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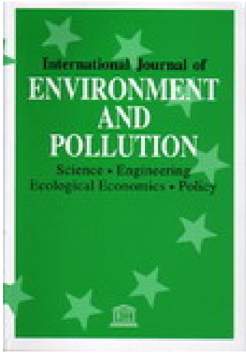


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# Energy poverty and energy efficiency in emerging economies

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**Abstract:** Energy poverty and low energy efficiency of households in emerging economies is a challenging sustainability issue. Using the general least squares technique for time series it is found that if households' expenditures for utilities grow by one percentage point, the poverty headcount ratio below national poverty lines increases by three percentage points in Ukraine during the period 1999–2018. With GDP per capita rising by 100 USD, there is a decrease in the headcount ratio below national poverty lines by six percentage points. That is, even a slight increase in household incomes has a significant effect on reducing energy poverty. The results suggest that if GDP per capita increases by 1000 USD, the energy efficiency of GDP improves by one USD per kg of oil equivalent. Therefore, increased population well-being is a factor of energy poverty reduction and energy efficiency improvements. The rise of utilities prices contributes to the profitability growth of energy-efficient measures and the increase in utilities expenditures.

**Keywords:** energy poverty; energy efficiency; emerging economies; econometric model; Ukraine; household; sustainable development; utility prices; warm loans; energy cooperative.

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## 1 Introduction

Energy poverty reduction and ensuring energy efficiency development is a priority for many national governments today. The reasons for this are possibilities for increasing states' energy independence, saving their energy resources, reducing greenhouse gas emissions, meeting energy needs (Bilan et al., 2019; Cebula et al., 2018; González-Eguino, 2015; Lyeonov et al., 2019; Lihtmaa et al., 2018; Mlaabdal et al., 2018; Prokopenko et al., 2021; Sineviciene et al., 2017; Sotnyk et al., 2015; Vasylieva et al., 2019) as well as improving the quality of life of the population, in particular, due to making utilities more available and affordable to households (Bouzarovski and Petrova, 2015; Bouzarovsky and Tirado Herrero, 2017; Braubach and Ferrand, 2013; Hernández and Bird, 2010; Kaygusuz, 2011; Li et al., 2019; Melnyk et al., 2019; Melnyk et al., 2016; Mihalcova et al., 2021; Petrova et al., 2013; Thomson et al., 2017; Urge-Vorsatz and Tirado Herrero, 2012). Moreover, energy poverty reduction is one of the sustainability goals.

For emerging economies, whose institutional changes have a high potential for implementing energy-efficient transformations and reducing energy poverty, the adoption of timely and justified political decisions is an important practical issue of improving the social, economic, and energy performance (Thomson et al., 2017; Bouzarovsky and Tirado Herrero, 2017; Buzar, 2007; Cirman et al., 2013; Dubois and Meier, 2016; Gerbery and Filčák, 2014). The energy poverty problem has been widely researched in recent years (see, for example, Bouzarovski and Petrova, 2015; Bouzarovski and Tirado Herrero, 2017; Fankhauser and Tepic, 2007; González-Eguino, 2015; Hernández and Bird, 2010; Hills, 2012; Kaygusuz, 2011; Petrova et al., 2013; Thomson et al., 2017; Trofymenko et al., 2021; Shkola et al., 2021) in many individual economies. Thus, energy poverty at Bouzarovsky and Tirado Herrero (2017) is defined as "the inability to secure a socially and materially necessitated level of energy services in the home". Based on this definition, Lihtmaa et al. (2018) examine this phenomenon in the context of its relationship with efficiency-based renovation subsidies for apartment buildings in

Estonia. Their research shows that many European Union (EU) countries are characterised by high levels of energy poverty: from 14.8% for the Czech Republic to 39.5% for Romania and 40.1% for Bulgaria. Many other researchers found similar estimates of energy poverty rates in EU (see, for example, Bouzarovski et al., 2016; Buzar, 2007; Dubois and Meier, 2016; Gerbery and Filčák, 2014; Legendre and Ricci, 2015; Papada and Kaliampakos, 2016; Phimister et al., 2015; Voitko et al., 2021) and have become the background for active political action. For instance, in 2017, the Republic of Ireland, which has high levels of energy poverty, announced the funding of €10 million for the Warmth and Well-being scheme that provides free energy efficiency upgrades for households who are classified as energy-poor and contain young children with chronic respiratory diseases (Health, 2017). Lower incomes are generally associated with worsened health indicators (Kubatko and Kubatko, 2017, 2019). Therefore, many EU countries and states within the USA (DSIRE, 2019) proposed different financial support programs to low-income households to increase their energy efficiency.

Estache et al. (2002) and Foster et al. (2000) used affordability indicators to measure energy poverty in Latin America; similarly, affordability of electricity, district heating, and water as the share of monthly household income was used by Fankhauser and Tepic (2007) for low-income consumers in transition countries. The energy poverty definition proposed by researchers (see, for example, Hills, 2012; Maxim et al., 2016; Pye et al., 2015) reveals the close links between energy poverty and energy efficiency issues. By linking energy poverty directly with unsatisfactory levels of nations' energy efficiency, the UNECE identifies an energy inefficiency trap as "a situation in which countries with lower energy efficiency are unable to change status due to lack of funds, experience, technology, motivation and initiative" (UNECE, 2009, p.7). To overcome this trap, Cirman et al. (2013) propose the proper subsidy targeting energy efficiency improvements for Central and Eastern European states, where the inefficient housing stock is critical. The authors argue that grants and subsidies for energy efficiency development serve as a powerful tool to encourage the cooperation of individual owners and improve the organisational performance of the management of privatised multi-dwelling buildings.

Analysing the energy poverty of American households, Hernández and Bird (2010) claim that the energy poverty of US households and found that the energy burden for the low-income population is much higher than many policymakers could assume. Therefore, weatherisation, utility, and housing assistance policies provided by state and local authorities can significantly help to reduce energy poverty. The direct negative consequences of energy poverty are the inability of the population to pay for consumed energy and other utilities due to low household incomes and high prices for such resources. Moreover, Urge-Vorsatz and Tirado Herrero (2012) pointed out that rising energy prices by national governments, for example, stimulate greenhouse gas emissions reduction without adequately protecting vulnerable social groups, can lead to social discontent opposite effect in the form of changing into high-carbon economies. Therefore, to deal with energy poverty outcomes, researchers pay particular attention to the impact of different factors on reducing energy poverty of the population (Bouzarovski and Petrova, 2015; Buzar, 2007; Chester and Morris, 2012; Herrero and Ürge-Vorsatz, 2012; Hernández and Bird, 2010; Maxim et al., 2016; Okushima, 2016; Pye et al., 2015).

