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FACULTY OF ELECTRICAL ENGINEERING
Electrical Engineering Department

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FUNDAMENTALS AND TERMINOLOGY IN POWER ENGINEERING. COLLECTION OF METHODICAL MATERIALS FOR PRACTICAL CLASSES

for students specialized in
035 «Philology»

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DniproTech
2021

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Preface

The main problem of modern translation is that the same term can have several meanings and serve to define different concepts, or vice versa – different terms can be used for the same concept [1]. In order for energy professionals from around the world to understand each other, share experiences and communicate freely about professional topics, the International Electrotechnological Commission (IEC) has created the International Electrotechnical Vocabulary (IEV), which has the status of the IEC 60050 standard, contains terms and definitions of about 20,000 concepts has been translated into 11 languages.

Since the discipline is called "Fundamentals and terminology in electrical engineering", when considering the issues, we will primarily focus on terminology, which serves to define the concepts associated with the processes of production, transmission and distribution of electricity.

Structurally, the discipline is divided into two parts – traditional and alternative energy [1]. In the first part we consider the basic concepts of electrical engineering: electric current, voltage, power, measurement of electrical quantities, basic equipment used in energy in the production, transmission and distribution of electricity. In the second part we will consider the types of renewable energy sources, the principles of solar, wind and bioenergy installations and discuss the problems and prospects for renewable energy in Ukraine.

The curriculum of the discipline "Fundamentals and terminology in electrical engineering”; provides for both lectures and practical classes. Practical classes are aimed at consolidating the material in the form of games: interactive tasks and business games that allow you to practice the use of electrical terms (in English), communicate in teams, discuss and solve problems aimed at developing soft-skills.

Methodical recommendations for practical classes are intended for third-year full-time students specialized in 035 "Philology", and are composed in such a way that their content touches on the most important points initiated above.

Task 1. Case study "Calculating electric circuits based on the fundamental laws of electricity"

The aim of the task – calculating and measuring electrical parameters (quantities), commonly used in electrical engineering practice.

Setting objectives:

The Ohm's Law – is a fundamental law of electricity stating the voltage at the terminals of the ideal resistor is proportional to the current in the resistor [2]. Mathematically, the law may be written as

$$I = \frac{U}{R}, \qquad (1)$$

where U – voltage at the resistor, Volts; R – resistance in the resistor, Ohms.

Electrical power, consumed by the resistor, is called as an active power, noted as P and defined by formula (2):

$$P = U \cdot I = R \cdot I \cdot I = R \cdot I^2 = R \cdot (\frac{U}{R})^2 = R^2 \cdot R \cdot \frac{U^2}{R^2} = \frac{U^2}{R} = G \cdot U^2. \qquad (2)$$

[P]= Watt, watts, W.

An electric quantity, which is the opposite to the resistance, calls an electrical conductivity, and defined as

$$G = \frac{1}{R}. \qquad (3)$$

[G]= Siemens, S.

Let us consider the electric circuit [2].

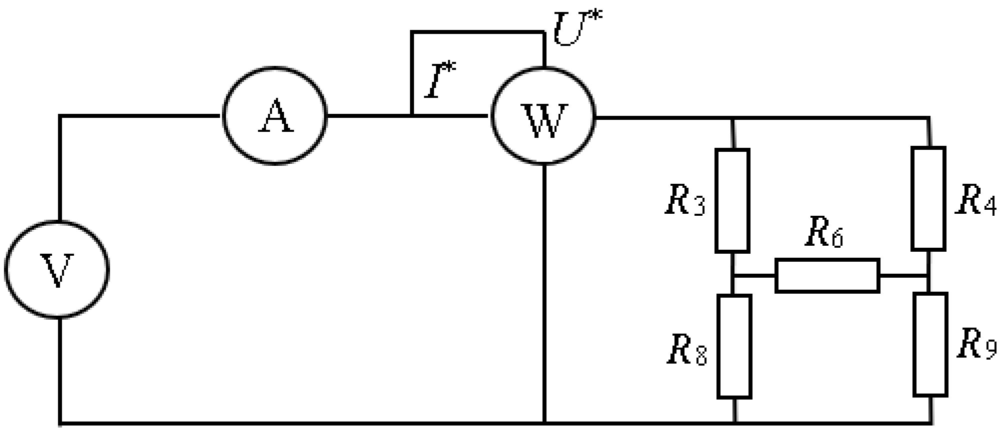


Fig. 1. Electric diagram for the investigated circuit

As we can see from the diagram, the electric load (on the right side of the diagram) is electrically connected resistors, noted as R_3, R_4, R_6, R_8, R_9 (after transforming due to the 1^{st} variant in [3]).The nominal values of the resistances are as follows $R_3 = 100\ \Omega$, $R_4 = 300\ \Omega$, $R_6 = 200\ \Omega$, $R_8 = 510\ \Omega$, $R_9 = 75\ \Omega$. There are also the main devices (on the left) that are usually used in electrical engineering for measuring values of electric current, voltage, and power.

Ammeter – instrument intended to measure the value of a current. The ammeter connected in series mode between energy supply and load [2] (Fig.2).

Fig. 2. Appearance of ammeter

Fig. 3. Appearance of voltmeter

Voltmeter – instrument intended to measure the value of a voltage. The voltmeter is connected in parallel mode for the energy supply and load [2] (Fig.3).

Wattmeter – instrument intended to measure active power. The current's clams of the wattmeter connected in series mode between energy supply and load. The voltage's clams of the wattmeter connected in parallel mode for the energy supply and load [2] (Fig.4).

Fig. 4. Appearance of wattmeter

Multimeter – multirange multifunction measuring instrument intended to measure voltage, current and sometimes other electrical quantities such as resistance [2] (Fig.5).

Fig. 5. Appearance of multimeter

The readings of electrical measuring instruments are determined based on the division price of the device [3,4].

The price of the division of the ammeter and voltmeter is determined by the following formulas:

– for the ammeter $C_A = I_{пр} / N$; (4)
– for the voltmeter $C_V = U_{пр} / N$, (5)

where $U_{пр}$, $I_{пр}$ - upper limits of device measurement; N – number of scale divisions; C_A, C_V – the price of one division.

Example. The price of the division of the ammeter C_A, shown in Fig. 2, $C_A = I_{пр}/N = 50/50 = 1$ (mA /div). The price of the division of the voltmeter C_V, shown in Fig. 3, $C_V = U_{пр}/ N = 50/50 = 1$(V/div).

The price of the wattmeter division is determined by the formula [3,4]

$$C_P = U_{пр} \cdot I_{пр}/N, \quad (6)$$

where $U_{пр}$, $I_{пр}$ - upper limits of device measurement; N – upper limits of device measurement; C_P – price of one division.

Example. The price of the division of the wattmeter C_P, shown in Fig.4, $C_P = U_{пр} \cdot I_{пр}/N = 30 \cdot 0,5/150 = 0,1$ (W/div).

Table 1

The measured values of the electrical quantities

Electrical quantity	R_3, Ω	R_4, Ω	R_6, Ω	R_8, Ω	R_9, Ω	I, A	U, V	P, W
Measured								

The task for practical class – to calculate electrical parameters (quantities) at the circuit and compare them with the measured values got from the experiment.

The algorithm for the calculation is as follows:

1. As we know from the theory, if we transform the resistors' connections that remind a "star" to the resistors connected as a "triangle" (or vs "triangle" to "star"), it will allow us to simplify the electric circuit and calculate it more easily. R_3, R_4, R_6 – is the "triangle" of resistors. Let us transform $\Delta \rightarrow \curlywedge$

2. To realize the transformation, we should use formulas

$$R_{34} = \frac{R_3 \cdot R_4}{R_3 + R_4 + R_6}; R_{36} = \frac{R_3 \cdot R_6}{R_3 + R_4 + R_6}; R_{46} = \frac{R_4 \cdot R_6}{R_3 + R_4 + R_6}.$$

As a result, we get the simplified (equivalent) diagram:

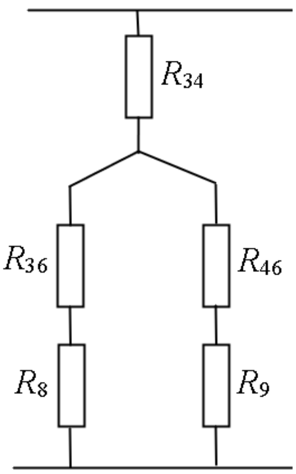


Fig.6. Electric diagram after transforming

R_{36} and R_8 are connected in series mode, so we can transform them into one resistor R_{368}:

$$R_{368} = R_{36} + R_8.$$

R_{46} and R_9 are connected in series mode as well

$$R_{469} = R_{46} + R_9.$$

3. After transforming the diagram may be presented in the following way

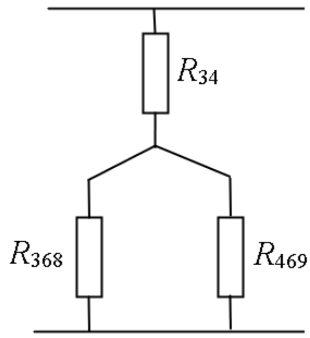


Fig.7. Equivalent diagram of the resistors

R_{368} and R_{469} are connected in parallel. Total resistance of the two connected resistors is determined by formula

$$R_{34689} = \frac{R_{368} \cdot R_{469}}{R_{368} + R_{469}}.$$

4. Let us find input (equivalent) resistance:

$$R_e = R_{34689} + R_{34}.$$

5. Input current in the circuit (according to the Ohm's Law) will be

$$I = \frac{U}{R_e},$$

where U – input voltage, V.

