



# TOWARDS THE DEVELOPMENT OF ECO- CITIES BUILDING INTEGRATED PHOTOVOLTAICS

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*Obstacles and prospects for sustainable lifestyles  
and green economy in Europe. Post carbon cities*

PolSCA Meeting, Brussels 23/10/2012

# UNIVERSITY OF ECOLOGY and MANAGEMENT (WSEiZ) in WARSAW -



OVER 4000 STUDENTS EDUCATED ON THE FACULTIES OF:

ECOLOGY

ARCHITECTURE

MANAGEMENT

7 specializations

40 Professors

~ 80 Doctors

Scientific work is based on individual research projects mainly. They are concerned on e.g.:

- **RECYCLING OF MATERIALS**
- **RENEWABLE ENERGY SOURCES**
- **NEW-URBANISM**

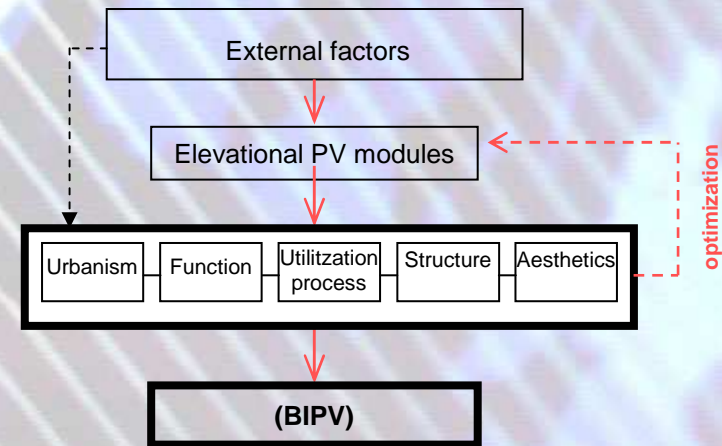
Effects of scientific work are being presented on the national S-T conference held by WSEiZ every year in Zakopane, ent.

**"PROBLEMS OF CONTEMPORARY BUILDING AND ARCHITECTURE"**

## AUTHOR'S FIELDS OF RESEARCH

As the result of the author's two-year research, a monography = *"Photovoltaic Facades"* has just been published.

It presents an original wide approach to evaluation of the relations between photovoltaics and building's architecture based on systemic approach.



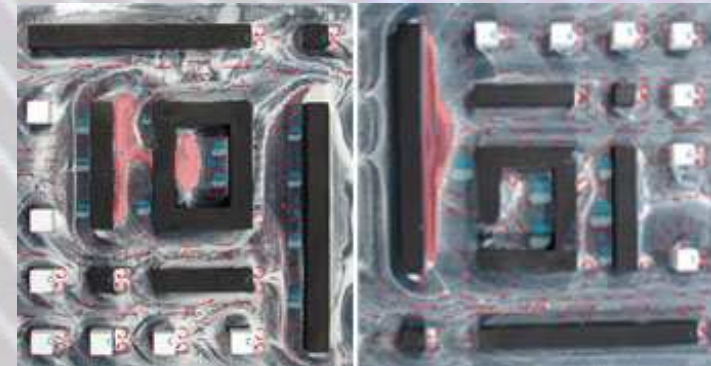
## COOPERATION with WARSAW UNIVERSITY OF TECHNOLOGY

In a cooperation with dr.K.Zielonko-Jung (head of Ecological Architecture Unit, Faculty of Architecture). it have been examined the interactions between green architecture and high technologies.

The effect is a book *"Combining high- and low technologies in proecological architecture"* (under the grant of the Ministry of Science, 2008-2010).

Futher research of dr. K.Zielonko-Jung is focused on ecological architecture in urban structures.

The research is a basis for common studies in the field of BIPV within postcarbon cities.



Experimental study of air flows in two different urban structures, according to wind direction (oil method)– a fragment of research on ecological architecture in urban structures [K.Zielonko-Jung]

## BIPV IN CITIES – WORLD-WIDE EXAMPLES

**BIPV – Building Integrated Photovoltaics means PV technology to be used as an alternative for traditional buildings components/materials.**