Bouzarovski and Petrova (2015) have identified such drivers for energy poverty as: "restrictions for energy access, which is urgent for developing countries with underdeveloped energy infrastructure, affordability of energy expenditures for households, the flexibility of energy resources that homes can use, efficiency of energy conversions in the home, households' needs in energy and existing practices of energy use". Okushima (2016) pointed out that energy price escalation and lowering income are the main factors increasing energy poverty in Japan. According to Maxim et al. (2016), the impact of thermally inefficient housing stock, low incomes, and rising energy prices influence energy poverty and determine (1) tenure status, (2) type of dwelling, (3) heating system efficiency, and (4) residential consumption of energy, (5) people at risk of poverty or social exclusion and (6) affordability of energy that depend on the population income level. Poputoaia and Bouzarovski (2010), Herrero and Ürge-Vorsatz (2012), and Chester and Morris (2012) consider the specific factors contributing to energy poverty in post-communist countries in Eastern Europe, which include inefficient district heating networks and increasing energy costs after market liberalisation and unbundling of energy companies.

As noted above, energy-efficient changes have a significant positive impact on reducing energy poverty. Therefore, identifying and managing the factors affecting energy efficiency reduces poverty and has been the subject of many recent research publications. For example, Ameli and Brandt (2015) explored the determinants of households' investment in energy efficiency and renewable Energy for OECD countries, found that (1) socio-economic characteristics of households, (2) the characteristics of their dwelling, (3) households' attitudes, knowledge and behaviour regarding the environment as well as (4) households' knowledge about their energy spending are the main drivers of energy-efficient changes in the residential sector. Similar factors are mentioned by Trotta (2018) for British households. Sardianou and Genoudi (2013) pointed out that high income, higher education, middle age of homeowners as the determinants positively influencing energy efficiency changes in homes. Bulkeley and Broto (2013) claimed energy prices and a favourable policy as important reasons for energy efficiency improvements. Analysing the residential sector's energy efficiency for a panel of 48 states of the USA, Filippini and Hunt (2011, 2012)consider energy consumption, income, economic growth, energy prices, number of population, household size, climate condition variables, and value-added as a significant contributor to energy-efficient changes. Jin and Kim (2019) include energy consumption, gross fixed capital formation, labour force, economic output, and the industrial structure of a country to the list of energy efficiency drivers. Gillingham et al. (2009) noted access of investments in energy efficiency technologies as one of the remarkable factors to enhance energy efficiency improvements, while Cattaneo (2019), Davis and Metcalf (2016), Gillingham and Palmer (2014), Newell and Siikamäki (2014), and Houde (2018) confirm that lack of relevant information and its asymmetry leads to underinvestment of energy efficiency. Camara (2020) has found that during 1990–2012, some OECD economics cannot reach decoupling between gross domestic product and carbon dioxide emissions.

Overall, the range of factors influencing energy poverty and energy efficiency in different countries is relatively wide and sometimes confusing to adopt the right policy. Despite the large number of publications, which explore these issues in developed and developing countries, the literature covering emerging economies is poor. Due to the high potential of energy efficiency changes, low households incomes, high energy prices, and issues of energy-efficient development are highly relevant to emerging economies. The most vulnerable EU countries belong to Central and Eastern Europe, which had a socialist past, and many former Soviet Union republics, with inherited from those times, outdated housing stock (Buzar, 2007; Fankhauser et al., 2008; Kerimray et al., 2018;

Korppoo and Korobova, 2012; Lihtmaa et al., 2018; Petrova et al., 2013; Poputoaia and Bouzarovski, 2010; Thonipara et al., 2019). Renovation of this stock requires considerable investment to reduce energy costs for its maintenance. To encourage the population to upgrade their housing stock through innovative energy-efficient technology use, many national governments are resorting to increasing utility tariffs, which rising world prices for imported energy may also dictate. However, most of the housing stock in the former socialist countries is now privately owned, and the funds of its owners are often insufficient for energy-efficient upgrades. There is a vicious circle of energy poverty: "*households cannot pay for high-value utilities, which are often used inefficiently, and are unable to reduce their consumption without significantly reducing their quality of life due to lack of funds. On the other hand, utility suppliers can't receive sufficient funds for services provided, which leads to quality deterioration, bankruptcy threat of public utilities, and ultimately the collapse of the housing and utilities sector*". Therefore, the empirical research studying the factors affecting both fluctuations in energy poverty and households' energy-efficient changes in emerging economies is highly relevant. Identification and effective management of drivers through improving national and local policies will help to reduce energy poverty and exclude the countries from being in the energy inefficiency trap.

Ukraine is a typical example of an emerging economy that suffers from energy inefficient housing stock and has a high potential for energy efficiency measures. Due to the low incomes of the population and rising energy prices, the country struggles to stop escalating energy poverty and implement energy-efficient changes in the residential sector and the construction sector (Fankhauser et al., 2008; Komelina and Maksimenko, 2014; Petrova et al., 2013; Ilyash et al., 2020; Mokiy et al., 2020). Therefore, the empirical analysis of energy poverty and energy efficiency issues for Ukraine would help to reveal the main drivers for future positive changes and form policy recommendations that could be applied for other emerging economies with similar development problems.

The paper aims to explain how utility expenditures and other related factors affect energy-efficient development and energy poverty in Ukraine during 1999–2018. Also, the paper fills a gap in scholarly research in understanding the drivers of energy-efficient development and energy poverty in emerging economies.

Based on the empirical results obtained, it is offered conclusions and recommendations for improving the national and local policies to decrease the energy poverty level and ensure energy-efficient development.

## 2 Methodology

The research uses statistical, structural, comparative analysis methods to identify trends, assess the status, and determine factors for Ukraine's housing stock and communal infrastructure development in 1999–2018. A proper econometric model is constructed to determine the impact of utility expenditures and related factors on Ukraine's population's poverty and the domestic economy's energy efficiency. Firstly, the chosen study period is explained by comparative data available from the State Statistics Committee of Ukraine database. Secondly, the 20-year period allows building econometric models characterised by acceptable reliability of the results. Thirdly, 1999 was the last year of the crisis decade, in which the income of the population had started to increase gradually.

Considering the introduction of new indicators and the removal of some indicators collected by the State Statistics Service of Ukraine, the *effective indicators of poverty headcount ratio are taken below national poverty line*s (% of the population) as a proxy for energy poverty indicator. Also, it is taken *GDP per unit of energy* (constant 2011 PPP USD per kg of oil equivalent) as a proxy for the energy efficiency indicator. It is also included GDP per capita (constant 2010 USD) as a proxy for household income, gross capital formation (current USD) as a proxy for investment in energy-efficient measures, expenditures for utilities (%) as a share of household expenditures on payment for utilities in their income and crude oil average prices (USD) as a proxy for utilities (Energy) consumer prices. The use of proxies is the necessary step since there are no available direct data that could reflect the real situation in the sector.