6. Active power, consumed with the load, will be $P = U \cdot I.$

Then the calculated values of the electrical quantities are as follows:

Table 2

The calculated values of the electrical quantities

Electrical quantity	R_e, Ω	I, A	P, W
Calculated			

7. Let us determine the calculation error:

$$\Delta P = \left|\frac{P_m - P_c}{P_m}\right| \cdot 100\%,$$

where P_m – the measured value of power, W; P_c – the power calculated in the algorithm, W.

If $\Delta P<5\%$ - the error meets the requirement for technical calculations.

Questions for discussion

1. Formulate Ohm's Law.
2. Describe series, parallel and mixed connection of elements of an electric circle.
3. Explain the features of connecting ammeter and voltmeter to an electric circuit.
4. How to determine the price of the division of the ammeter, voltmeter, wattmeter?
5. Explain the scheme of connecting wattmeter to an electric circuit.

Task 2. Case study "Calculating cost-effectiveness of projects for installing mini-solar power stations in private households"

The aim of the task – assess cost-effectiveness of projects for installing mini-solar power stations in private households.

Fig. 1. Solar power station

Setting objectives:

According to the legislation in Ukraine, the capacity of solar power plants in private households should not exceed 30 kW. In this regard, the manufacturers of stations offer typical solutions for creating solar power plants of different capacities. Technical and economic indicators for solar power plants with a capacity of 1 kW to 10 kW are given in Table 1.

Table 1

Typical solutions for creating grid solar power stations (private households)

Station power, kW	Area of photo modules, m2	Annual production, kW	Cost of equipment, hryvnas	Installation costs, hryvnas
1	6,5	1197	44940	13482
2,5	16,2	2992	95172	28552
5	32,4	5985	170346	51131
10	64,8	11970	337911	101373

The cost of equipment ranges from 2,000 to 13,000 dollars. Installation costs are about 30% of the cost of equipment. It should be noted that when connecting to the "green tariff", we must pay additional costs that depend on the capacity. For each additional kilowatt (exceeding the standard 3 kW), we will have to pay UAH 1,400, as well as UAH 7,000 – for the electricity meter. Current costs consist of electricity shortage compensation, maintenance and calibration of the electricity meter (every four years).

Table 2

Capital and current costs for solar grid plants

Station power, kW	1,0	2,5	5,0	10,0
Capital costs, hryvnas	58 422	123 724	231 367	456 084
- cost of equipment	44 940	95 172	170 436	337 911
- installation costs	13 482	28 552	51 131	101 373
- connection to "green" tariffs	-	-	9 800	16 800
Current expenses, hryvnas	384	580	2 370	2 940
- power shortage compensation	84	210	420	840
- technical service	300	370	450	600
- calibration of electric meter	-	-	1500	1500

The task for practical class is to calculate the payback period of grid-connected solar power plants of different capacities installed in private households.

1. When calculating, we assume that the average monthly electricity consumption by a family of 3-4 people is about 300 kW*h. Excess (overproduction) of electricity is when a solar power plant produces more than 300 kW*h of energy, i.e. if we look at the technical and economic performance of stations of different capacities, we see that not all of them can provide excess electricity during the year. For example, a station with a capacity of 2.5 kW will be

able to provide excess energy only in the summer months, while a station with a maximum capacity of 10 kW, allows you to receive additional energy almost all year round.

Therefore, using the technical and economic indicators of solar stations (indicators that characterize their work during the year), calculate the savings and profits achieved as a result of electricity production (Table 3 – Table 6).

The calculation formulas (1), (2) are given below, i.e. to calculate the savings it is necessary to multiply the amount of energy produced by the cost of electricity for the population at the current tariff (currently the tariff is 1.68 UAH / kW*h).

Profit is calculated as the product of excess electricity by the value of the "green" tariff for the population ("green" tariff is given in the Table 7) [5].

2. Then determine the total value of annual savings and profits in UAH, adding the appropriate figures for the months.

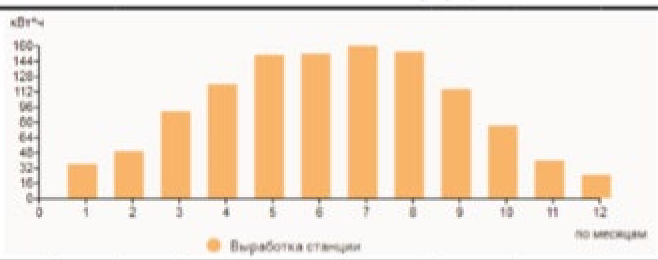
3. Calculate the payback period for the purchase and operation of solar stations of different capacities. It is defined as the ratio of the total costs (capital and current) to the total value of annual savings and profits.

$$Energy\ savings = Production \times Energy\ cost \quad (1)$$

$$Profit = Energy\ excess \times "green"\ tariff \quad (2)$$

Table 3

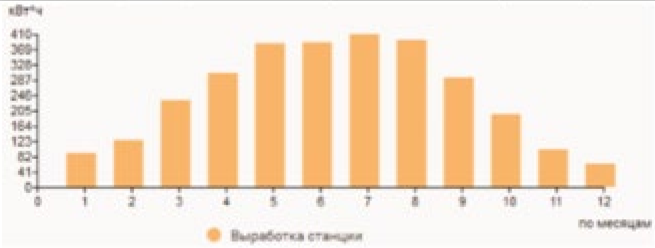
Technical and economic indicators of 1 kW solar power plant system



Month	01	02	03	04	05	06	07	08	09	10	11	12	Σ
Production, kW	36	50	88	120	158	160	162	161	116	80	38	28	1197
Lack/excess of energy, kW	–264	–250	–212	–180	–142	–140	–138	–139	–184	–220	–262	–272	–2403
Savings , grn													
Profit, grn	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 4

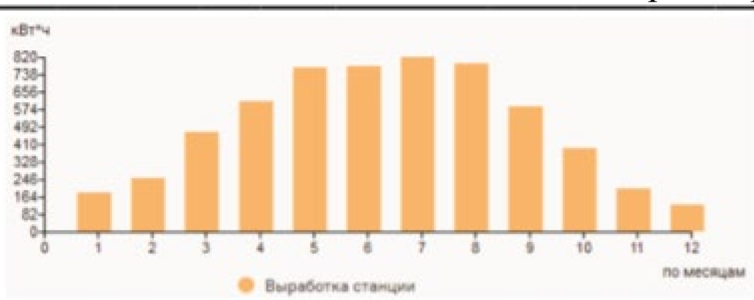
Technical and economic indicators of 2,5 kW solar power plant system



Month	01	02	03	04	05	06	07	08	09	10	11	12	Σ
Production, kW	90	125	220	300	395	400	405	402	290	200	95	70	2292
Lack/excess of energy, kW	–210	–175	–80	0	+95	+100	+105	+102	–10	–100	–205	–230	–608
Savings , grn													
Profit, grn	—	—	—	—					—	—	—	—	

Table 5

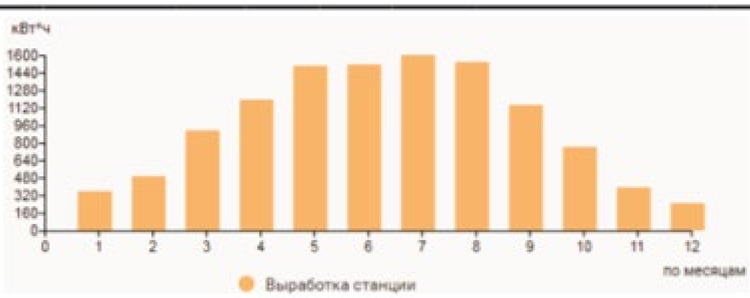
Technical and economic indicators of 5 kW solar power plant system



Month	01	02	03	04	05	06	07	08	09	10	11	12	Σ
Production, kW	180	250	440	600	790	800	810	805	580	400	190	140	5985
Lack/excess of energy, kW	–120	–50	+140	+300	+490	+500	+510	+505	+280	+100	–110	–160	+2385
Savings , grn													
Profit, grn	—	—									—	—	

Table 6

Technical and economic indicators of 10 kW solar power plant system



Month	01	02	03	04	05	06	07	08	09	10	11	12	Σ
Production, kW	360	500	880	1200	1580	1600	1620	1610	1160	800	380	280	11970
Lack/excess of energy, kW	+60	+200	+580	+900	+1280	+1300	+1320	+1310	+860	+500	+80	–20	+8370
Savings , grn													
Profit, grn												—	

Table 7

"Green" tariffs for private households

Commissioning period	Tariff, kop / kW · h (excl. VAT)
Solar energy	
From April 01 2013 to December 31, 2014,	1228,06
From January 1, 2015 to June 30, 2015	1104,51
From 01 July 2015 to 31 December 2015	685,94
From January 01, 2016 to December 31, 2016	650,91
From 01 January 2017 to 31 December 2019	619,56
From 01 January 2020 to 31 December 2024	**556,87 = 0,18 euros**
Wind energy	
From 01 July 2015 to 31 December 2019	398,29
From 01 January 2020 to 31 December 2024	357,72

You are supposed to work in teams for doing this task. Let the first team calculate 1 kW solar power station, the second team – 2,5 kW, the third – 5 kW, and the fourth – 10 kW. You have 30 minutes for brain-storming and discussion in teams, and then each team will have 10 minutes to give their presentations.