**The technology should be regarded as one of the substantial tools towards creation of green cities of tomorrow.**



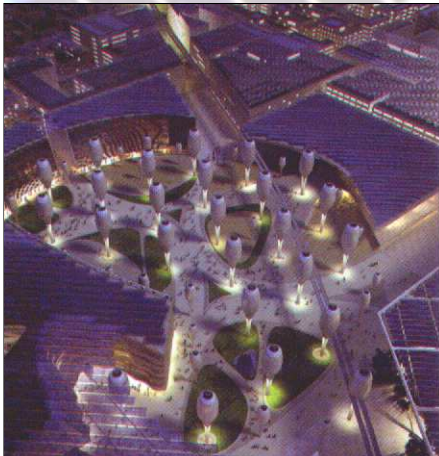
Amersfoort-Nieuwland (NL)

1997 - 2003

12 300m<sup>2</sup> of PV modules

500 buildings with BIPV

1,33MW<sub>p</sub> total power



Masdar City (UAE)

2006 – 2016

10MW – PV farm

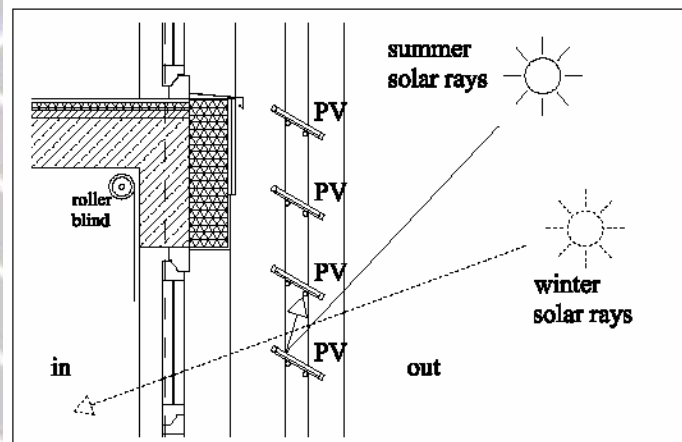
Each house fitted with PV

Ambrella-like canopies fitted with PV

## BIPV in POLAND - EXAMPLE

Office-residential building in Warsaw (*under construction, designed by the author*).

A "shadowvoltaic" system has been designed in front of the southern elevation. It is a part of a general concept of sustainable building.



### PV modules

Type: shadowing opaque blades (BIPV)