The selected indicators reflect the main factors of energy poverty and energy efficiency regarding the Literature review section, and the following models are proposed:

$$PR_t = \beta_0 + \beta_1 GDP\_pc_t + \beta_2 GFCF_t + \beta_3 EXU_t + u_t, \quad (1)$$

where $PR_t$ is the poverty headcount ratio below national poverty lines (% of the population) in year $t$; $GDP\_pc_t$ is the GDP per capita (constant 2010 USD) in year $t$; $GFCF_t$ is the gross capital formation (current USD) in year $t$; $EXU_t$ is the expenditures for utilities (%) in year $t$; $\beta_0$ is a constant term (cons); $\beta_1, \ldots, \beta_3$ are the regression coefficients of the model; $u_t$ is an error term.

$$GDP\_E_t = \alpha_0 + \alpha_1 GDP\_pc_t + \alpha_2 GFCF_t + \alpha_3 EXU_t + \alpha_4 CRO_t + \upsilon_t, \quad (2)$$

where $GDP\_E_t$ is the GDP per unit of energy (constant 2011 PPP USD per kg of oil equivalent) in year $t$; $CRO_t$ is the crude oil average prices (USD) in year $t$; $\alpha_0$ is a constant term (cons); $\alpha_1, \ldots, \alpha_4$ are the regression coefficients of the model; $\upsilon_t$ is an error term.

It is intentionally not included utilities (Energy) prices in the first model since this indicator can reflect the situation in the housing and utilities sector and many related industries. Also, the household utility expenditures included in the model partially reflect the impact of utility prices on energy poverty. For the second model, we added the utilities (Energy) prices factor since energy efficiency development in the housing and utilities sector depends on utilities prices and prices of other goods contributing to energy-efficient technologies for households. The linear specification is often used in modelling energy efficiency and poverty headcount ratio below national poverty lines. The models are analysed using the ordinary least square technique for time series data within the software application Stata 14.0.

## 3 Results

### *3.1 Prerequisites of energy poverty of the Ukrainian population*

After the collapse of the Soviet Union, given the scarcity of its energy resources, Ukraine was forced to purchase energy at world prices that were significantly higher than the Soviet ones. Absence of sufficient financial resources for renewal of communal infrastructure and housing stock on the energy-efficient basis for almost 30 years, constant conflicts with the Russian Federation on purchase prices for imported natural gas, low income of the majority of households, and inefficient state policy caused the accumulation of many structural problems of the sector that affected the emerging of energy poverty.

The energy poverty of Ukrainians should be considered precisely as the financial inability of households to pay for consumed energy and utilities, rather than as limited access to energy infrastructure, given its high development. Thus, in 2018, 37.4% of Ukrainian families had access to central heating, 45.2% – to individual heating, 80.9% – to water supply, 80.4% – to sewerage, 40.0% – to hot water supply, 77.8% – to the centralised gas supply, 11.7% – to bottled gas, around 100% – to electricity (State, 2019). Currently, the Ukrainian economy is characterised by a high level of energy intensity, which in 2018 exceeded the indicators of the developed countries by 2–4 times and the world average – by 2.08 times. Even compared to the former Soviet Union republics (e.g., Russia and Kazakhstan), the energy intensity of Ukraine's GDP was 1.1–1.3 times higher (Global, 2019). In the meantime, the housing and utilities sector, providing services to the population, is one of the most energy-intensive sectors, consuming more than 30% of the country's energy resources. For instance, in 2017, the share of final energy consumption in the household sector amounted to 32.8% of total final energy consumption by the national economy. This percentage share has increased by more than 22% over the last 10 years (26.8% in 2007). The reasons for the growth are both outdated housing stock and housing and utility infrastructure, which do not meet current energy-efficient requirements and are not updated on time, causing a backlog of the housing and utilities sector in rational resource use from other areas of economic activity. More than 25% of Ukrainian residential buildings are over 60–70 years old, and about 85% of the housing stock was built by the 1990s. At least 70% of buildings need ongoing or major repairs and 90% – complete thermal modernisation (MDL Opinion, 2018; Nova Poltava, 2016; State, 2019). The annual heat losses in the heating of old homes are estimated at up to 400 kWh/year compared to modern energy-efficient analogues with heat losses of 20–25 kWh/year. Therefore, the potential for reducing heat losses reaches 16–20 times.

According to the State Statistics Service (Ukraine), as of 1 January, 2019, the country's housing stock amounted to 993.3 million $m^2$ of total area, with the number of dilapidated and emergency buildings amounting to 45.5 thousand units, in which 59.8 thousand people lived. The most problematic regions were Kharkiv, Zhytomyr, and Odesa regions, with 0.64–0.77% of dilapidated buildings, and Donetsk, Poltava, Cherkasy, and Odesa regions with 0.19–0.21% of emergency housing stock (e.g., almost twicely as high as the national average) (State, 2019). Considering the age and condition of the housing stock, even the most optimistic estimates anticipated that less than 9% of the dwellings today satisfy current energy efficiency requirements, which is explained by the chronic lack of funds of the population and the reluctance of owners to invest in energy-efficiency. The issue of housing and utility infrastructure is not better. About 2/3 of the fixed assets of the sector have exhausted their lifetime, heat losses and water leaks in external networks reach 60%, heat losses in housing stock exceed 30% while obtaining more accurate estimates is complicated by the lack of complete input heat metering in households, who are the largest consumers of heat. Specific energy consumption in Ukraine is about 2.5 times higher than in the EU, while the number of breakdowns in the last decade has increased almost five times (Komelina and Maksimenko, 2014). On average in the country, more than 18% of heat and steam networks and about 35% of water supply networks are considered obsolete and emergency. In comparison, these figures reach 40–54% (particularly in Dnipropetrovsk, Lugansk, and Lviv regions) (State, 2019).

The threatening condition of the housing and utilities infrastructure, which is constantly deteriorating, causes a decrease in the quality of public utilities and increases its cost. As a result, the government is forced to raise energy prices in the face of growing consumer dissatisfaction with the quality of utilities provided and, therefore, a decrease in motivation to pay for consumed services of low quality. Thus, in 2014–2019 prices for such basic energy resources as natural gas and electricity increased almost 12 and 3 times, respectively (Naftogas, 2019; National, 2019b). However, this increase in prices was not accompanied by an adequate increase in the population's real incomes. Thus, in 2014–2015 the real incomes of the population showed a significant fall (to 88.5% and 79.6%, respectively) with the increase of the share of utilities in household expenditures from 10.3 to 12.5% due to a rise in consumer price indices for energy by 134.3% and 203% respectively (Table 1).