Questions for discussion

1. What conclusions can we draw from the results obtained?
2. What recommendations could you give to increase the number of mini-solar power plants in our country?

Task 3. Business game "Energy treasure hunt"

The aim of the task – develop plan of energy supply for the city by applying renewable energy sources.

The task is the same for all teams:

1) you are supposed to depict (on the scale of the layout) renewable energy facilities on maps of the potential use of different types of renewable energy (Fig. 1 – Fig. 4). It is necessary to take into account the peculiarities of climatic and environmental conditions prevailing in the city (Annex 1).

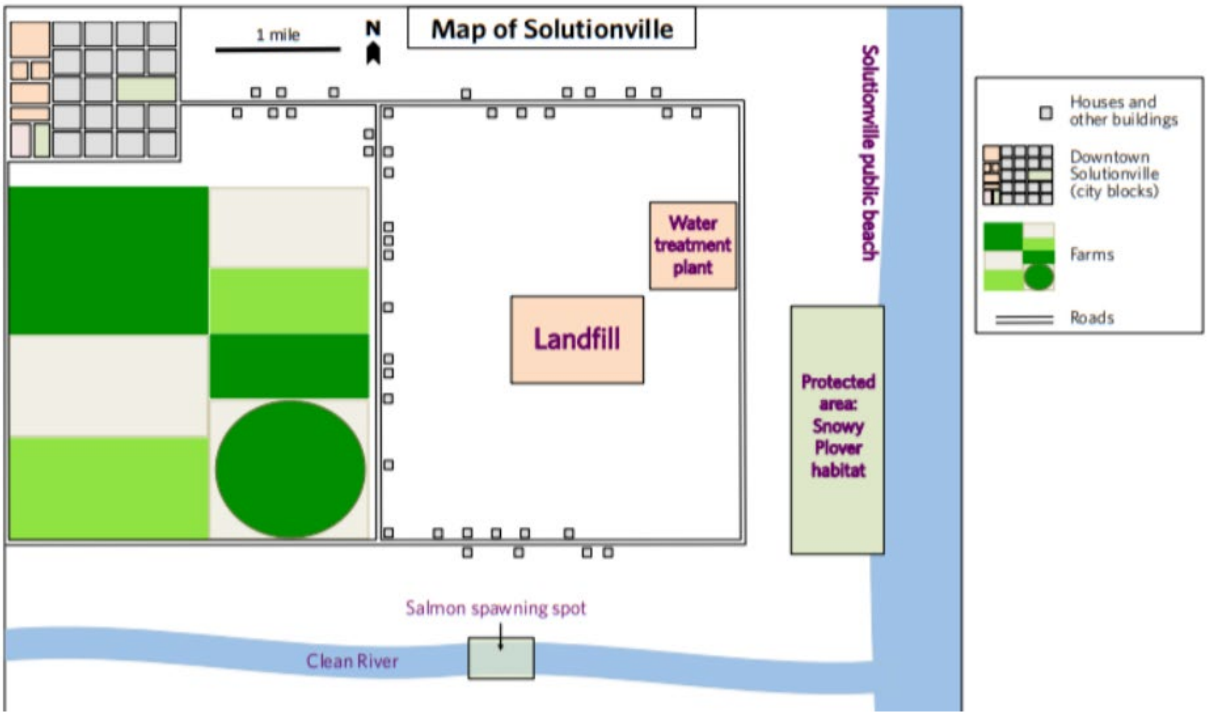


Fig. 1. Map of Solutionville

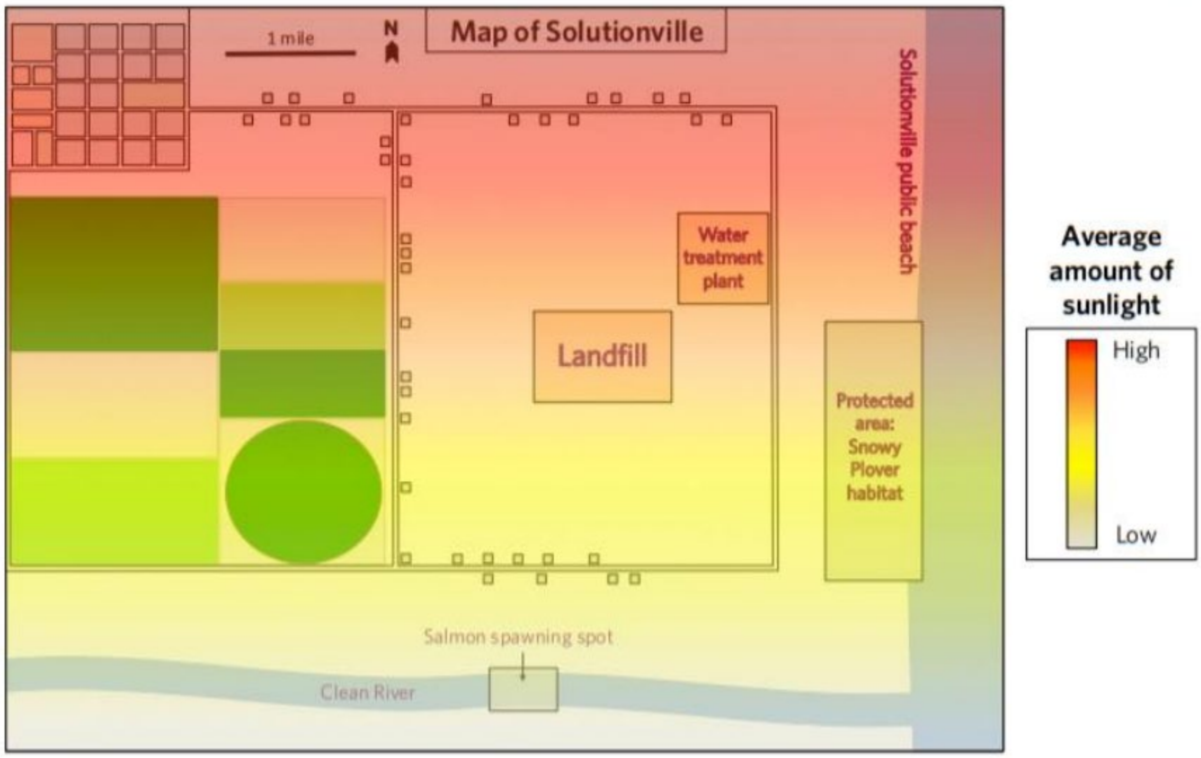


Fig. 2. Potential of solar energy

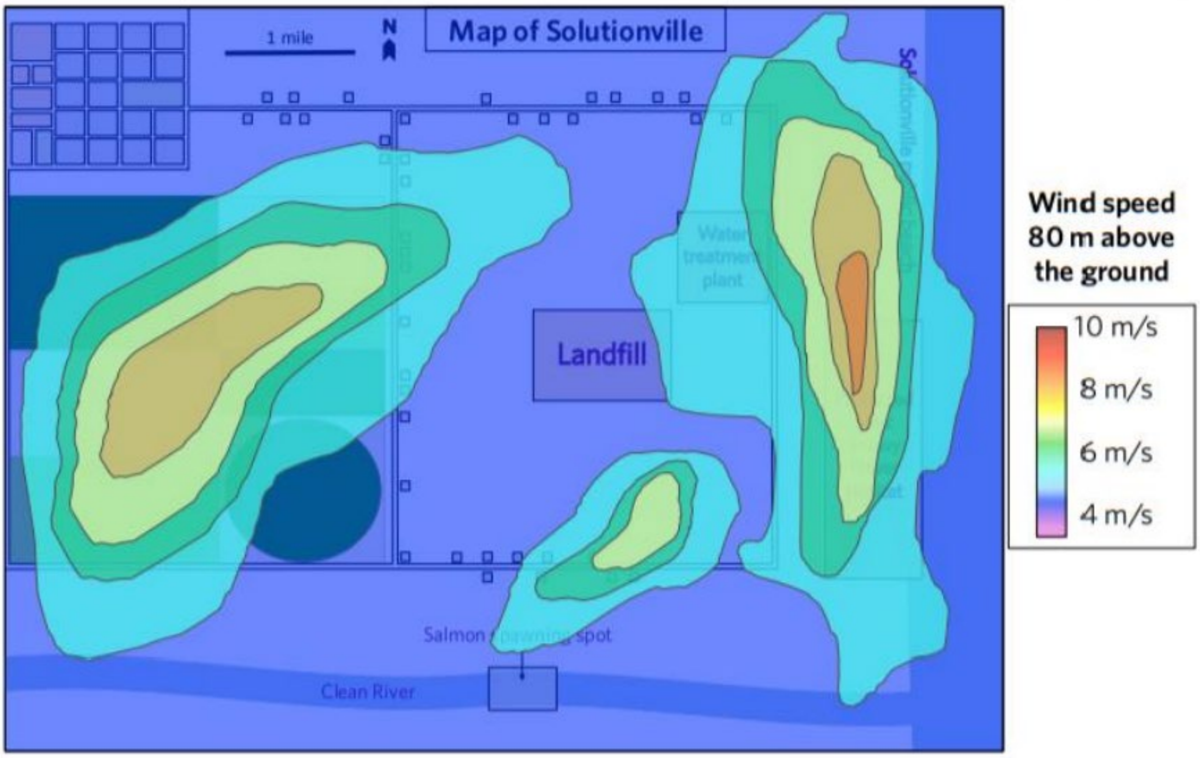


Fig. 3. Potential of wind energy

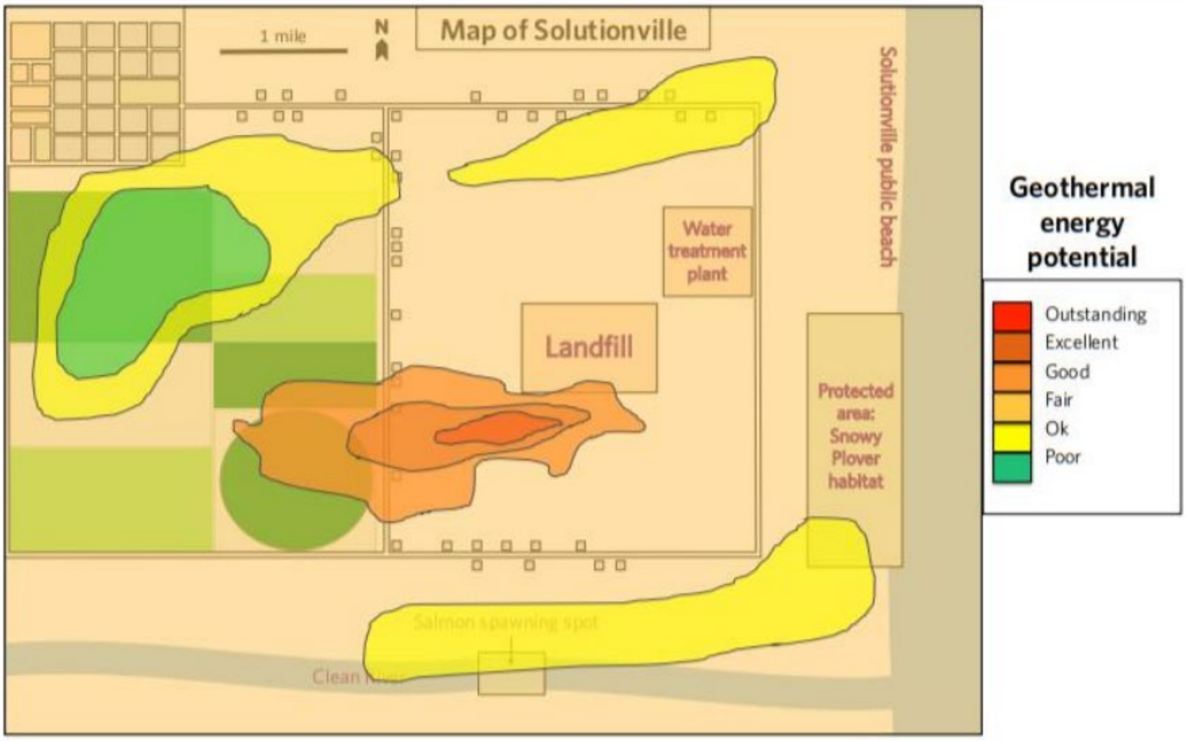


Fig. 4. Potential of geothermal energy

2) The following table (Table 1) will help calculate how much land you need to allocate these objects, calculate the amount of energy produced by the station and the cost of installing these facilities.

Table 1

Calculations on the power stations

Spreadsheet Tool: Pick your renewable energy sources!

Fill in the BLUE BOXES. As you adjust the number of units you build, watch how the cost and energy production change.
Be sure to stay under budget and produce *at least* the minimum amount of energy needed to power Solutionville!
Pay attention to the pink boxes, which will tell you how much total space you will need for each technology.

	Small geothermal power plant	Wind turbine	Solar roof array	Hydroelectric dam
Fill in the number of units you want to build:				
Energy Production (kWh)				
per unit built	70 000 000	6 000 000	30 000	4 000 000
TOTAL energy produced				
Building costs ($)				
per unit built	$10 000 000	$3 000 000	$25 000	$2 000 000
TOTAL cost				
Land/water space requirements				
per unit built	1 square miles	0,25 square miles	1 roof	0,25 miles along a river
TOTAL space requirements	square miles	square miles	roofs	miles along a river

3) The last sheet shows general Table 2 containing the total values of energy produced and costs. Therefore, when considering the number of renewable energy projects, you need to make sure that you do not go beyond the budget, and produce at least a minimum amount of energy to meet the needs of the city.

Table 2

Total values of energy produced and costs

	Required	MY PLAN	Difference
