



**Warsaw  
Energy**  
Use Sensibly!

**Carbon-CAP**  
Consumption-based Accounting and Policy



## ACTIONS RELATED TO GREENER ENERGY AND TRANSPORT IN THE CITY OF WARSAW

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# The City of Warsaw

## Main features of the capital city of Poland:

- administrative area: 517 km<sup>2</sup>
- inhabitants within this area: 1.7 million
- inhabitants within agglomeration: up to 3.3 million
- density of population: 3300 per km<sup>2</sup>
- registered enterprises: 360 000
- registered vehicles: 1.2 million
- budget expenditure for 2016: € 3.5 billion  
(PLN 14.7 billion)
- unemployment: 4.5%
- 78 universities and colleges
- 270 thousand students





# Sustainable Energy Action Plan

## Covenant Of Mayors initiative

Warsaw joined in 2009

Key document: *Sustainable Energy Action Plan for Warsaw in the perspective of 2020 (SEAP)*



### SEAP target – improvement of energy efficiency and reduction of GHG emissions - calculated as:

- 80% of CO<sub>2</sub> emission in 2020 comparing to the base year,
- 80% of energy consumption in 2020 comparing to the base year,
- at least 20% of energy will be produced from RES,
- information and promotion actions regarding energy management/conservation will be implemented.



In 2015 Warsaw prepared, within the new Polish scheme, the **Low-Carbon Economy Plan**, based on SEAP and being its enhancement. It covers specific projects with secured funding, will help in getting additional funds for their implementation and will give us a general vision of low-carbon Warsaw in future.

Year	Energy consumption [MWh/year]	CO <sub>2</sub> emission [MgCO <sub>2</sub> /year]
2007	28 394 431	12 952 984
2020	<b>22 715 545</b>	<b>10 362 387</b>

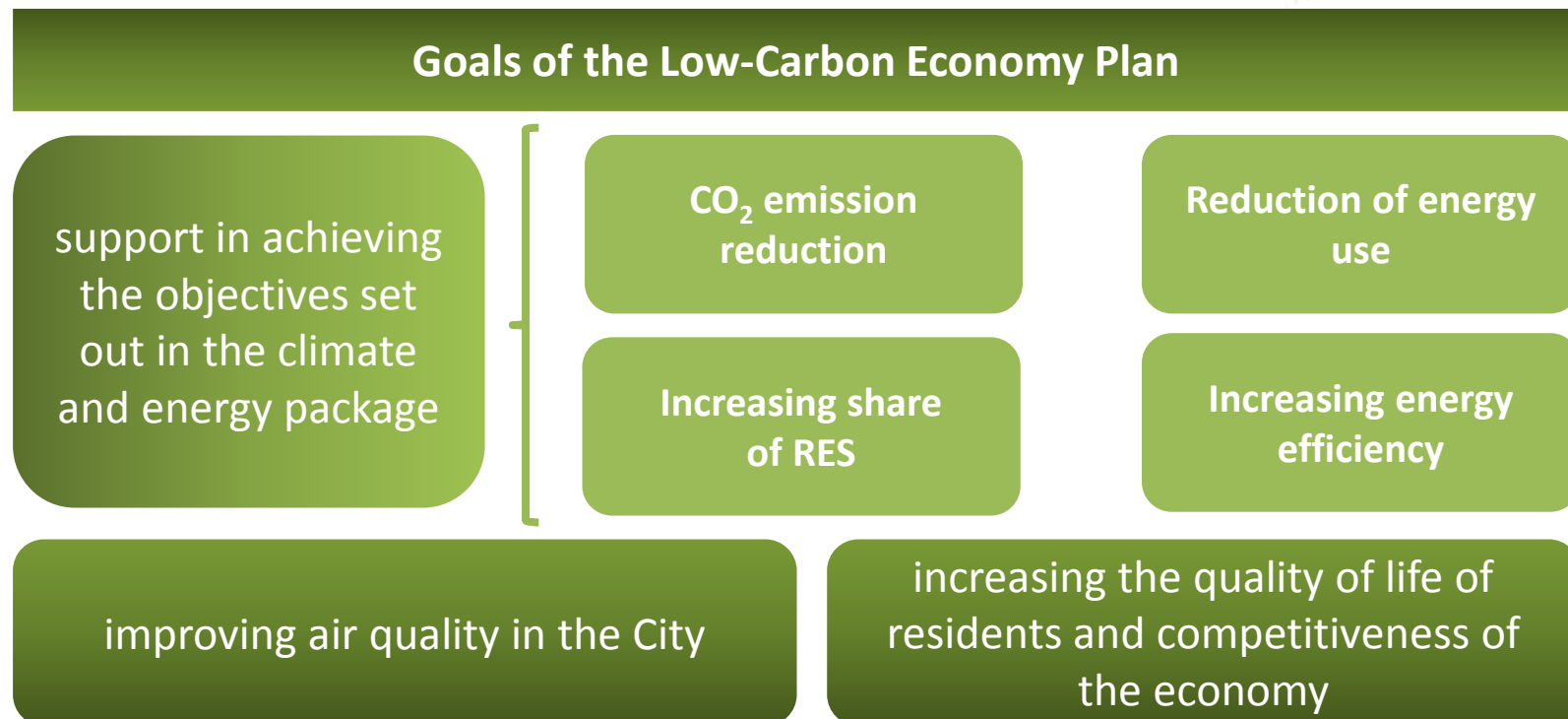
**SEAP targets for 2020 compared to the base year 2007**





