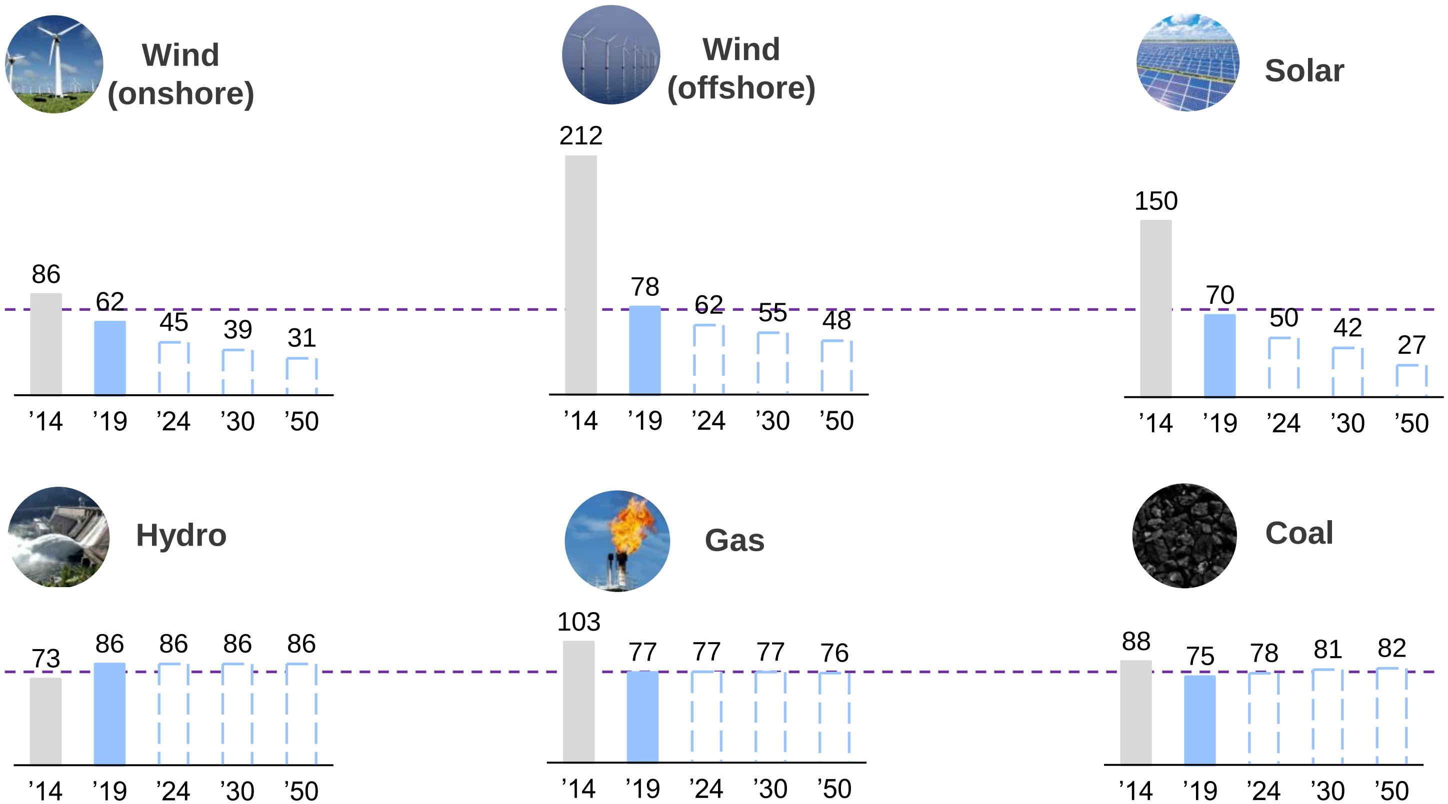
LCOE OF DIFFERENT GENERATION SOURCES, USD /MWH

- - - *Nuclear 2019 global (76 USD / MWh)*



During last 10 years the global weighted-average LCOE of wind onshore solutions decreased by almost 40% and solar decreased by 77%

INVESTMENT ASPECTS OF NPP PROJECTS

ROSATOM

NPP POJECT GENERAL PARAMETRS

10+ bn USD	Project cost
6-8 years	Construction period
15+ years	Payback period after commissioning
60+ years	Electricity generation 24/7