**Table 1** Indicators of real incomes of Ukrainian households, its share of total energy expenditures, and utilities (energy) consumer price indices for the population in 2010–2018

| *Year* | *Real disposable households' incomes, % to the corresponding period of the previous year* | *Share of monthly total households' expenditures on housing, water, electricity, gas, and other fuels per household, %* | *Consumer price indices for housing, water, electricity, gas, and other fuels for households, % to December of the previous year* | *Percentage of households with an average per capita equivalent monthly cash income below subsistence minimum** (%) | |
|---|---|---|---|---|---|
| | | | | *Statutory* | *Actual* |
| 2010 | 117.1 | 10.0 | 113.8 | 24.3 | – |
| 2011 | 108.0 | 10.3 | 111.0 | 11.4 | – |
| 2012 | 113.9 | 10.7 | 100.7 | 12.1 | – |
| 2013 | 106.1 | 10.2 | 100.3 | 11.6 | – |
| 2014 | 88.5 | 10.3 | 134.3 | 12.0 | – |
| 2015 | 79.6 | 12.5 | 203.0 | 9.4 | 60.7 |
| 2016 | 102.0 | 16.6 | 147.2 | 9.3 | 63.1 |
| 2017 | 110.9 | 17.7 | 110.6 | 6.4 | 48.0 |
| 2018 | 109.9 | 16.0 | 110.6 | 4.1 | 38.8 |

*The average monthly amount of the statutory subsistence minimum in 2015 was 1227.33 UAH, in 2016 – 1388.08 UAH, in 2017 – 1603.67 UAH, in 2018 – 1744.83 UAH per capita per month; the average monthly actual subsistence minimum in 2015 was 2257.0 UAH, in 2016 – 2642.38 UAH, in 2017 – 2941.46 UAH, in 2018 – 3262.67 UAH per capita per month (State, 2019).

In 2016–2017, the share of utility expenditures of the population continued to increase to 17.7%, with prices rising to 147.2% and 110.6% in 2016 and 2017, respectively. Hence, during 2014–2016, the growth rates of energy and utilities prices were steadily higher than the dynamics of real household incomes (State, 2019), although its growth in 2017–2018 stagnated somewhat (Table 1). However, considering the growth rates of real incomes in 2014–2018, the incomes have not even managed to catch up with rising energy and utility prices. According to official estimates, about 40% of Ukraine's population is below the poverty line, receiving cash income below the actual subsistence level, and could potentially be invested in energy-efficient projects, with the largest share of such population in 2016 (see Table 1). Considering the statutory subsistence level, which is practically half of the actual subsistence minimum, during the last nine years, the population of Ukraine was the poorest one in 2010, 2012, and 2014. Therefore, in a situation where 40 to 60% of the country's households have cash incomes below the subsistence level, it is not advisable to expect large-scale investments in improving the energy efficiency of the residential sector.

A significant obstacle to increasing the energy efficiency of the housing and utilities sector and overcoming energy poverty in Ukraine is the population's mentality, which is accustomed to expecting assistance from the state. It is evidenced by the slow dynamics of the share of condominiums formed (housing cooperatives), building cooperatives, and other bodies of self-organisation of the population in the country's regions that voluntarily undertake the management and maintenance of own housing. Thus, as of October 2019, only 17.6% of all apartment buildings in Ukraine had housing cooperatives, 7% had their own elected governors, 22.7% of the houses got a manager appointed by local self-government bodies according to the results of competitions (Minregion, 2019). The passivity of the population to elect the managers of apartment buildings due to the necessity to incur additional financial costs for the maintenance of common property continues to generate mismanagement and worsens the condition of the housing stock.

In turn, the lack of housing stock's renewal on energy-efficient grounds leads to a vicious circle of energy poverty, the essence of which is described above. Therefore, there is a need to identify and manage the drivers of energy poverty and energy efficiency in the context of providing energy-efficient development of the state and eradicating energy poverty.

## *3.2 Identifying energy poverty and energy efficiency drivers*

To identify long-term trends in energy poverty and energy efficiency of the national economy, it is evaluated the available empirical data with econometric models (1) and (2). The estimation results are presented in Tables 2 and 3.

**Table 2** Relationship between poverty headcount ratio, GDP per capita, gross capital formation, and expenditures for utilities in Ukraine in 1999–2018 (authors' calculations)

| *Source* | *SS* | *df* | *MS* | *Number of obs* | = | *20* |
|---|---|---|---|---|---|---|
| Model | 15808.9745 | 3 | 5269.65 | Prob. > *F* | = | 0.0000 |
| Residual | 1433.90748 | 16 | 89.619 | Adj. *R*-squared | = | 0.9012 |
| Total | 17242.882 | 19 | 907.52 | Root MSE | = | 9.4667 |
| *PR* | *Coef.* | *Std. err.* | *t* | *P>\|t* | *95% Conf.* | *Interval* |
| GDP_pc | –0.059620 | 0.0086136 | –6.92 | 0.000 | –0.0778803 | –0.0413602 |
| GFCF | 2.42e-11 | 3.06e-10 | 0.08 | 0.938 | –6.24e-10 | 6.73e-10 |
| EXU | 3.018121 | 0.9587459 | 3.15 | 0.006 | 0.9856702 | 5.050571 |
| cons | 174.2383 | 16.23436 | 10.73 | 0.000 | 139.823 | 208.6536 |

**Table 3** Relationship between GDP per unit of Energy, GDP per capita, gross capital formation, expenditures for utilities, and crude oil average prices in Ukraine in 1999–2018 (authors' calculations)

| *Source* | *SS* | *df* | *MS* | *Number of obs* | = | *20* |
|---|---|---|---|---|---|---|
| Model | 7.7460 | 4 | 1.93650 | Prob. > *F* | = | 0.0000 |
| Residual | 0.57195665 | 15 | 0.038130444 | Adj. *R*-squared | = | 0.9129 |
| Total | 8.3179 | 19 | 0.437787831 | Root MSE | = | 0.19527 |
| *GDP_E* | *Coef.* | *Std. err.* | *t* | *P>\|t* | *95% Conf.* | *Interval* |
| GDP_pc | 0.001040 | 0.0002478 | 4.20 | 0.001 | 0.0005125 | 0015689 |
| GFCF | –1.57e-11 | 6.34e-12 | –2.47 | 0.026 | –2.92e-11 | –2.15e-12 |
| EXU | 0.1144372 | 0.0225127 | 5.08 | 0.000 | 0.0664524 | 0.1624219 |
| CRO | 0.0066722 | 0.003486 | 1.91 | 0.075 | –0.000758 | 0.0141023 |
| cons | –1.151111 | 0.3811954 | –3.02 | 0.009 | –1.96361 | –0.3386122 |

The regression results (Table 2) indicate that if households' expenditures for utilities grow by one percentage point, the poverty headcount ratio below national poverty lines increases by three percentage points. In our assessment, this outcome shows that the majority of Ukraine's population has low incomes, and therefore the increase in expenditures for utilities causes a disproportionate increase in poverty.