Solutionville's energy budget (per year)	$30 000 000	$0	
Solutionville's energy production (kWh per year)	100 500 000	0	

Time for the task – 1 hour.

You are supposed to work in teams for doing this task. Each team must present its plan, and we will determine which team coped with the task better. To do this, we will calculate the cost of 1 kW * h of electrical energy (how many cents we need to produce 1 kW * h of electricity), dividing total costs by the amount of energy produced.

Task 4. Brainstorming "Benefits and drawbacks of renewable energy sources"

The aim of the task – discussing the benefits and drawbacks of different types of energy that are commonly used in our daily life: solar energy, wind energy, hydroelectric energy, and fossil fuels.

Setting objectives:

You are supposed to work in teams for doing this task. Let the first team take and analyse solar energy, the second team – wind energy, the third – hydroelectric energy, and the fourth – fossil fuels.

Each team will have to fill in the Table 1, where you are supposed to list and write down benefits and drawbacks of your type of energy in terms of three factors: environmental, social and cultural, and economic.

Environmental factors mean factors that influence the environment. In this position you should reflect on how your type of energy influences the environment.

Social and cultural factors. In the second point you have got to decribe what social and cultural effect your type of energy may have. For example, in public hearings, people may reject a renewable enrgy project for installing wind power station, as it may cause too much noise around a settlement.

Economic factors mean that you should assess your type of energy from an economic point of view.

All the factors may be either positive or negative, so you can refer to them as benefits or drawbacks. Handouts on different types of energy (Annex 2) are given at the end of the Guidelines, and will be useful for carrying out the task.

Table 1

Benefits and drawbacks of different types of energy

	Benefits	Drawbacks
Environmental Factors		
Social & Cultural Factors		
Economic Factors		

Time for the task – 1 hour.

You have 1 hour for brain-storming and discussion in teams, and then each team will have 15 minutes to give their presentations.

Task 5. Teamwork projects on "Clean" energy for the city

The aim of the task – to prepare group presentations on "Clean" energy for the city".

Setting objectives:

The task is the same for all teams – to design a renewable energy plan for Dnipro City according to the scheme (Fig. 1).