PV cells: polycrystalline

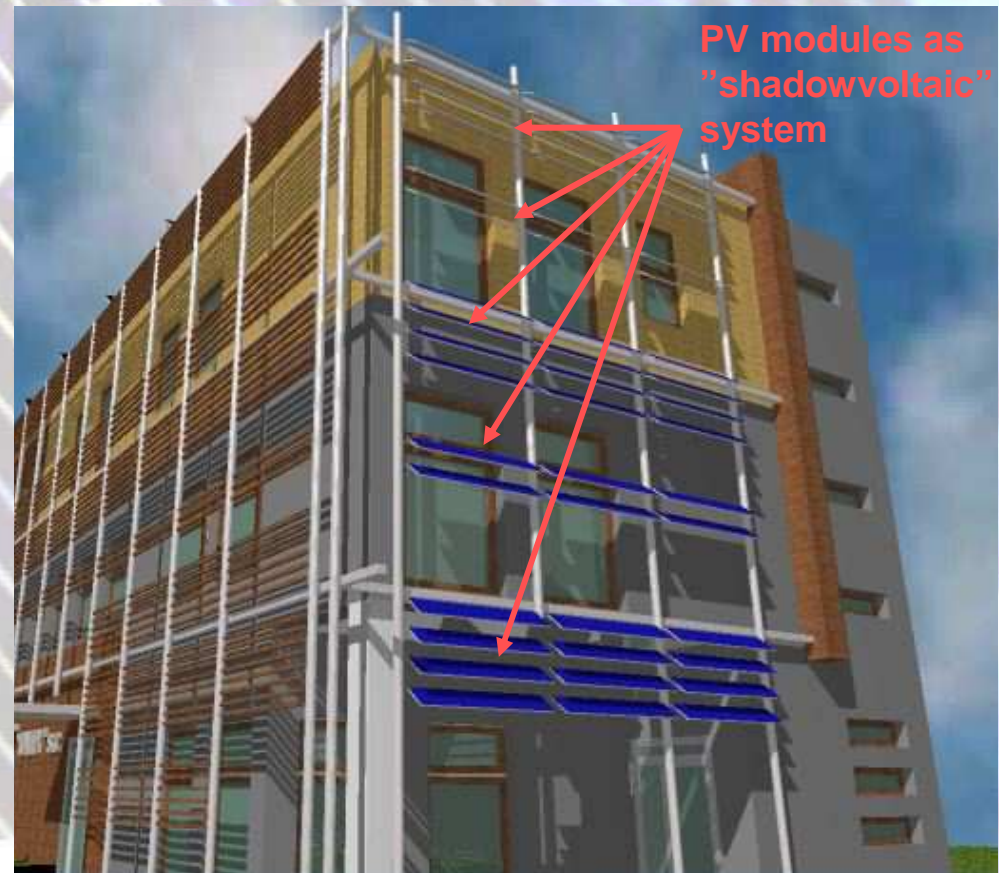
Number: 48

Total power: 2 kW

Total surface area: 16m<sup>2</sup>

Location – southern elevation

Tilt angle: 30 degrees



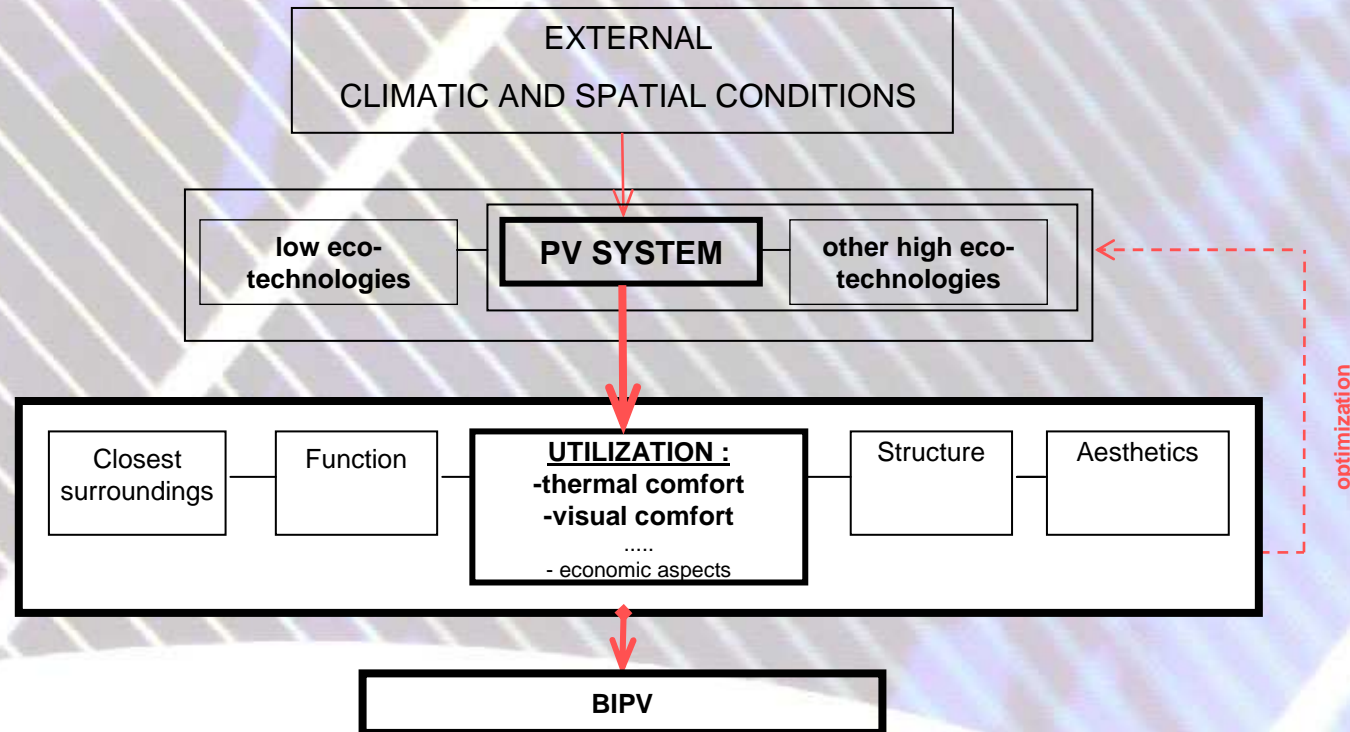
## BIPV in POLAND - EXAMPLE

The building's architectural idea is based on a systemic model of BIPV. It is the result of studies on:

- low- and high-tech technologies in proecological architecture
- photovoltaic facades

The model is a universal tool in considering relations between architectural and proecological aspects.