2 units NPP of 2400 MW provides ~ 15 TWh of electricity per year

Risks of large infrastructure projects

- Risk of Delays in Construction
- Risk of Cost Overruns
- Do No Significant Harm (DNSH criteria)

Governmental support and guarantees are essential to support nuclear power plants projects, both in financial and non-financial aspects

NUCLEAR INDUSTRY RESPONDS TO RISKS

- Safety - top priority
- Time and cost management
- SMR solutions
- Closed fuel cycle

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THE GREEN SQUARE CONCEPT

Nuclear energy provides reliable base load electricity supply that is independent of weather conditions

ELECTRICITY GENERATION BY SOURCE

Country	Nuclear	Hydro	Wind, solar
France	71%	12%	7%
Norway		95%	3%
Hungary	50%		4%
Switzerland	37%	55%	3%
Finland	33%	19%	9%
Portugal		23%	23%

AFTER THE LOCKDOWN: ECONOMIC RECOVERY IN 2021+

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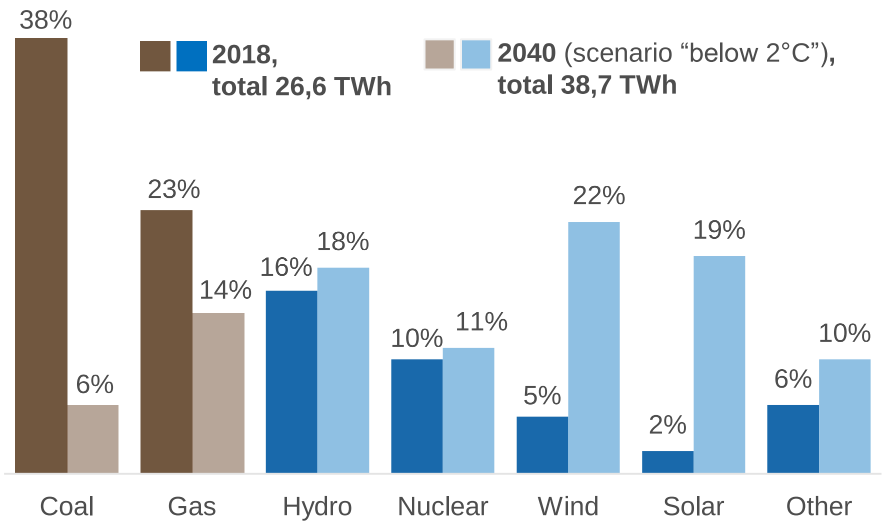
+25%

Forecast of world population growth

The world population will **increase by 25%** from **7.7 to 9.7 billion by 2050** causing the **energy demand at least to double**

Source: United Nations, World Population Prospects (2019)

SHARE OF ENERGY SOURCES IN GLOBAL ELECTRICITY GENERATION



Source: IEA, World Energy Outlook 2019

Sustainable energy mix

- Low-carbon
- Safe and reliable
- Commercially efficient
- Transparent

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Technical Academy

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STATE ATOMIC ENERGY CORPORATION «ROSATOM»

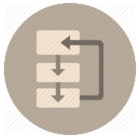
Role of Nuclear Power in Mitigating Global Climate Change:

Data Visualization for Predictive Analytics

Introduction

Presentation Outline:

- **Data Visualization**



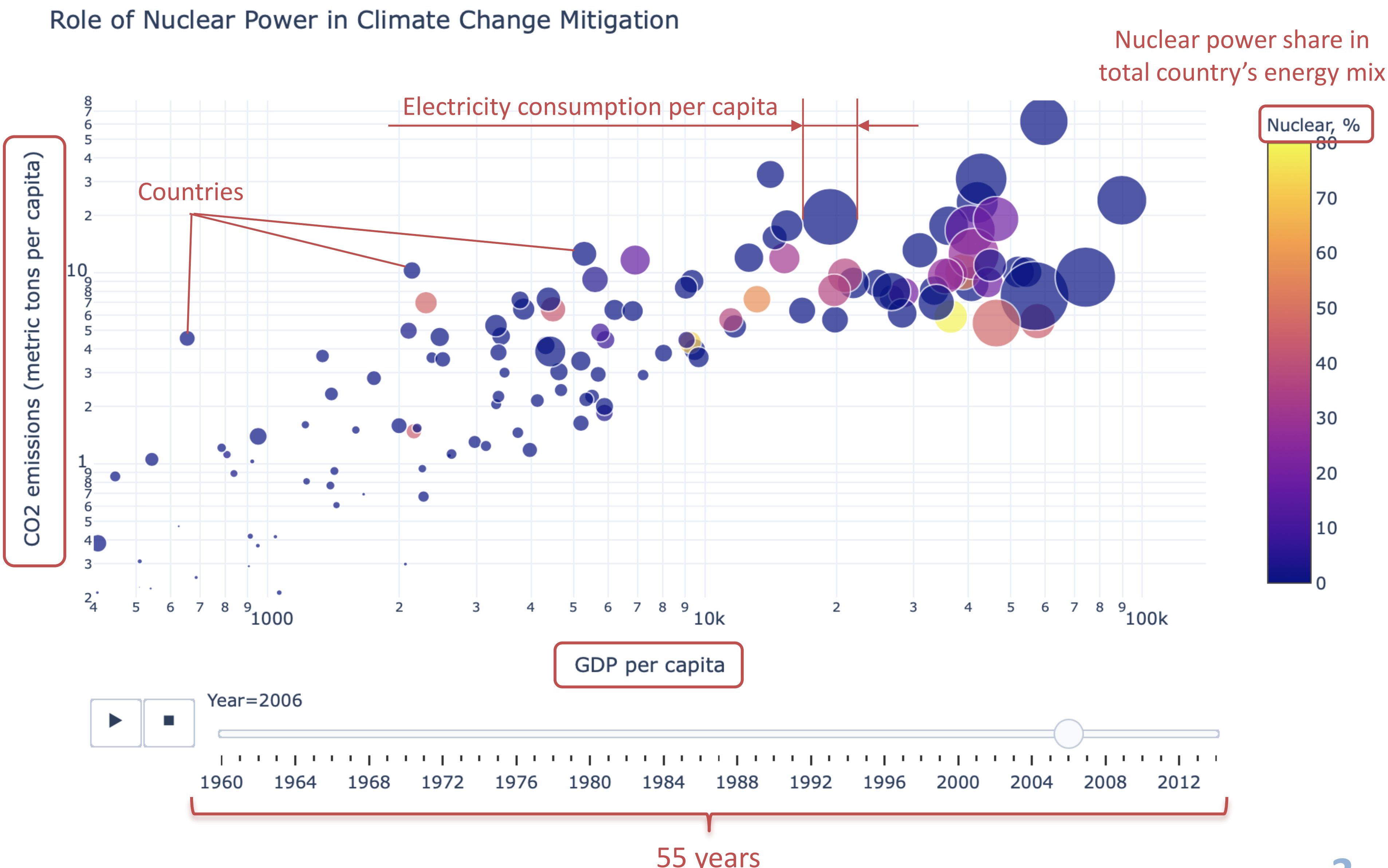
- **Data Visualization Logic**

- **Data Used**

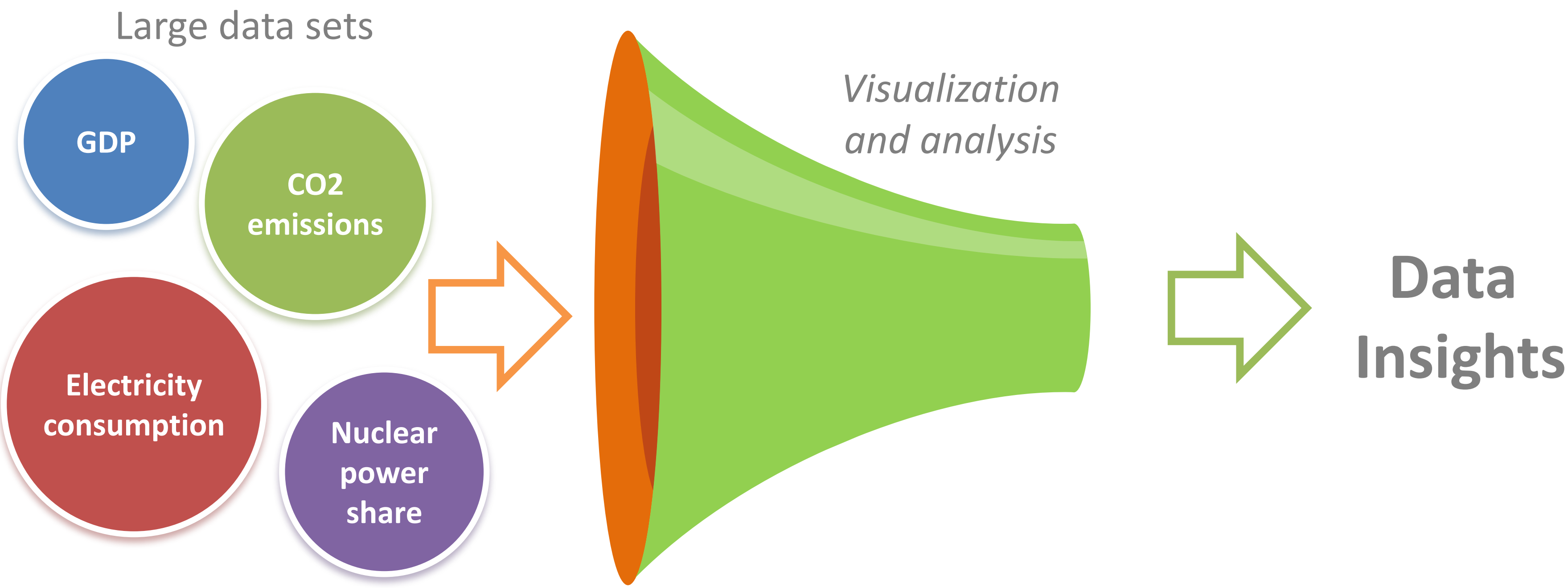
- **Tools Used to Develop the Visualization**

- **Main Messages of Visualization**

Data Visualization



Data Visualization Logic



Requirements for data

Freely accessible – **transparent**