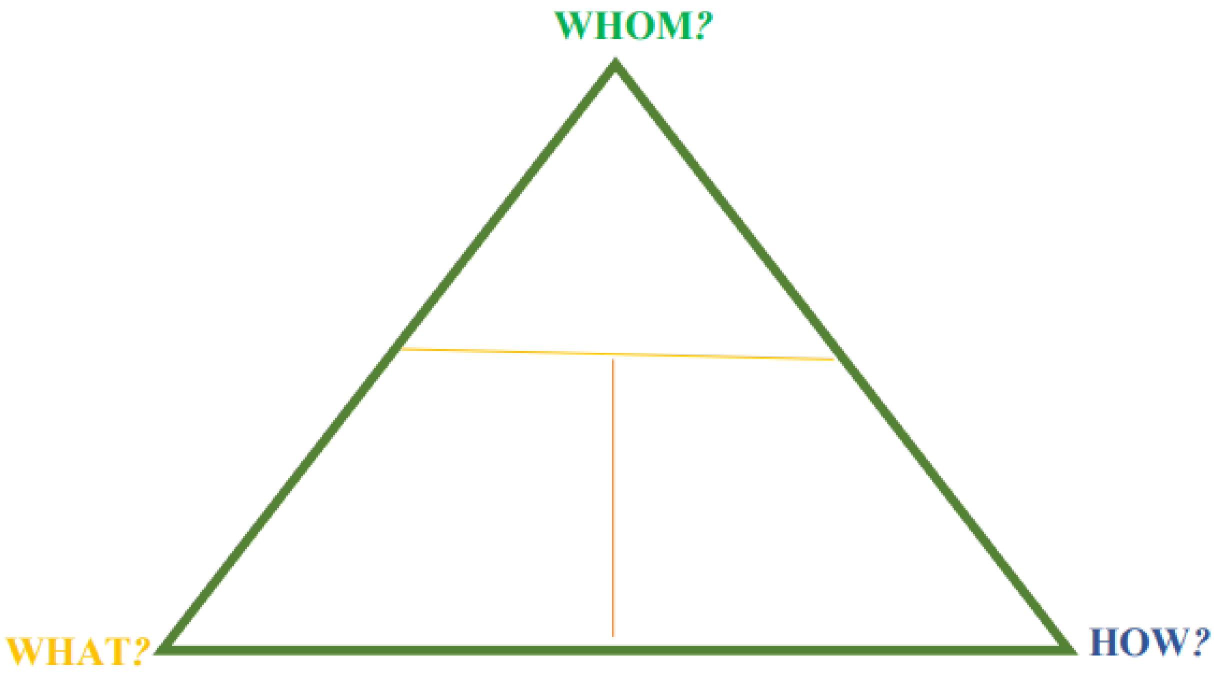


Fig. 1. Project plan: "Clean" energy for the city

In the left corner of the triangle, you should write down the answer on the question: "WHAT" types of clean energy are the most effective for the city and why? At the top, you should write "FOR WHOM" this energy is planned to be used (proposed) ? And finally, you have got to describe "HOW" are you planning to use renewable energy? Are there any obstagles for increasing the use of "clean" energy?

In handouts at the end of the Guidelines (Annex3) you will find a case study with short facts about Dnipro City that can be useful for carrying out the task.

Time for the task – 1 hour.

You have 1 hour for brain-storming and discussion in teams, and then each team will have 15 minutes to give their presentations.

***Business game*: "Energy Treasure Hunt"**

Student Activity Guide

Introduction: In the Ukraine, we currently use nonrenewable source for most of our energy; however, they can have negative impacts on Earth's climate and the environment. Citizens of the (fictitious) town of Solutionville. want to replace coal as their main source of electricity with cleaner and more renewable sources, but the use of many of these renewable energy technologies are limited by things like geography, climate, and cost. How would you deal with these limitations?

Your Challenge: With a partner, design a renewable energy plan for the town of Solutionville..

1. Using the information on the following pages and the Spreadsheet Tool:
   • Figure out what combination of renewable energy technologies can provide a constant and reliable 100,500,000 kilowatt-hours (kWh) of electricity per year for all of the residents and businesses of Solutionville. without going over budget.
   • Draw (to scale!) the locations of where you will build your renewable energy technologies on the Map of Solutionville. on page
2. Your Spreadsheet Tool will help you calculate how much land space you will need for each. Use a ruler and the scale bar on your map to carefully choose your locations. Be ready to justify why you built things where you did!
   • Using the maps on pages 4-6, show that your plan meets all of the geographic energy potential constraints (that the renewable energy technologies will work where you put them).

Tips and Hints

• Remember that some renewable energy sources like the wind and sun are intermittent, meaning that they aren't necessarily available all the time. You might not want to rely solely on intermittent energy sources!
• You can use any combination of renewable energy sources as long as they meet the outlined conditions and you can justify your choices with logical explanations.

Solutionville Facts and Figures

Population 30,000 people, 3 people per household on average

Energy needs 10,000 kWh of energy per home per year, plus an additional 500,000 kWh of energy (total) for agriculture and other community facilities

Energy budget $30 million per year

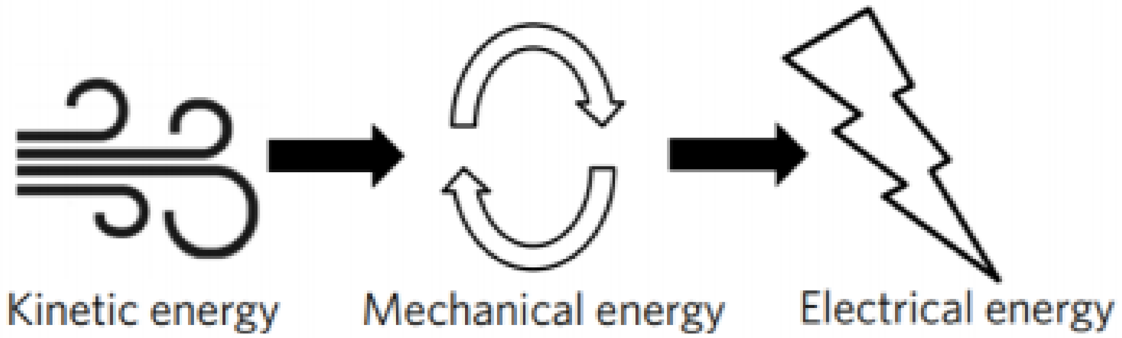
Climate Warm, dry, and sunny summers and cool, wet, cloudy winters

Economy Mostly agricultural; Solutionville farms grow a variety of fruits and vegetables and raise animals.

Biodiversity Solutionville's coastal waters are home to many plants and animals, several of which are endangered. Part of the shoreline has been designated as protected habitat for the threatened snowy plover shorebird. There are other species of seabirds, including gulls and pelicans. Salmon migrate seasonally up the Clean River to spawn.

Wind Energy

Have you ever tried to make a toy pinwheel spin by blowing on it? We can harness the power of moving air on a much larger scale and use it to produce electricity with wind turbines. When the wind is strong enough (has enough kinetic energy), the blades of a wind turbine turn, which spins a shaft connected to a generator. The generator converts the mechanical energy of the spinning shaft into electrical energy that can be transmitted to homes and buildings through power lines.



There are many different kinds of wind turbines, from small turbines that can be put on the roof of a house to really large turbines that can be built together in wind farms to power entire communities. Wind energy—a renewable resource—can be produced anywhere where there is wind, but the stronger and more consistently the wind blows, the better. Unfortunately, in most places the wind isn't blowing all of the time, and in places that aren't very windy, wind turbines probably aren't a good way to generate reliable electricity.

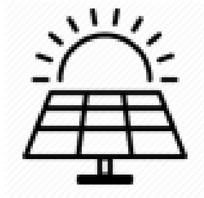
Wind energy doesn't directly produce carbon dioxide or other greenhouse gases that can cause damage to the climate. Wind power is also relatively inexpensive. The wind itself is a free resource, and although it costs money to build and operate wind turbines, advancements in technology have significantly reduced these costs over time. Wind energy doesn't pollute like coal burning, and pollution can cause health problems for people[1]. However, like with any infrastructure, some people express concern about wind turbines being too noisy or ruining the look of a landscape, and therefore don't necessarily want wind turbines near their homes.

Some kinds of wind turbines, particularly larger ones, can cause harm to birds and bats[2]; however, people are working on ways to reduce the impact of wind turbines on birds and bats, such as changing the height or location of the turbines.

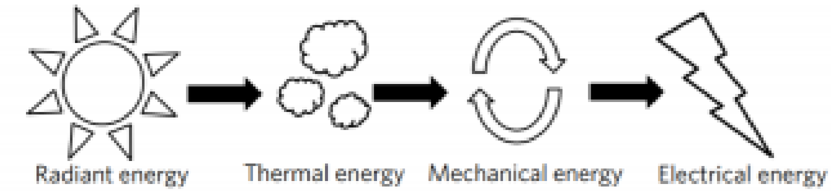
1 World Health Organization: What are the effects on health of transport-related air pollution?

2 Smallwood

Solar Energy



Solar energy is a way to harness sunlight for heating or electricity. There are different ways to convert sunlight into usable energy. Concentrated solar power uses mirrors to focus the energy from the sun onto a smaller area. This concentrated thermal energy heats water into steam, which turns a turbine connected to a generator. The generator converts the mechanical energy of the spinning turbine into electrical energy. Concentrated solar power plants need between 500 to over 1,000 acres of land—more than 400 football fields!—to have enough mirrors to generate electricity efficiently. Often they are found in unpopulated desert regions—like the Ivanpah Solar Electric Generating System in the Mojave desert—which means the electricity generated has to be transmitted a long distance to where it will be used. It also means that large regions of desert ecosystems can be impacted[1].