The building will hopefully serve for further research focused on the impact of PV system on chosen aspects of utility process (thermal and visual comfort) in the context of BIPV.



systemic model of BIPV in proecological architecture - with emphasis on relations between PV system and utility process of the building (author)

## BIPV in POLAND-ECONOMIC ASPECTS

**Relations between PV technology use and building's utility process in the economic aspect must be reevaluated in Poland.**

**The reason is expected introduction of Feed-In Tariff in 2013**

Type and power of PV installation	Rate per 1kW/h
PV installation within buildings $P \leq 10\text{kW}$	1,30zł. = ~0,32 €
PV installation within buildings $100\text{kW} \geq P > 10\text{kW}$	1,15zł. = ~0,28 €

DURATION TIME	15 years
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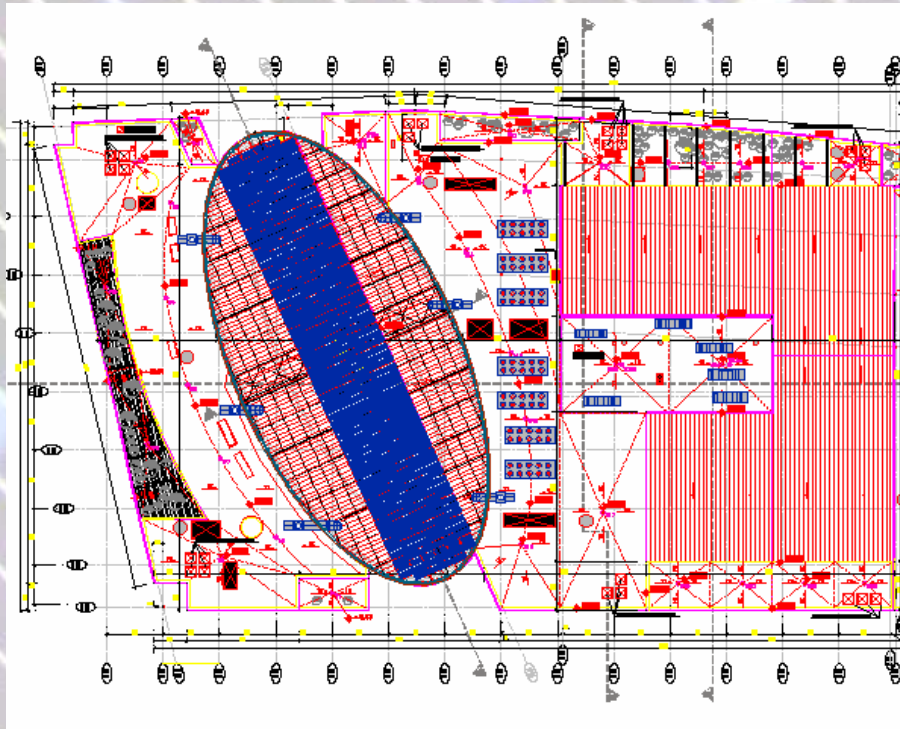
TOTAL PV POWER EXPECTED BY 2020	600 MW
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According to the draft of The Act on Renewable Energy Sources. 6.10.2012.

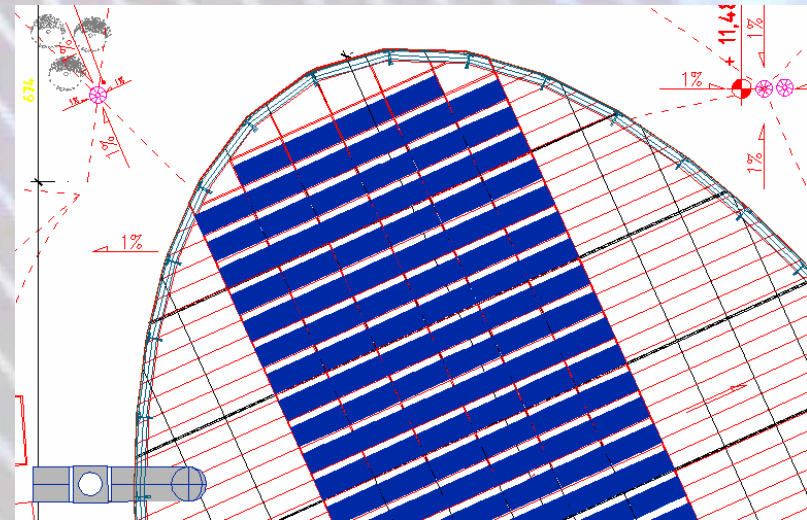
# BIPV in POLAND - PROSPECTS

Economic evaluation on the example of a multipurpose building in Bytom

PV technology has been conceived as "shadowvoltaic" system on the glazed roof of the passage