With GDP per capita increasing by 100 USD, there is a decrease in the headcount ratio below the national poverty lines by six percentage points. It confirms our statement about the low incomes of most households that are bordering on poverty. That is, even a slight increase in household incomes has a significant effect on reducing poverty. Instead, gross capital formation is not statistically significant. It does not affect the poverty indicator since investment in the energy efficiency of the residential sector is not a key priority at the current stage of the country's development, so it does not have a significant impact on the dynamics of the population energy poverty.

The results obtained from Table 3 indicate that if GDP per capita increases by 1000 USD, energy efficiency improves by 1 USD per kg of oil equivalent. The obtained empirical result proves that wealthier communities have more resources to invest in energy-saving technologies and thus, have higher energy efficiency ratios. In 2018 the GDP per capita in Ukraine was 3110 USD, and the GDP per unit of energy was 3.75 USD per kg of oil equivalent. The 1000/3110 = 32% increase in GDP per capita is associated on average with 1/3.75 = 26% improvements in the energy efficiency of GDP.

According to the outcomes from the third model, the increment in gross capital formation negatively affects GDP per unit of energy. It means that gross capital formation is not related to energy-saving technologies in Ukraine and even impedes energy-efficient progress. Also, gross capital formation by definition includes construction and different manufacturing costs, which by definition could increase energy consumption.

As households' expenditures for utilities grow by 10 percentage points, the energy efficiency indicator improves by 1 USD per kg of oil equivalent. Each additional percentage of expenditures for utilities (in the structure of total household expenditures) leads to an increase in the energy efficiency of 0.11 USD per kg of oil equivalent.

With rising crude oil average prices by 10 USD, GDP per unit of energy improves by 0.067 USD per kg of oil equivalent.

The results of econometric modelling have confirmed the positive impact of an increase in GDP per capita, expenditures for utilities, and crude oil average prices on improving energy efficiency in the long run. Therefore, increased population well-being is a factor of energy poverty reduction and energy efficiency improvements. In contrast, the investment factor negatively affects energy efficiency, indicating gaps in the state's investment policy and the lack of energy efficiency goals in its priorities, as noted above.

## 4 Discussion

Analysing the aggregate results, it should be indicated that there are some contradictions between achieving the goals of reducing energy poverty and increasing energy efficiency. In this context, the perspective directions of improving state and local policies can be as follows.

*1. Expansion of financing of the 'warm' loan state program for the population.*

In Ukraine, the State Targeted Economic Program for Energy Efficiency and Development of Renewable Energy Sources and Alternative Fuels for 2010–2020 has been working since October 2014 (better known to the public as the 'warm' loan program (CMU, 2010), which provides financial support to every citizen for implementing energy-efficient projects at home. In 2014–2019, more than 700,000 families became participants of the program, attracting 8.2 bln UAH for energy-efficient measures and receiving about 2.7 bln UAH of state compensation. Housing cooperative demand is even more illustrative. In total, over 5000 housing cooperatives across the country have benefited from the program, spending over 1.3 bln UAH in 'warm' loans for energy efficiency activities in multi-apartment buildings. It is worth noting that the average amount of loan taken by a housing cooperative increases annually. These organisations are gradually moving to the implementation of more complex large-scale projects for the thermal modernisation of buildings (SAEE, 2019; Sklyarov, 2019).

In 2017–2018, the government implemented annual monitoring and evaluation of the program's performance. The limited amount of resources given to the program reduces the overall effectiveness of energy-saving measures and increases social tension in society (Sklyarov, 2019; Sotnyk et al., 2019).

Given the current popularity of the 'warm' loan program, it would be advisable to extend it in the coming years and provide low-income families, which are ready to implement energy-efficient changes at home, with additional compensation under the program. It is common in many developed countries, such as Ireland, Estonia, the USA, etc. (DSIRE, 2019; Health, 2017; Lihtmaa et al., 2018). Today, the state program provides 35% compensation for low-income households with 'warm' loans to purchase non-gas or non-electric boilers and energy-efficient equipment or materials not exceeding 12,000 UAH. If a housing cooperative has low-income families, such condominiums are reimbursed at a weighted average of between 40% and 70%, depending on the number of low-income households. Also, in many regions of Ukraine, there are local programs to reduce the cost of 'warm' loans, for which additional compensation (from municipal budgets) is provided for principal amounts or interest on such loans (SAEE, 2019).

To encourage energy-efficient measures in the poorest households, increasing the compensation to 50–70% for these recipients' individual 'warm' loans would be advisable. Moreover, funding for the program for the population should be further expanded. To increase the interest of low-income families in implementing energy-efficient measures and ensuring 100% transition of the population to commercial metering of resources and services consumed, maximum compensation (up to 90%) should be provided for the loans on acquisition and installation metering devices in households. This step will create the preconditions for controlling the resource consumption by the population and potentially justify the indicators of its reduction based on the implementation of the energy-saving measures even by the poorest families.

*2. Maintaining a feed-in tariff for electricity generated by households' renewable energy facilities and the creation of green energy cooperatives.*

The involvement of renewable energy sources in energy generation is one of the ways to increase energy efficiency in the residential sector. It is worth mentioning that the state incentive policy in renewable energy, the main instruments of which are feed-in tariffs, tax, and customs privileges, was introduced in Ukraine in 2009. Still, it was applied only to legal entities (Sotnyk et al., 2019). In 2014, the Law of Ukraine "On electric power industry" (Verkhovna, 1997) was amended, whereby economic incentives were spread to private households' solar and later wind power plants.

These actions have contributed to the activation of renewable energy generation facilities in the residential sector. However, the share of households' green energy assets in the country's energy balance is negligible today. Thus, by the end of 2018, it constituted only 2.3%. The remaining 97.7% of green electricity was generated by commercial high-power renewable energy facilities (National, 2019a). One of the key reasons is the high initial investment in constructing solar and wind power plants, which is overwhelming for the vast majority of the population with low incomes. Thus, only wealthy households and business entities have the opportunity to capitalise on feed-in tariffs, while the poorest citizens are forced to pay a rising price for green electricity since the feed-in tariff is offset by increasing the weighted average electricity price in the wholesale market.