Another technology that can convert the energy of sunlight into electricity is solar photovoltaics (PV). When sunlight strikes a solar photovoltaic cell, it is absorbed by a semiconductor—a material like silicon that can conduct electricity under the right conditions. This excites electrons in the semiconductor, which then flow, generating an electrical current. A bunch of solar photovoltaic cells can be grouped together to create a solar panel. Solar panels can be installed on the roofs of homes and buildings in solar arrays, so they are better options for cities. Solar panels are relatively easy to take care of and aren't noisy.

Solar photovoltaic technology produces no direct carbon dioxide or other greenhouse gases that can warm the climate. Sunlight is free, abundant, and renewable, since it won't run out for billions of years. The Earth's surface continuously receives 10,000 times more energy from the sun than the world currently uses[2]!

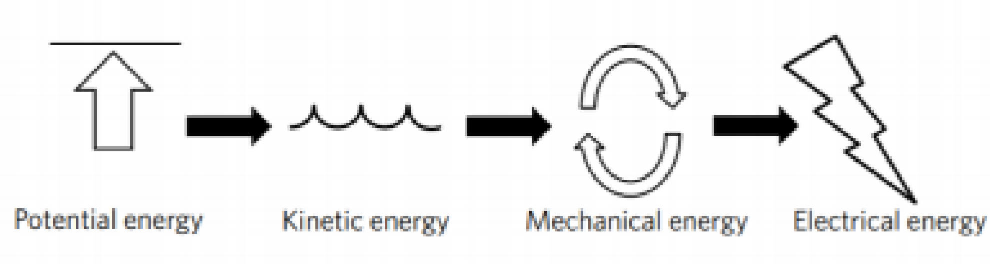
Unfortunately, solar energy isn't a great option everywhere or all of the time. Regions that don't get a lot of constant or direct sunlight aren't ideal places to use solar energy. Solar panels don't work at night and don't work as well when it is cloudy. Solar technology is becoming cheaper, but there is a cost to build a large concentrated solar power plant or install solar panels.

1 The New York Times: BrightSource Alters Solar Plant Plan to Address Concerns Over Desert Tortoise

2 Department of Energy

Hydroelectric Power

Hydroelectric power (or 'hydropower') uses the energy of moving water to generate electricity. But how exactly can we capture and transform this energy into usable electricity? One of the main ways to do this is by building a dam on a river. By trapping water behind a dam, we can increase the level of the water behind the dam, building up its potential energy. When special gates in the dam are opened, the water—pulled by gravity—flows down through the dam and through turbines connected to a generator. The potential energy of the water is turned into kinetic energy as it flows, and then mechanical energy that turns the turbines. The generator converts the mechanical energy of the spinning turbines into electrical energy that can be transmitted to homes and buildings through transmission lines.



The water reservoirs (lakes and ponds) created behind dams can serve as recreational spaces for people who enjoy fishing, swimming, or boating. The water in these reservoirs can also be used for irrigation in agricultural areas.

Hydropower does not pollute the water nor the air. It also produces no direct carbon dioxide or other greenhouse gases that can cause damage to the climate. However, building a dam on a river can have significant impacts on ecosystems. Some fish species like salmon that migrate seasonally up rivers and streams to spawn are blocked from reaching their spawning destinations by dams[1]. The reservoir created behind a dam often floods land that wasn't originally underwater. In addition to impacting the plants and animals living on this land, this can displace people too.

Hydropower is reliable as long as there is enough available water. During a drought, this can be a problem. And while flowing water is free, building a dam can be expensive. Dams also don't just trap water, but anything being moved by the river. Sand and rocks can build up behind a dam over time, not only decreasing the amount of water the dam can store and release, but reducing the amount of sand that is carried into the coastal ocean to supply beaches[2].

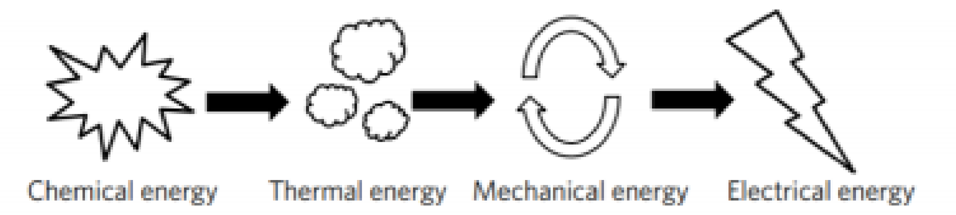
1 NOAA Fisheries: About Dams & Fish

2 CoastalCare.org: Dams–Cutting Off Our Beach Sand

Fossil Fuels

Coal, oil/petroleum[1] , and natural gas are three main types of fossil fuels. They are called 'fossil fuels' because they formed from the remains of decaying plants and animals that were buried by layers of rock 300 million years ago. As this material was buried by more and more rock, high heat and pressure transformed it over millions of years. And depending on whether this occurred in vegetated swamps or plankton-filled seas, either coal, oil, or natural gas was formed.

When fossil fuels are burned—when they undergo a chemical reaction with oxygen—they release a lot of energy that we can use to power things. For example, in a coal-fired power plant, coal is burned in a boiler, releasing chemical energy that heats water into steam. The steam turns a turbine—a thing with blades that spins—connected to a generator. The generator converts the mechanical energy of the spinning turbine into electrical energy that can be transmitted to homes and buildings through transmission lines. While coal is typically used to produce electricity, oil can be refined into a variety of liquid fuels to power cars, trucks, and airplanes and is also made into a wide variety of everyday products, including plastics, cosmetics, clothes, electronics, and more. Natural gas is commonly used for heating and cooking in homes.



Coal, oil, and gas can generate huge amounts of energy and power a wide variety of things. Fossil fuels are relatively cheap, but as they become harder to extract from the Earth, they will become more expensive. Fossil fuels are easily stored and easily transported, and thus they can be used to power things almost anywhere and anytime.

One problem with fossil fuels is that they are nonrenewable resources, meaning that we are extracting them from the Earth and using them faster than they can form. Mining or pumping fossil fuels from the ground can damage ecosystems and the environment, as can accidents like oil tanker spills that are expensive to clean up[2] . Fossil fuels produce air pollution when they are burned. They also release carbon dioxide and other greenhouse gases into the atmosphere that not only warm the climate, but change the chemistry of the ocean.

1 'Oil' and 'petroleum' are often used interchangeably.

2 Fortune Magazine: 6 big oil spills, and what they cost

PROJECT: "CLEAN" ENERGY FOR THE CITY

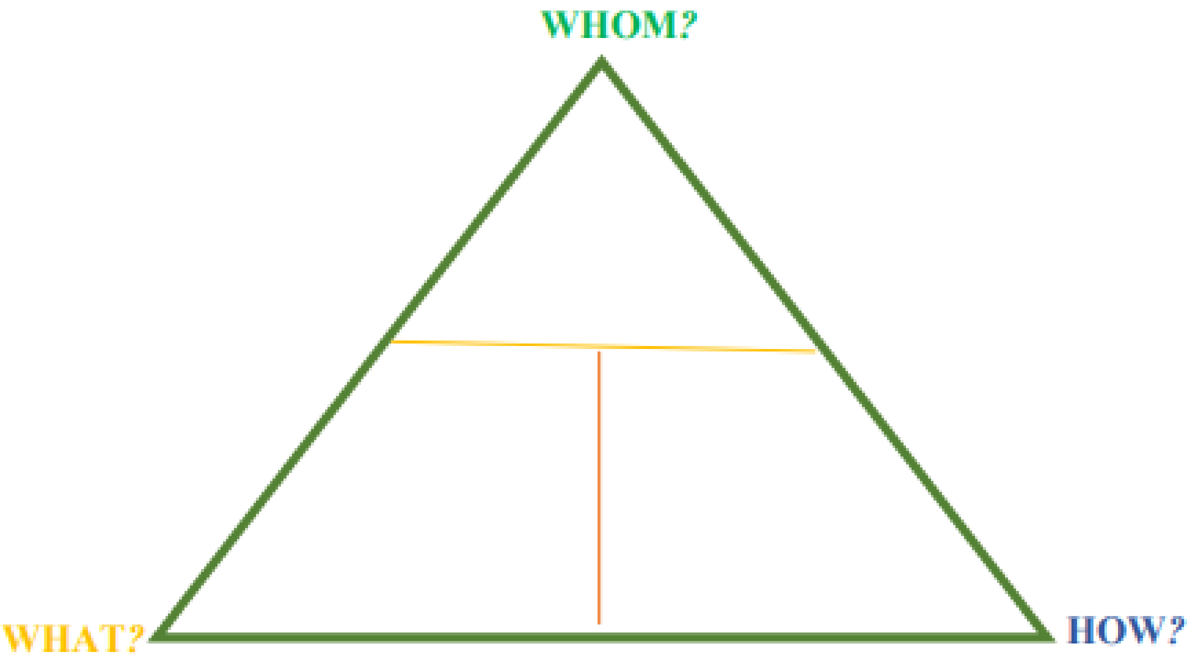
Ukraine, Dnipro

Introduction:

In the Ukraine, we currently use coal, oil (petroleum), and natural gas for most of our energy; however, these fossil fuels are nonrenewable and can have negative impacts on Earth's climate and the environment. Citizens of the town of Dnipro want to transit to cleaner and more renewable sources.