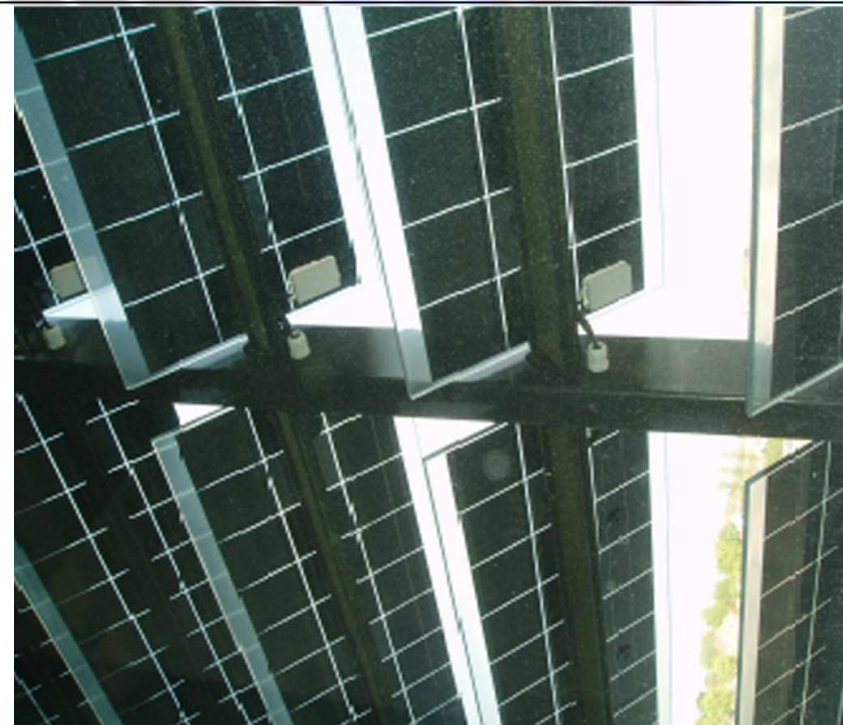
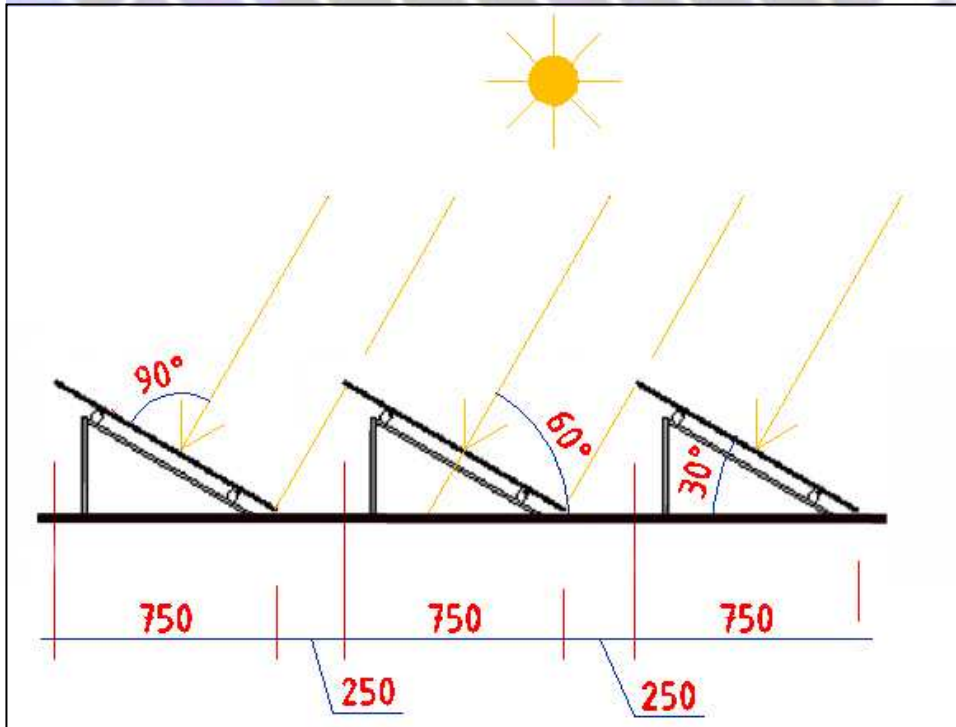
General view of the roof – PV modules marked in navy blue