Referenced – **reliable**

Linked to economic indicators – **valuable**

Difficult in analysis – **big data**

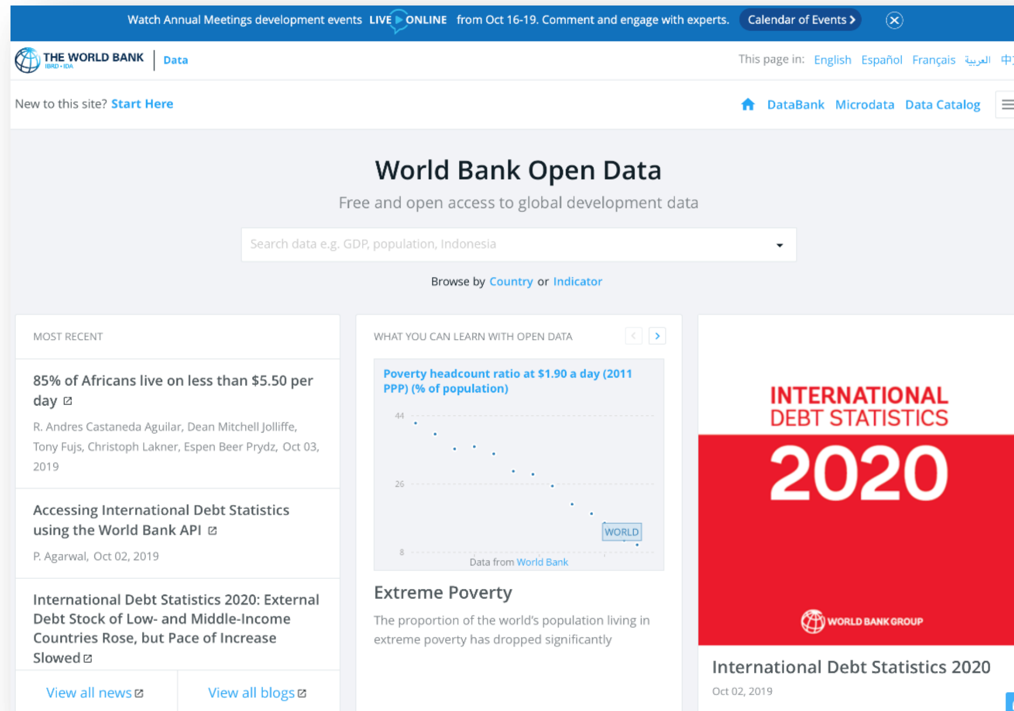
Data Used

THE WORLD BANK is an international financial institution that provides loans and grants to the governments of poorer countries for the purpose of pursuing capital projects.