Your Challenge:

design a renewable energy plan for the town according to this scheme



- ***WHOM?***
  The city 's problems that clean energy can solve?
  Which industries/enterprises should be primarily involved in the clean energy program?

- ***WHAT?***
  Types of "clean" energy, which are the most effective for the city 's conditions?

- ***HOW?***
  What are the barriers to increasing the use of "clean" energy?

Information:

DNIPRO

Status: Dnipro is Ukraine's fourth-largest city, with about one million inhabitants. It stands 391 kilometres (243 mi) southeast of the Ukrainian capital Kiev on the Dnieper River, in the south-central part of Ukraine.

Geography: The city is built mainly upon both banks of the Dnieper, at its confluence with the Samara River. The centre of the city is constructed on the right bank which is part of the Dnieper Upland, while the left bank is part of the Dnieper Lowland. The old town is situated atop a hill that is formed as a result of the river's change of course to the south. Nowadays both the north and south banks play home to a range of industrial enterprises and manufacturing plants. The airport is located about 15 km (9.3 mi) south-east of the city.

Climate: Dnipro has either a humid continental climate, though it borders on a Mediterranean-influenced hot-summer humid continental climate as summers are relatively dry than the rest of the year. Snowfall is more common in the hills than at the city's lower elevations. The city has four distinct seasons: a cold, snowy winter; a hot, dry summer; and two relatively wet transition periods.

During the summer, Dnipro is very warm (average day temperature in July is 24 to 28 °C (75 to 82 °F), even hot sometimes 32 to 36 °C (90 to 97 °F). Winter is not so cold (average day temperature in January is −4 to 0 °C (25 to 32 °F), but when there is no snow and the wind blows hard, it feels extremely cold. A mix of snow and rain happens usually in December.

Climate data for Dnipro [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	12.3 (54.1)	17.5 (63.5)	24.1 (75.4)	31.8 (89.2)	36.1 (97.0)	37.8 (100.0)	39.8 (103.6)	40.9 (105.6)	36.5 (97.7)	32.6 (90.7)	20.6 (69.1)	16.3 (61.3)	40.9 (105.6)
Average high °C (°F)	−1.0 (30.2)	0.0 (32.0)	6.0 (42.8)	15.2 (59.4)	22.1 (71.8)	25.6 (78.1)	28.0 (82.4)	27.5 (81.5)	21.5 (70.7)	13.8 (56.8)	5.1 (41.2)	0.2 (32.4)	13.7 (56.7)
Daily mean °C (°F)	−3.6 (25.5)	−3.4 (25.9)	1.8 (35.2)	9.7 (49.5)	16.2 (61.2)	19.9 (67.8)	22.1 (71.8)	21.4 (70.5)	15.6 (60.1)	8.9 (48.0)	2.0 (35.6)	−2.4 (27.7)	9.0 (48.2)
Average low °C (°F)	−6.1 (21.0)	−6.3 (20.7)	−1.6 (29.1)	4.9 (40.8)	10.6 (51.1)	14.6 (58.3)	16.7 (62.1)	15.8 (60.4)	10.7 (51.3)	5.0 (41.0)	−0.6 (30.9)	−4.7 (23.5)	4.9 (40.8)
Record low °C (°F)	−30.0 (−22.0)	−27.8 (−18.0)	−19.2 (−2.6)	−8.2 (17.2)	−2.4 (27.7)	3.9 (39.0)	5.9 (42.6)	3.9 (39.0)	−3.0 (26.6)	−8.0 (17.6)	−17.9 (−0.2)	−27.8 (−18.0)	−30.0 (−22.0)
Average precipitation mm (inches)	45 (1.8)	43 (1.7)	43 (1.7)	38 (1.5)	42 (1.7)	60 (2.4)	54 (2.1)	43 (1.7)	41 (1.6)	37 (1.5)	46 (1.8)	47 (1.9)	539 (21.2)
Average rainy days	9	8	11	13	13	13	12	9	10	11	12	11	132
Average snowy days	16	15	9	1	0	0	0	0	0	1	7	15	64
Average relative humidity (%)	88	85	79	67	62	66	65	62	70	77	87	88	75

Source: Pogoda.ru.net[79]

Economy: Dnipro is a major industrial centre of Ukraine. It has several facilities devoted to heavy industry that produce a wide range of products, including cast-iron, launch vehicles, rolled metal, pipes, machinery, different mining combines, agricultural equipment, tractors, trolleybuses, refrigerators, different chemicals and many others.

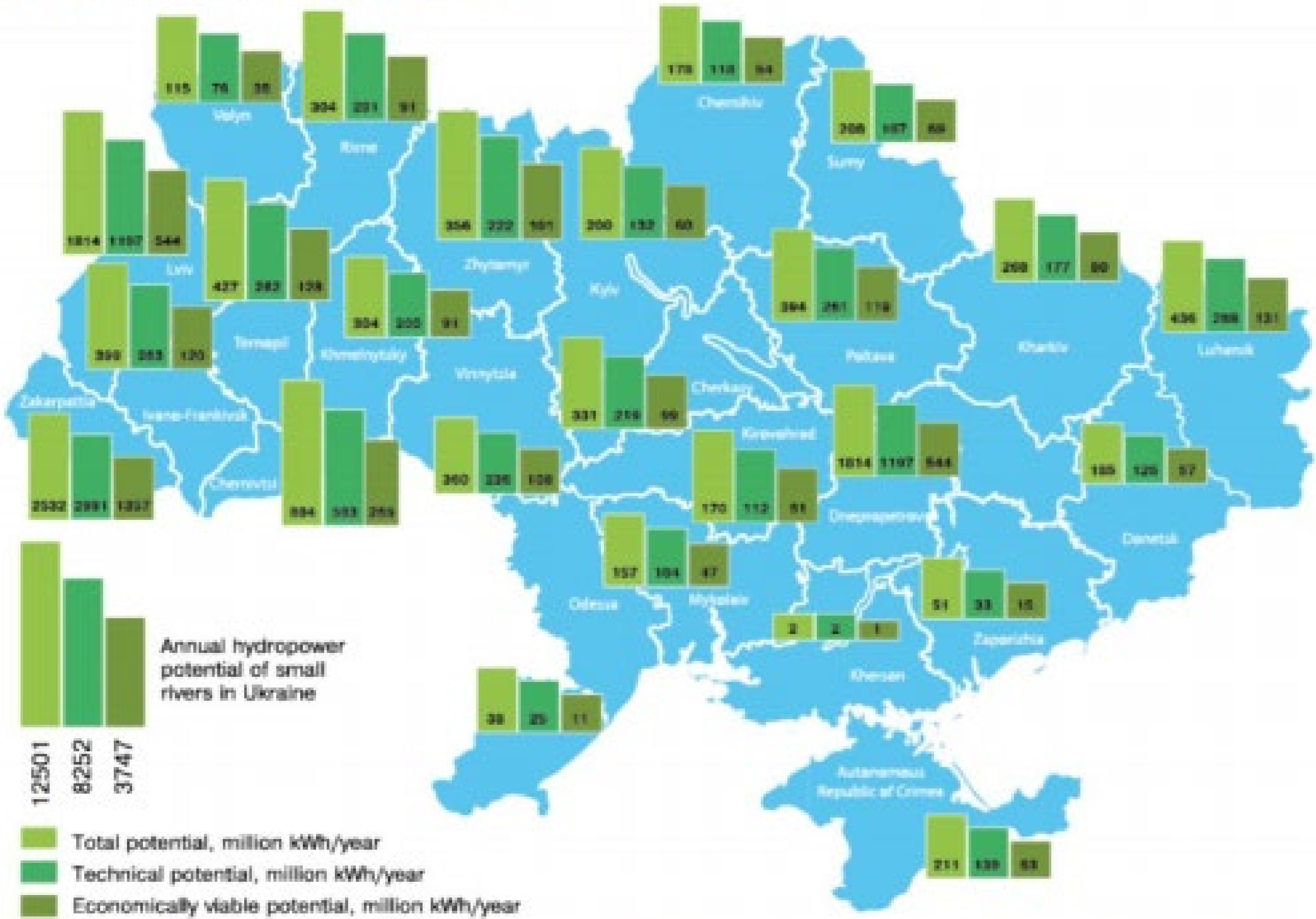
The city also has big food processing and light industry factories. Many sewing and dress-making factories work for France, Canada, Germany and Great Britain, using the most advanced technologies, materials and design. Dnipro has also dominated in the aerospace industry since the 1950s. In 2018 a private Texas-based aerospace firm Firefly Aerospace opened a Research and Development (R&D) center in Dnipro to develop small and medium-sized launch vehicles for commercial launches to orbit.