The close-up of the roof

# BIPV in POLAND - PROSPECTS

Economic evaluation of the example of a multipurpose building in Bytom



A scheme of the PV modules application:  
optimal spacing and inclination

A photo showing how the PV modules  
should look like

# BIPV in POLAND - PROSPECTS

## Economic evaluation on the example of a multipurpose building in Bytom

Basic technical data of the PV system	
PV modules total surface area	575,0 m <sup>2</sup>
Number of PV modules	712 pcs.
Total power of PV system	60,5 kW
Power output guaranteed	20 years
Ecological calculation *	
Annual energy production	48 400,0 kWh
Energy produced after 20 years	968,0 MWh
Annual reduction of CO <sub>2</sub> emission	40,2 t
CO <sub>2</sub> emission reduced after 20 years	803,4 t
Annual reduction of NO <sub>x</sub> emission	29,0 kg
NO <sub>x</sub> emission reduced after 20 years	580,8 kg
Annual reduction of SO <sub>2</sub> emission	29,0 kg
SO <sub>2</sub> emission reduced after 20 years	580,8 kg
Annual reduction of dust	1,6 kg
Dust reduced after 20 years	32,9 kg

\* reduction compared with coal based energy generation

# BIPV in POLAND - PROSPECTS

Economic evaluation of the example of a multipurpose building in Bytom

## Investment cost calculation...

Pieces	Product description	Polish złoty (zł.)	Euro (1€=4,08zł.) *
712	Solar modules, polycrystalline silicon	850 000.00	208 333.33
15	Inverters/ Powerlynx 4,5HV	130 000.00	31 862.75
1	Mounting system (custom made + mounting)	110 000.00	26 960.78
1	Electrical components	80 000.00	19 607.84
1	Transport	10 000.00	2 450.98
<b>TOTAL PV</b>		<b>1 180 000.00</b>	<b>289 215.68</b>
	Sun protection roof system (aluminium lamelas)	- 575 000.00 (1000/m2)	-140 931.37 (245,10/m2)
<b>TOTAL BIPV</b>		<b>605 000.00</b>	<b>148 284.31</b>
		<b>10zł./Wp</b>	<b>2,45€/Wp</b>

\* according to the NBP's rate of exchange; 10/10/2012

## Investment cost payback-time

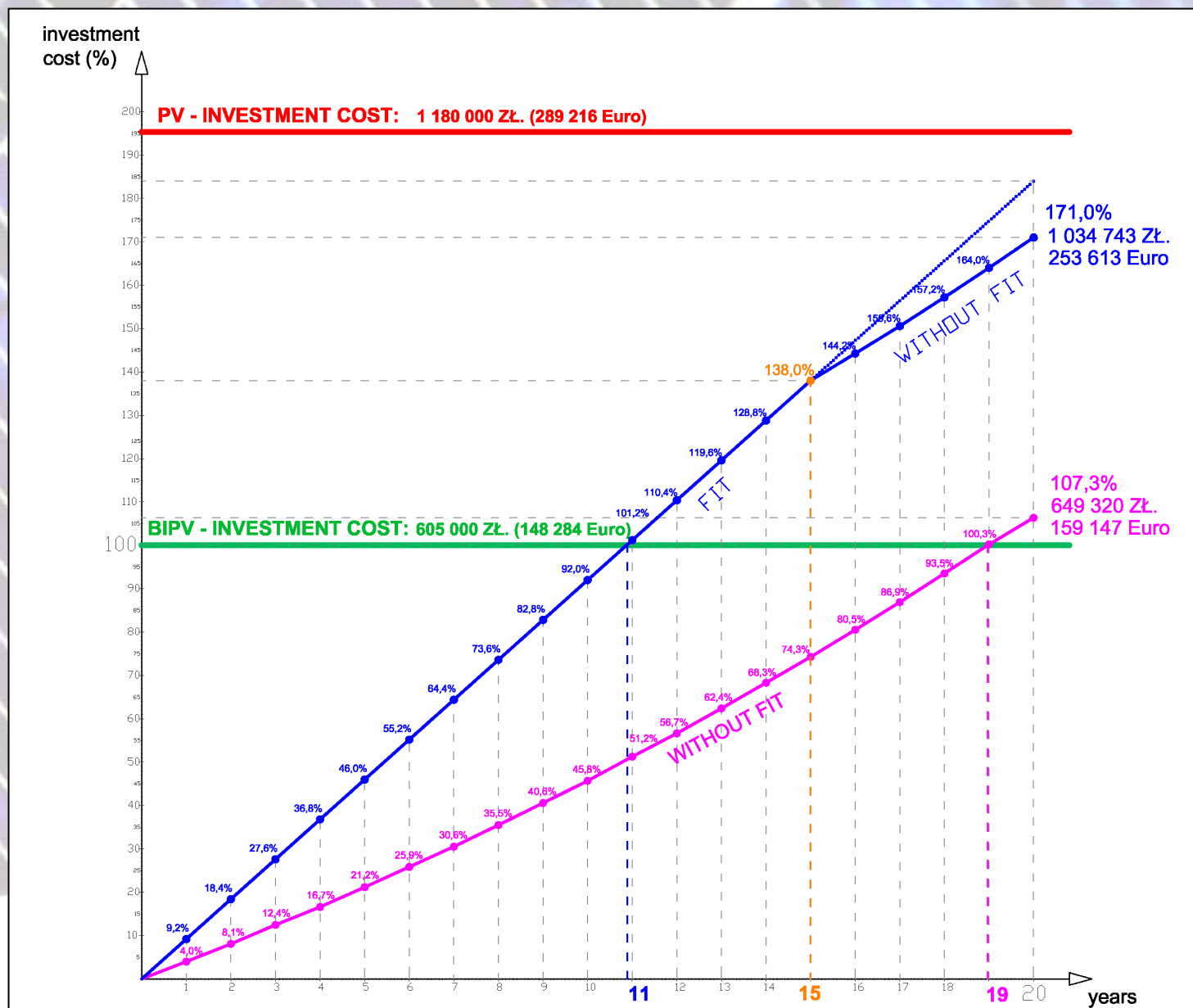
Year	Total energy production (kWh)	Economic gain due to free energy generation		Investment pay-off (%)
		Zł.	Euro	
1.	48400	24 200	5 931	4,0
2.	96800	49 126	11 862	8,1
3.	145200	74 778	18 328	12,4
4.	193600	101 200	24 804	16,7
5.	242000	128 419	31 475	21,2
6.	290400	156 436	38 342	25,9
7.	338800	185 300	45 417	30,6
8.	387200	215 012	52 699	35,5
9.	435600	245 601	60 196	40,6
10.	484000	277 107	67 918	45,8
11.	532400	309 561	75 873	51,2
12.	580800	343 012	84 072	56,7
13.	629200	377 460	92 515	62,4
14.	677600	412 955	101 214	68,3
15.	726000	449 497	110 171	74,3
16.	774400	487 152	119 400	80,5
17.	822800	525 920	128 902	86,9
18.	871200	565 830	138 684	93,5
19.	919600	606 970	148 767	100,3
20.	968000	649 320	159 147	107,3