# Low-Carbon Economy Plan

**Adopted by the City Council in December 2015, secures spending of € 4 billion until 2020 for investments improving energy efficiency and air quality, including also low-emission transport**





## SEAP– main activities on reduction of energy consumption



No.	Tasks	Planned energy savings in 2020	Reduction of CO <sub>2</sub>	Investment s
		[MWh/a]	[t/a]	[million €]
1	Complex buildings retrofit in housing sector	1 399 200	415 562	1020
2	Complex buildings retrofit in service sector	1 150 783	341 782	612
3	Complex buildings retrofit in public sector	359 718	106 836	191
4	Modernization of heating system (e.g. replacement of local heat sources with more efficient heat sources)	105 000	31 185	87
5	Retrofit of industrial buildings	185 820	55 189	49
6	Modernization of indoor lighting	85 228	83 693	9
7	Modernization of street and outdoor lighting	55 000	54 010	25
8	Replacement of old home electronic equipment	16 667	16 367	57
9	Replacement of old IT equipment	22 727	22 318	38
10	<b>Implementation of part of tasks listed in the Strategy for the Sustainable Development of the Warsaw Transportation System to the Year 2015 and Beyond</b>	<b>3 268 766</b>	<b>843 342</b>	<b>964</b>





## Selected Warsaw activities in the transportation sector



- Improvement of public transport network.
- Replacement of rolling stock, including recent total purchases
  - ✓ 261 new trams capable of recovering braking energy,
  - ✓ 35 six-coach energy efficient underground sets ,
  - ✓ 19 units for Rapid City Train,
  - ✓ 273 modern buses including EVs, HEVs and LNG buses ,
  - ✓ 90 EVs, HEVs and CNG vehicles in city units/companies.
- Extension of second metro line (the central stage with 7 stations operational since March 2015).
- Setting bus-only lanes.
- Development of P&R car parking lots (currently 14).
- Expansion of the bicycle paths system (now >450 km).
- Veturilo public bike (now 204 stations with 3000 bikes).
- Training of drivers in eco-driving.
- Promotion of public transport.





## Development of low-emission bus fleet by the MZA company - Warsaw municipal bus operator

- Purchase of bus fleet that reduces emissions of pollutants and utilizes modern technologies.
- Operation of **4 hybrid** 18-metre Solaris buses since 2011.
- **35 gas buses** joined the Warsaw fleet in 2015 (operational since mid-February).
- **10 e-buses** purchased in 2014 (operational since Saturday – 27th June 2015).
- Operation of electric buses besides environmental benefits will also bring significant savings in operating costs.
- Warsaw – member of C40 since 2007 and participant of its Low Emission Vehicle Network - signed the C40 Clean Bus Declaration in 2015.
- In accordance with the Declaration, MZA shall operate **130** electric and hybrid buses until 2020.





# Testing conditions for clean buses

- All clean buses are tested within the same bus line in the downtown Warsaw – line no. 222.
- On this line MZA operates daily 4 models of 12-metre buses, what allows for creating reference database for tested vehicles.
- 12-metre diesel buses operating on this route consume around 49 l of oil/100 km.







# Selected tests of clean buses

## e-bus Solaris Urbino E8,9

- tested on October 2013
- range of 100 km without recharging in the traffic
- 121 kWh battery (200 Ah)
- charging time (max.) 4-5 hours
- cable & plug charging
- 2429 km/22 days



## e-bus BYD K9C

- tested in 2013
- length: 12-metre
- range of 171 km without recharging in the traffic
- 324 kWh battery (600 Ah)
- charging time:
  - ✓ 4-5 hours fast charging
  - ✓ 8-9 hours slow charging
- cable & plug charging
- 2004 km/12 days





# Hybrid buses

- **City bus Solaris Urbino 18 Hybrid**
- **Technical specification:**
  - ✓ Bus length - 18 m
  - ✓ Bus width – 2.55 m
  - ✓ Bus total height – 3.32 m
  - ✓ Engine - Cummins ISB6.7EV 250H
  - ✓ Gearbox - Allison Ev50
  - ✓ Energy storage system – Allison ESS





# Hybrid buses

## Analysis of the Warsaw University of Technology from September 2013

- The analysis covered fuel consumption on the selected bus line (no. 125), in the same period (August-September 2013) and in the same traffic conditions, as to diesel buses **MAN NG313** and diesel-electric hybrids **Solaris U18 Hybrid**.
- The estimated average yearly fuel consumption by Solaris U18 Hybrid amounted to 45.76 l/100km, while in case of bus MAN NG313 – 61.98 l/100km.
- Therefore, the difference in **fuel consumption** and in related **emissions of CO<sub>2</sub> and pollutants** amounted to as much as **16%**.