https://en.wikipedia.org/wiki/World_Bank#Open_data_initiative

Open Data Initiative

- The World Bank collects and processes large amounts of data and generates them on the basis of economic models.
- These data and models have gradually been made available to the public in a way that encourages reuse.



https://www.worldbank.orge

Reliable, Referenced, Diverse Large Sets Of Data

Tools Used to Develop the Visualization

Big data is a field that treats ways to analyze, systematically extract information from, or otherwise deal with data sets that are too large or complex to be dealt with by traditional data-processing application software.

https://en.wikipedia.org/wiki/Big_data

https://sdtimes.com/data/big-data-go/

Data science is a multi-disciplinary field that uses scientific methods, processes, algorithms and systems to extract knowledge and insights from structured and unstructured data..

https://en.wikipedia.org/wiki/Data_science

https://towardsdatascience.com/data-science-for-beginners-850c3376a34a

Tools Used to Develop the Visualization

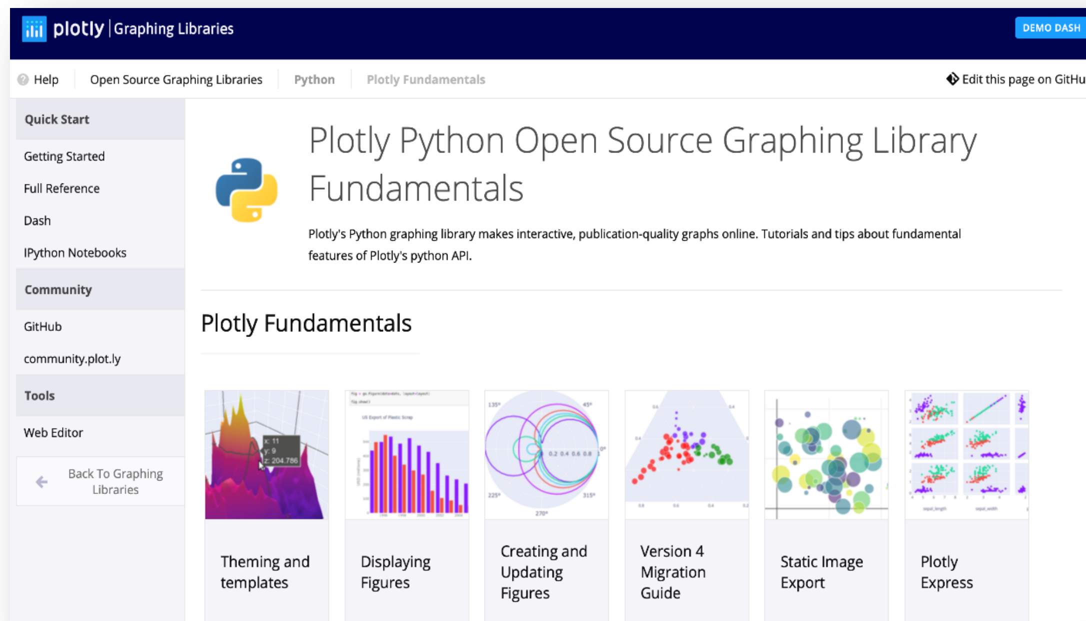
python™ is an interpreted, high-level, general-purpose programming language.

https://en.wikipedia.org/wiki/Python_(programming_language)#Features_and_philosophy

Some features of the language:

1. Easy to Learn and Use
2. Free and Open Source
3. Large Standard Library
4. …

Extensive Data Visualization libraries



https://plot.ly/python/

Main Messages of Visualization

The visualization shows that:

- GDP and electricity consumption are tend to grow over time.
- CO_2 emissions per capita increase with the increase of GDP and electricity consumption per capita accordingly.
- Countries’ efforts on reducing CO_2 emissions are effective but insufficient.
- Nuclear power plays an essential role in reducing CO_2 emissions and fighting global climate change.
- These data and models have gradually been made available to the public in a way that encourages interaction of stakeholders and decision makers.
- There is a need in finding optimal mix of nuclear and renewables from an economic point of view.

Thank you for attention!

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