A good way out of the current situation could be preferential lending to renewable energy projects for private households. It should be noted that some steps have already been taken in this direction. Several commercial banks in Ukraine have opened programs aimed at lending to green energy projects, but the lending conditions for such programs are not attractive to the public. Therefore, at the state level, it is advisable to provide additional state compensation for such loans to the poorest households, which would allow them to become participants in the green energy market and increase their incomes.

At the same time, considering the high investment in power plants and other renewable energy facilities, financial state support for each low-income private household can reach 90–95% of the facility cost, which will be an unbearable burden on the state budget. Consequently, it is necessary to extend the preferential terms of obtaining a feed-in tariff for the households at condominiums and building cooperatives, as well as to streamline the legal aspects of the activity of energy cooperatives created by the groups of individuals for the green energy generation (Kurbatova and Hyrchenko, 2018). In this context, it should be possible to create new collective renewable energy facilities for the population and provide increased state compensation for construction loans in proportion to the share of low-income project participants.

*3. Expanding cooperation with international financial institutions to implement energy-efficient reform measures for households and utility suppliers.*

The problem of involving the poor segment of the population in the green energy market could be solved with the help of the European Bank for Reconstruction and Development credit lines opened in Ukraine, namely: Ukraine Sustainable Energy Lending Facility (USELF, 2019), Ukraine Energy Efficiency Programme (UKEEP, 2019) and IQ-energy (2019). However, nowadays, none of these credit programs is applied in the private household sector. Since 7 April, 2016 individuals could participate in the IQ-energy program, but on 10 September, 2018, the validity period of the program was over. Furthermore, lending under this program covered only the purchase of solid fuel biomass boilers, solar collectors, and heat pumps and had no significant impact on the deployment of renewable energy projects in the residential sector. Thereby, a promising way for Ukraine is to renew and expand cooperation with international financial institutions to open new credit lines, even for low-income households with collective participation in energy-efficient projects and utilities suppliers, housing, and building cooperatives.

*4. Abolition of government subsidies for fossil fuels.*

The financial assistance for energy-efficiency improvements in the Ukrainian residential sector should be supported by other organisational and economic measures that will achieve the desired goals. There is the gradual abolition of government subsidies on natural gas, electricity, and heat for the population, which will make it economically feasible to install renewable power plants by private householders and increase the profitability of energy-saving measures. The gradual abolition of government subsidies on energy consumption from nonrenewable has to correspond to the rise of population well-being in order not to create the preconditions for energy poverty.

*5. Strengthening information support for energy-efficient measures in the residential sector.*

Increasing public awareness on the advantages and practicalities of implementing energy-efficient and renewable energy projects as well as on the financial benefits that can be received from selling excess electricity at a feed-in tariff by households could greatly accelerate the enhancement of these projects in the residential sector. Unfortunately, most citizens do not have any clue about loan programs for increasing the energy efficiency of their homes and detailed instructions for its implementation. This deficiency should be corrected as soon as possible. Providing opportunities for every family, even the poorest ones, to capitalise on energy efficiency and renewable energy in the face of rising utility prices and households' expenditures as well as expanding access to low-cost financial resources to implement energy-efficient measures at home will contribute to a comprehensive solution to the problems of energy poverty and ensuring energy efficiency growth of Ukraine's economy. The limitation of the study is related to the fact that based on the example of Ukraine, energy poverty and ensuring energy efficiency drivers are discussed for the whole set of emerging economies.

Future research directions are related to comparing energy poverty and energy efficiency drivers in emerging and developed economies to figure out both common and contrasting factors.

## 5 Conclusions

The paper presents the empirical study of determining the drivers for reducing the population's energy poverty and improving the residential sector's energy efficiency in emerging economies. It contributes to expanding the knowledge of the nature of these phenomena and mechanisms for their management in emerging economies. On the example of Ukraine, which is a typical representative of the country in the energy inefficiency trap, the authors have estimated the tendencies of households' energy poverty and energy efficiency reform development as well as the impact of different factors on their fluctuations.

Regarding the available data, two econometric models have been tested for the period 1999–2018. The first one has revealed the determinants affecting the energy poverty of the population, which have appeared to be the household expenditures for utilities and households' income. The significant findings are that even a slight increment in GDP per capita results in an essential decline in energy poverty level, and the slight decrease in the households' utilities expenditures significantly reduces this indicator. Therefore, any improvements in real incomes of the population due to utilities (Energy) prices reducing, implementing energy-efficient measures at homes, economic stabilisation, and rising wages will greatly contribute to energy poverty descending. In contrast to these outcomes, investment in energy-efficient measures does not play any significant role in poverty declining due to the absence of strong energy efficiency state priorities for the residential sector and lack of finances for these purposes at the national and local levels. The second model has identified the main drivers of energy-efficient changes in Ukrainian households: increasing population incomes, utilities expenditures, and utilities (energy) prices. In contrast, the investment factor has appeared to be a demotivator for energy-efficient development. The last finding has confirmed the absence of strong policy priorities for energy-efficient development of the Ukrainian residential sector.

Rising utilities prices contribute to both the profitability growth of energy-efficient measures and the increment in households' utilities expenditures and, therefore, to escalating energy poverty in the short run. Given the empirical results, it is advisable to expand state energy efficiency programs for the housing and utilities sector of Ukraine, which will provide a significant contribution to reducing energy poverty. However, in the long run, residents' energy-efficient improvements help eliminate the negative impact of utilities (energy) prices and increasing utilities expenses due to significant energy savings of the population.

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## References

Ameli, N. and Brandt, N. (2015) 'Determinants of households' investment in energy efficiency and renewables: evidence from the OECD survey on household environmental behavior and attitudes', *Environmental Research Letters*, Vol. 10, No. 4, Retrieved from https://iopscience.iop.org/article/10.1088/1748-9326/10/4/044015/meta

Bilan, Y., Streimikiene, D., Vasylieva, T., Lyulyov, O., Pimonenko, T. and Pavlyk, A. (2019) 'Linking between renewable energy, $CO_2$ emissions, and economic growth: challenges for candidates and potential candidates for the EU membership', *Sustainability (Switzerland)*, Vol. 11, No. 6, doi:10.3390/su11061528.

Bouzarovski, S. and Petrova, S. (2015) 'A global perspective on domestic energy deprivation: Overcoming the energy poverty – fuel poverty binary', *Energy Research & Social Science*, Vol. 10, pp.31–40, https://doi.org/10.1016/j.erss.2015.06.007.