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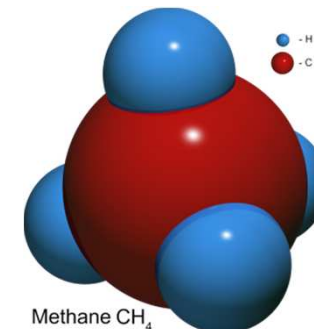






## Gas buses

- The Warsaw tender (covering also refuelling infrastructure and delivery of fuel) was open for both **CNG**- and **LNG**-powered buses.
- The **LNG** offer was selected, in large extent due to higher energy density of LNG (so LNG buses are lighter and may have longer range) and other advantages (e.g. LNG is transferred directly to bus tanks, without compressors, which consume additional electric energy in case of CNG).
- Disadvantages: very small share of LNG buses in the market so far (which results in lack of operational experience with them), narrow choice of manufacturing companies.
- 35 LNG buses finally purchased in 2013, manufactured by the Polish company – **SOLBUS**.







# Gas buses

## Comparison of parameters

18-metre buses from SOLBUS	LNG	diesel	unit
length	18	18	m
weight	15 570	15 500	kg
number of seats	40	43	-
maximum number of passengers	175	180	-
fuel tank capacity	568	380	dm <sup>3</sup>
range with fuel consumption 55 dm <sup>3</sup> /100km	350	600	km
refuelling time	5 - 7	4 - 6	minutes



# Gas buses

## LNG buses from economic standpoint

- In the first stage of operations, in comparison of LNG in kg and oil in dm<sup>3</sup>, LNG buses consumed 3% less fuel than diesel buses, while in April 2015 – 7% less fuel.
- The data from April 2015:



	Average fuel consumption		Price of fuel		Cost of fuel		Difference
diesel bus	56.0	dm <sup>3</sup> /100 km	3.37	PLN/dm <sup>3</sup>	1.89	PLN/km	0.75
LNG bus	52.1	kg/100 km	2.19	PLN/kg	1.14	PLN/km	-40%



# Gas buses

## LNG buses from environmental standpoint

- For older gas engines (produced until 2005) CO<sub>2</sub> emissions were higher by 14% compared to diesels.
- Currently, due to improved efficiency of gas engines, their CO<sub>2</sub> emissions are lower by 2÷5%.
- Gas compressors powered by electric engines, which are used in case of CNG, generate around 10% of additional CO<sub>2</sub> emissions (taking into account that Polish energy mix is still mainly based on coal).



g/km	fuel	
1452	oil	
1377	LNG	-5,2% of CO <sub>2</sub> emissions



## Electric buses

- The tender from 2014 finally concluded with awarding the contract for the first 10 electric **buses** to the Polish manufacturer **Solaris** (its competitor was BYD with K9 model).
- In future we plan to purchase also e-buses of different construction (e.g. with smaller batteries/utilizing opportunity charging).
- The selected model of bus is **Solaris Urbino 12 electric**:
  - ✓ Bus length - 12 m
  - ✓ Bus width – 2.55 m
  - ✓ Bus height – 3.25 m
  - ✓ Engine – 160 kW (218 PS)
  - ✓ Batteries – Li-Io
  - ✓ Energy stored in batteries – 210 kWh
  - ✓ Nominal voltage – 600 V
  - ✓ Time of 0-100% charging (with 200 kW) – 1 hour
  - ✓ Range (with maximum load and air conditioning on) – 150 km
  - ✓ Number of seats – up to 34
  - ✓ Maximum number of passengers - 85