Metals and metallurgy is the city's core industry in terms of output. Employment in the city is concentrated in large-sized enterprises. Metallurgical enterprises are based in the city and account for over 47% of its industrial output. These enterprises are important contributors to the city's budget and, with 80% of their output being exported, to Ukraine's foreign exchange reserve.

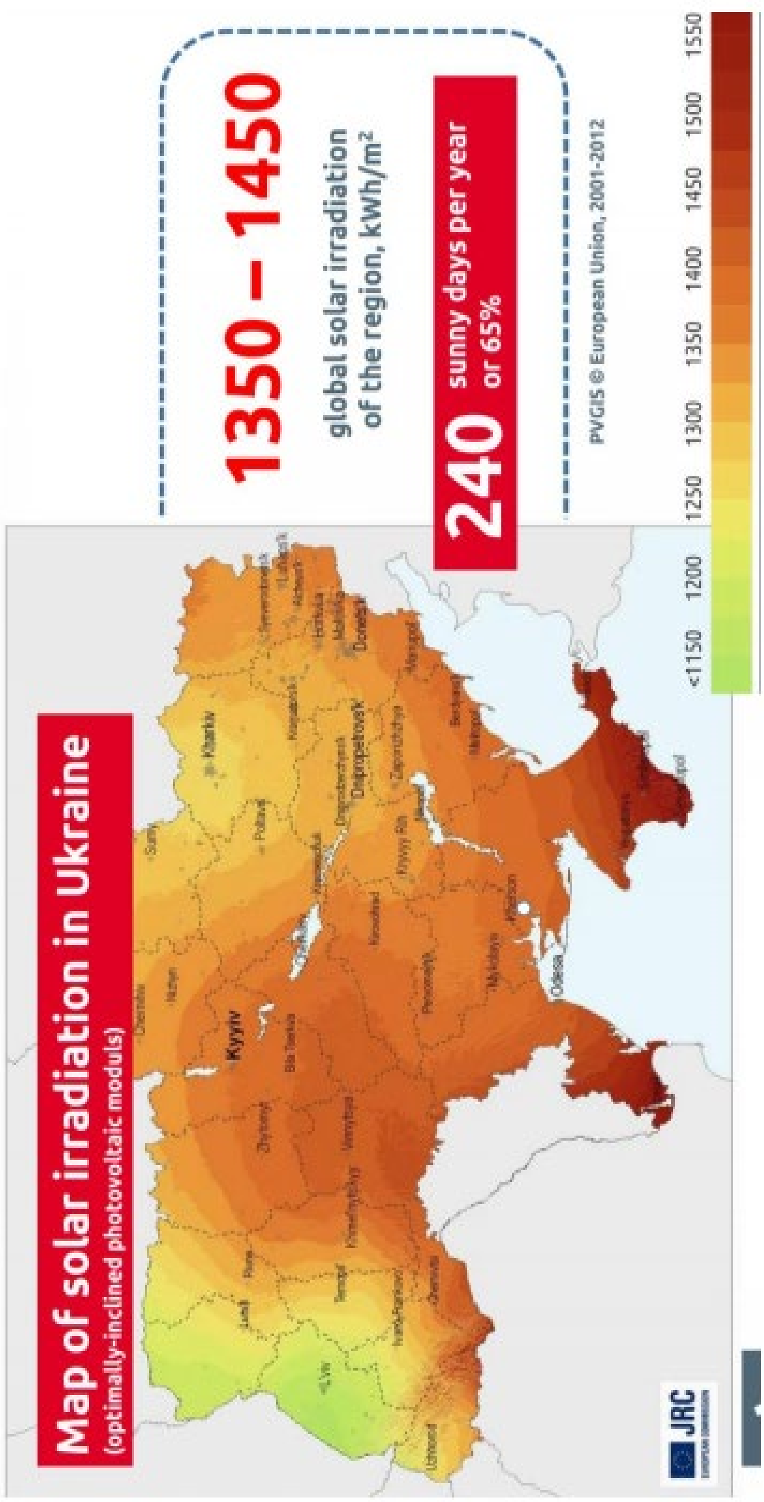
The city is characterized with significant pollution of air with industrial emissions. The "severely polluted air and water" and allegedly "vast areas of decimated landscape" of Dnipro and Donetsk are considered by some to be an environmental crisis.

Dnipro is a major educational centre in Ukraine and is home to two of Ukraine's top-ten universities; the Oles Honchar Dnipro National University and National Technical University «Dnipro Polytechnic». The system of high education institutions connects 38 institutions in Dnipro.

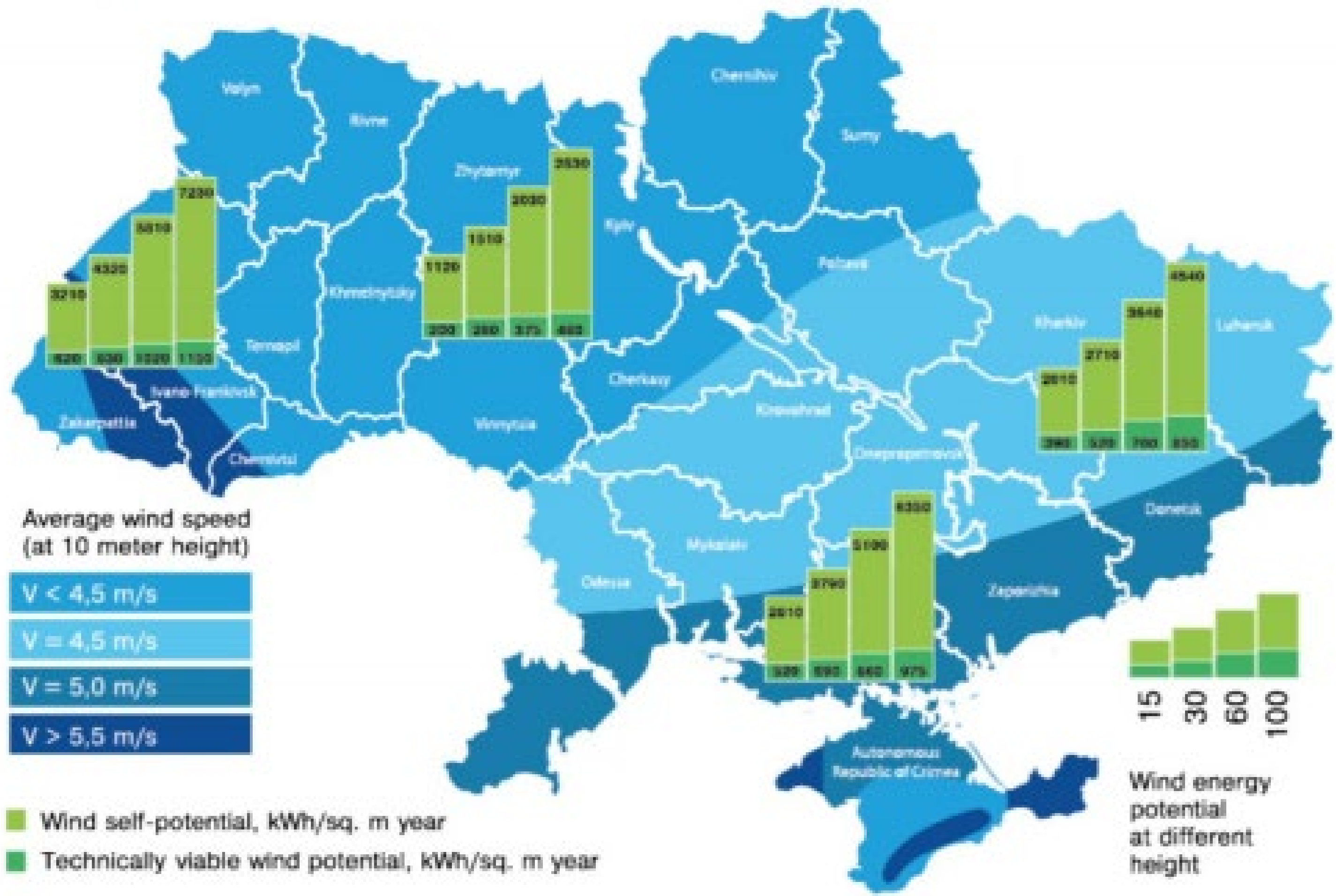
Hydro power potential of Ukraine



Source: Atlas of Renewable Energy Sources Potential of Ukraine. Institute of Electodynamics of National Academy of Sciences of Ukraine with support of State Committee for Energy Conservation of Ukraine


Map of solar irradiation in Ukraine
(optimally-inclined photovoltaic moduls)
1350 – 1450
global solar irradiation of the region, kWh/m²
240 sunny days per year or 65%
PVGIS © European Union, 2001-2012
<1150 1200 1250 1300 1350 1400 1450 1500 1550
Kyyiv
Kharkiv
Dnipropetrovsk
Donetsk
Odesa
JRC

Wind power potential of Ukraine



Source: Atlas of Renewable Energy Sources Potential of Ukraine.
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