Calculation for BIPV without FIT

Year	Total energy production (kWh)	Economic gain from FIT		Investment pay-off (%)
		1,15zł/kW Zł.	0,28 €/kW Euro	
1.	48400	55 660	13642	9,2
2.	96800	111 320	27284	18,4
3.	145200	166 980	40926	27,6
4.	193600	222 640	54569	36,8
5.	242000	278 300	68211	46,0
6.	290400	333 960	81853	55,2
7.	338800	389 620	95495	64,4
8.	387200	445 280	109137	73,6
9.	435600	500 940	122779	82,8
10.	484000	556 600	136422	92,0
11.	532400	612 260	150064	101,2
12.	580800	667 920	163706	110,4
13.	629200	723 580	177348	119,6
14.	677600	779 240	190990	128,8
15.	726000	834 900	204632	138,0
		Economic gain due to free energy generation		
16.	774400	872 555	213862	144,2
17.	822800	911 323	223363	150,6
18.	871200	951 253	233150	157,2
19.	919600	992 393	243234	164,0
20.	968000	1 034 743	253613	171,0

Calculation for BIPV with FIT (for 15years)

# Investment cost payback-time



Multipurpose building in Bytom. Calculation of investment cost payback-time with and without Feed In Tariff [author]

## REMARKS and CONCLUSIONS

1. FEED- IN TARIFF WILL ALLOW TO REDUCE INVESTMENT PAY-BACK TIME SERIOUSLY. NEVERTHELESS EXTRA SUPPORTIVE FINANCIAL INSTRUMENTS ARE REQUIRED.
2. TAKING FALLING PRICES OF PV SYSTEMS (about 10% per year) , GROWING ENERGY PRICES (about 3% per year) AND FIT INTO ACCOUNT, WE WILL BE PROBABLY EXPERIENCE A GRADUAL GROWTH OF INTEREST IN BIPV IN THE COMING YEARS IN POLAND.
3. BIPV ECONOMIC PROFITS MUST BE WIDELY PERCEIVED AS:

**DIRECT PROFITS (free electricity, investment cost reduced by traditional building components/ materials to be replaced by PV modules);**

**INDIRECT PROFITS:**

- Ecological (reduced emissions of CO<sub>2</sub>,NO<sub>x</sub>,SO<sub>2</sub>,dust);
- Energy (possible influence on reduction of mechanical HVAC systems work);
- Social (aesthetical and functional building's improvement);
- Marketing (promotion of building's ecological orientation).