Bouzarovski, S. and Tirado Herrero, S. (2017) 'The energy divide: integrating energy transitions, regional inequalities and poverty trends in the European Union', *Eur. UrbanReg. Stud.*, Vol. 24, pp.69–86, http://dx.doi.org/10.1177/0969776415596449

Bouzarovski, S., Tirado Herrero, S., Petrova, S. and Ürge-Vorsatz, D. (2016) 'Unpacking the spaces and politics of energy poverty: Path-dependencies, deprivation and fuel switching in post-communist Hungary', *Local Environ.*, Vol. 21, pp.1151–1170, doi: 10.1080/13549839.2015.1075480.

Braubach, M. and Ferrand, A. (2013) 'Energy efficiency, housing, equality and health', *Int. J. Public Health*, Vol. 58, pp.331–332.

Bulkeley, H. and Broto, V.C. (2013) 'Government by experiment? Global cities and the governing of climate change', *Trans. Inst. Br. Georg*., Vol. 38, pp.361–375.

Buzar, S. (2007) 'The 'hidden' geographies of energy poverty in post-socialism: Between institutions and households', *Geoforum*, Vol. 38, No. 2, pp.224–240, https://doi.org/10.1016/j.geoforum.2006.02.007.

Camara, M. (2020) 'Determinants of production-based and consumption-based $CO_2$ emissions: a comparative analysis', *Int. J. Environment and Pollution*, Vol. 67, No. 1, pp.22–47, DOI: 10.1504/IJEP.2020.108362.

Cattaneo, C. (2019) 'Internal and external barriers to energy efficiency: which role for policy interventions?', *Energy Efficiency*, Vol. 12, No. 5, pp.1293–1311, https://doi.org/10.1007/s12053-019-09775-1

Cebula, J., Chygryn, O., Chayen, S.V. and Pimonenko, T. (2018) 'Biogas as an alternative energy source in Ukraine and Israel: current issues and benefits', *International Journal of Environmental Technology and Management*, Vol. 21, Nos. 5–6, pp.421–438, doi:10.1504/IJETM.2018.100592.

Chester, L. and Morris, A. (2012) 'A new form of energy poverty is the hallmark of liberalised energy sectors', *Aust. J. Soc. Issues*, Vol. 46, pp.435–459.

Cirman, A., Mandic, S. and Zorič, J. (2013) 'Decisions to renovate: identifying key determinants in Central and Eastern European post-socialist countries', *Urban Studies*, Vol. 50, pp.3378–3393, 10.1177/0042098013482509.

CMU (2010) *State Targeted Economic Program for Energy Efficiency and Development of Renewable Energy Sources and Alternative Fuels for 2010–2020: Decree of the Cabinet of Ministers of Ukraine (CMU) No. 243*, 01.03.2010, Available online: https://zakon.rada.gov.ua/laws/show/243-2010-п (in Ukrainian) (Accessed 29 December, 2020).

Davis, L.W. and Metcalf, G.E. (2016) 'Does better information Lead to better choices? Evidence from energy-efficiency labels', *Journal of the Association of Environmental and Resource Economists*, Vol. 3, No. 3, pp.589–625.

DSIRE (2019) *Find Policies & Incentives by State*, Available online: https://www.dsireusa.org/ (Accessed 17 December, 2019).

Dubois, U. and Meier, H. (2016) 'Energy affordability and energy inequality in Europe: Implications for policymaking', *Energy Res. Soc. Sci.*, Vol. 18, pp.21–35, doi: 10.1016/j.erss.2016.04.015.

Estache, A., Wodon, Q. and Foster, V. (2002) *Accounting for Poverty in Infrastructure Reform: Learning from Latin America's Experience*, World Bank, Washington DC.

Fankhauser, S., Rodionova, Y. and Falcetti, E. (2008) 'Utility payments in Ukraine: affordability, subsidies and arrears', *Energy Policy*, Vol. 6, pp.4168–4177.

Fankhauser, S. and Tepic, S. (2007) 'Can poor consumers pay for energy and water? An affordability analysis for transition countries', *Energy Policy*, Vol. 35, pp.1038–1049.

Filippini, M. and Hunt, L.C. (2011) 'Energy demand and Energy efficiency in the OECD Countries: A stochastic demand frontier approach', *Energy J.*, Vol. 32, pp.59–80, doi: 10.5547/ISSN0195-6574-EJ-Vol32-No2-3.

Filippini, M. and Hunt, L.C. (2012) 'US residential energy demand and energy efficiency: a stochastic demand frontier approach', *Energy Economics*, Vol. 34, pp.1484–1491, doi: 10.1016/j.eneco.2012.06.013.

Foster, V., Tre, J-P. and Wodon, Q. (2000) *Energy Prices, Energy Efficiency and Fuel Poverty*, World Bank, Washington DC.

Gerbery, D. and Filčák, R. (2014) 'Exploring multi-dimensional nature of poverty in Slovakia: access to energy and concept of energy poverty', *EkonomickỳČasopis*, Vol. 18, pp.579–597.

Gillingham, K. and Palmer, K. (2014) 'Bridging the energy efficiency gap: policy insights from economic theory and empirical evidence', *Review of Environmental Economics and Policy*, Vol. 8, No. 1, pp.18–38.

Gillingham, K., Newell, R.G. and Palmer, K. (2009) 'Energy efficiency economics and policy', *Annual Review of Resource Economics*, Vol. 1, No. 1, pp.597–620.

Global (2019) *Global Energy Statistical Yearbook 2019*, Available online: https://yearbook.enerdata.net/total-energy/world-energy-intensity-gdp-data.html (Accessed 20 December, 2019).

González-Eguino, M. (2015) 'Energy poverty: an overview', *Renewable and Sustainable Energy Reviews*, Vol. 47, pp.377–385, https://doi.org/10.1016/j.rser.2015.03.013

Health (2017) *Health Service Executive Minister Naughten announces €10 m for Warmth & Wellbeing in 2017*, Available online: https://www.hse.ie/eng/services/news/media/pressrel/minister-naughten-announces-€10m-for-warmth-wellbeing-in-2017.html (Accessed 16 December, 2019).

Hernández, D. and Bird, S. (2010) 'Energy burden and the need for integrated low-income housing and energy policy', *Poverty Public Policy*, Vol. 2, No. 4, pp.5–25, doi: 10.2202/1944-2858.1095.

Herrero, S.T. and Ürge-Vorsatz, D. (2012) 'Trapped in the heat: a post-communist type of fuel poverty', *Energy Policy*, Vol. 49, pp.60–68.

Hills, J. (2012) *Getting the Measure of Fuel Poverty: Final Report of the Fuel Poverty Review*, London School of Economics and Political Science, CASE Report 72, London, UK.

Houde, S. (2018) 'How consumers respond to product certification and the value of energy information', *RAND Journal of Economics*, Vol. 49, No. 2, pp.453–477.