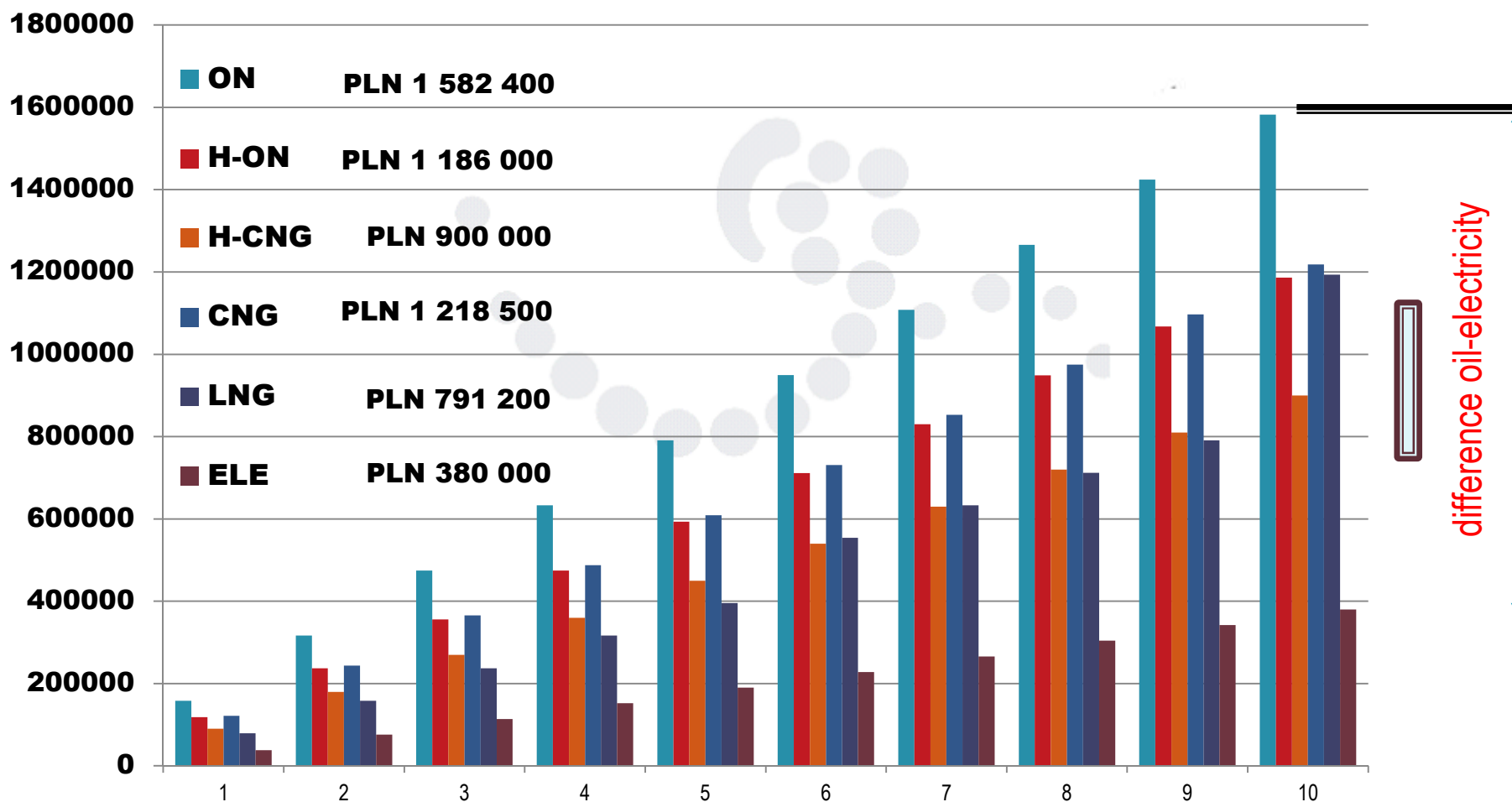




# Electric buses

## E-buses from economic standpoint

Estimated cost of fuel (for 10 years, 800 000 km on bus line with intense operations) for: diesels, diesel-electric hybrids, CNG-electric hybrids, CNG buses, LNG buses and e-buses





# Electric buses

## E-buses from environmental standpoint



- 12-metre bus – fuel consumption parameters for 2 sets of operational conditions:

	Average bus line		Bus line with intense operations	
	diesel bus	e-bus*	diesel bus	e-bus*
Fuel/energy consumption	40 dm <sup>3</sup> /100 km	130 kWh/100 km	49 dm <sup>3</sup> /100 km	160 kWh/100 km
CO <sub>2</sub> emissions	1061 g/km	0*	1300 g/km	0*
Total CO <sub>2</sub> emissions - LCC (800 000 km/10 years)	849 t/LCC**	0*	1040 t/LCC**	0*
* emissions measured only in area of bus operations; ** LCC – Life Cycle Costing				



## Most recent developments

### Tender for 10 electric buses from 2016

- 3 competitors: Solaris Bus & Coach – PLN 26.4 milion; URSUS and AMZ-Kutno – PLN 25 million; 2G Bus & Coach and Blue Line – PLN 23.6 million.
- 2G was excluded from the procedure due to formal reasons (their experience required in manufacturing e-buses did not count as it included only hybrids with Diesel engine acting as electricity generator, instead of buses that can operate using only electricity).
- The winner: URSUS & AMZ-Kutno.
- Technical novelty: opportunity charging (smaller batteries on-board with additional use of pantographs).





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Thank you!