# WHAT IS TO BE DONE?

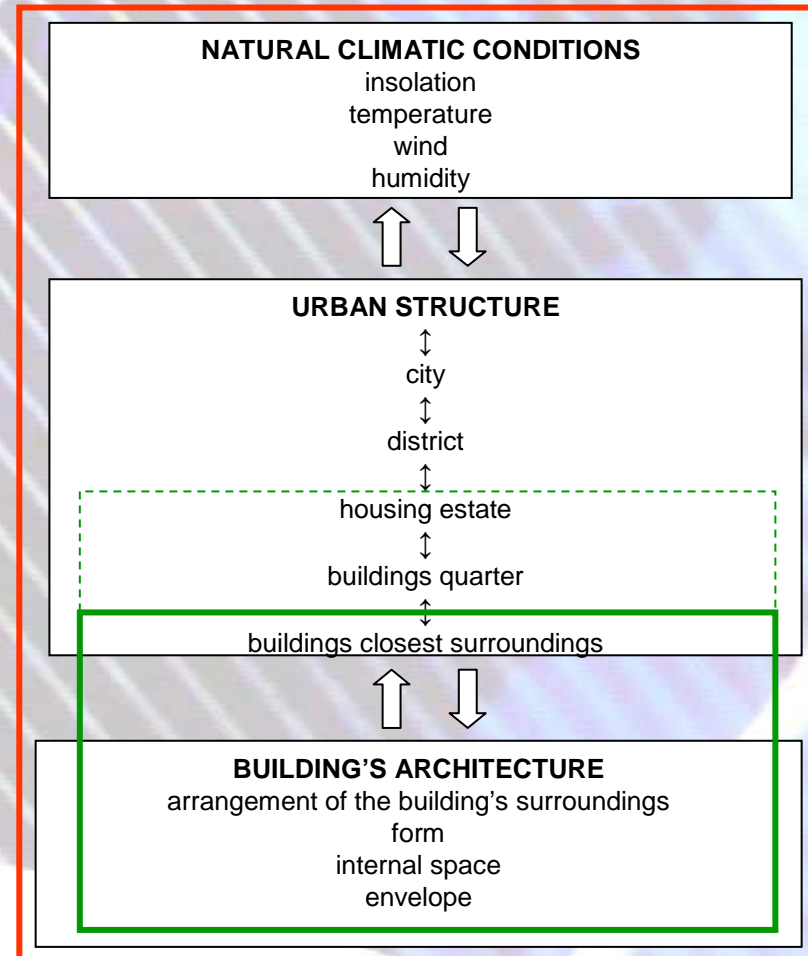
IN ORDER TO OPTIMIZE ECONOMIC (DIRECT AND INDIRECT) PROFITS OF BIPV IN CITIES, FURTHER RESEARCH IS REQUIRED.

IN THE FIELD OF ARCHITECTURE, THEY SHOULD REFER TO MACRO- AND MICROSCALE:

**MACROSCALE RESEARCH OUGHT TO BE FOCUSED ON RELATIONS BETWEEN COMPLEX URBAN CONTEXT AND BUILDINGS ARCHITECTURE**

DETAILED MICROSCALE STUDIES SHOULD BE CONCERNED ON :

- **MAXIMIZING ENERGY EFFICIENCY (BY NOT ONLY MAX. INSOLATION BUT ALSO COOLING LOAD PROVISION);**
- **INTEGRATION IN THE CONTEXT OF INFLUENCE ON THERMAL AND VISUAL COMFORT;**
- **COOPERATION WITH HVAC SYSTEMS (SOLAR HEAT CONTROL, THERMAL INSULATION, NATURAL VENTILATION SUPPORT).**



A model showing relations between urban context and proecological building's architecture [K.Zielonko-Jung]

***IN 2020 WE CAN ENJOY***  
***~360 GWh***  
***of clean energy coming from PV in Polish cities***  
***This means a decreased emission\* of :***  
***CO<sub>2</sub> by ~300 000 tons***  
***coal dust by ~1220 tons***

***\* in comparison with coal-based energy generation cities***

**THANK YOU FOR THE  
ATTENTION !**