Ilyash, O., Hrynkevych, S., Ilich, L., Kozlovskyi, S. and Buhaichuk, N. (2020) 'Economic assessment of the relationship between housing and communal infrastructure development factors and population quality of life in Ukraine', *Montenegrin Journal of Economics*, Vol. 16, No. 3, pp.93–108, http://doi.org/10.14254/1800-5845/2020.16-3.8

IQ-energy (2019) Available online: http://www.iqenergy.org.ua (Accessed 12 December, 2020).

Jin, T. and Kim, J. (2019) 'A comparative study of energy and carbon efficiency for emerging countries using panel stochastic frontier analysis', *Scientific Reports*, Vol. 9, p.6647, https://doi.org/10.1038/s41598-019-43178-7

Kaygusuz, K. (2011) 'Energy services and energy poverty for sustainable rural development', *Renewable and Sustainable Energy Reviews*, Vol. 15, No. 2, pp.936–947, https://doi.org/10.1016/j.rser.2010.11.003

Kerimray, A., de Miglio, R., Rojas-Solórzano, L. and Ó Gallachóir, B.P. (2018) 'Causes of energy poverty in a cold and resource-rich country: evidence from Kazakhstan', *Local Environment*, Vol. 23, No. 2, Published Online: 5 November, 2017, https://doi.org/10.1080/13549839.2017.1397613

Komelina, O.V. and Maksimenko, O.S. (2014) 'Modern factors for regional energy policy formation in housing and communal sector of Ukraine', *Economics and Organization of Management*, 1(17)–2(18), pp.129–137 (in Ukrainian).

Korppoo, A. and Korobova, N. (2012) 'Modernizing residental heating in Russia: End-use practices, legal developments, and future prospects', *Energy Policy*, Vol. 42, pp.213–220, DOI: 10.1016/j.enpol.2011.11.078.

Kubatko, O. and Kubatko, O. (2017) 'Economic Estimations of Pollution Related Cancer and Nerves Morbidity', *International Journal of Ecology & Development*, Vol. 32, No. 1, pp.33–43.

Kubatko, O. and Kubatko, O. (2019) 'Economic estimations of air pollution health nexus, *Environment, Development and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development*, Springer, Vol. 21, No. 3, June, pp.1507–1517, https://doi.org/10.1007/s10668-018-0252-6

Kubatko, O. and Kubatko, O. (2019) 'Economic estimation so fair pollution health nexus', *Environment, Development and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development*, Springer, Vol. 21, No. 3, June, pp.1507–1517, https://doi.org/10.1007/s10668-018-0252-6

Kurbatova, T. and Hyrchenko, Ye. (2018) 'Energy co-opsas a driverfor bio-energy sector growth in Ukraine', *IEEE 3rd International Conference on Intelligent Energy and Power Systems (IEPS)*, Kharkiv, Ukraine, 10–14 September, pp.210–213, https://doi.org/10.1109/IEPS.2018.8559516.

Legendre, B. and Ricci, O. (2015) 'Measuring fuel poverty in France: which households are the most fuel vulnerable?', *Energy Econ.*, Vol. 49, pp.620–628, doi: 10.1016/j.eneco.2015.01.022.

Li, R., Sineviciene, L., Melnyk, L., Kubatko, O., Karintseva, O. and Lyulyov, O. (2019) 'Economic and environmental convergence of transformation economy: the case of China', *Problems and Perspectives in Management*, Vol. 17, No. 3, pp.233–241, http://dx.doi.org/10.21511/ppm.17(3).2019.19

Lihtmaa, L., Hess, D.B. and Leetmaa, K. (2018) 'Intersection of the global climate agenda with regional development: unequal distribution of energy efficiency-based renovation subsidies for apartment buildings', *Energy Policy*, Vol. 119, pp.327–338, https://doi.org/10.1016/j.enpol.2018.04.013

Lyeonov, S., Pimonenko, T., Bilan, Y., Štreimikiene, D. and Mentel, G. (2019) 'Assessment of green investments' impact on sustainable development: linking gross domestic product per capita, greenhouse gas emissions and renewable energy', *Energies*, Vol. 12, No. 20, doi: 10.3390/en12203891.

Maxim, A., Mihai, C., Apostoaie, C-M., Popescu, C., Istrate, C. and Bostan, I. (2016) 'Implications and measurement of energy poverty across the European Union', *Sustainability, MDPI*, Vol. 8, No. 5, pp.1–20.

MDL Opinion (2018) *Housing Fund of Ukraine – Statistics, Problems, Ways of Recovery*, Available online: https://mdl.kyiv.ua/dumka-mdl-zhitlovij-fond-ukrayini-statistika-problemi-shlyahi-ozdorovlennya/ (in Ukrainian) (Accessed 20 December, 2020).

Melnyk, L., Kubatko, O., Dehtyarova, I., Matsenko, O. and Rozhko, O. (2019) 'The effect of industrial revolutions on the transformation of social and economic systems', *Problems and Perspectives in Management*, Vol. 17, No. 4, pp.381–391, doi:10.21511/ppm.17(4).2019.31.

Melnyk, L.G., Kubatko, O.V. and Kubatko, O.V. (2016) 'Were Ukrainian regions too different to start interregional confrontation: economic, social and ecological convergence aspects?', *Economic Research-EkonomskaIstrazivanja*, Vol. 29, No. 1, pp.573–582, doi: 10.1080/1331677X.2016.1174387.

Mihalcova, B., Koraus, A., Prokopenko, O., Hvastova, J., Frenákova, M., Gallo, P. and Beata, B. (2021) 'Effective management tools for solving the problem of poverty in relation to food waste in context of integrated management of energy', *Energies*, Vol. 14, p.4245, https://doi.org/10.3390/en14144245

Minregion (2019) *AlyonaBabak noted the Irreversibility of the Creation of Condominiums in Ukraine*, Available online: http://www.minregion.gov.ua/press/news/alona-babak-konstatuvala-nezvorotnist-protsesiv-stvorennya-osbb-v-ukrayini/ (in Ukrainian) (Accessed 20 December, 2019).

Mlaabdal, S.M.A., Chygryn, O., Kubatko, O. and Pimonenko, T. (2018) 'Social and economic drivers of national economic development: the case of OPEC countries', *Problems and Perspectives in Management*, Vol. 16, No. 4, pp.155–168, doi:10.21511/ppm.16(4).2018.14.

Mokiy, A., Ilyash, O., Pynda, Y., Pikh, M. and Tyurin, V. (2020) 'Dynamic characteristics of the interconnections urging the construction enterprises development and regions economic growth', *TEM Journal*, Vol. 9, No. 4, pp.1550–1561, DOI: https://doi.org/10.18421/TEM94-30

Naftogas (2019) *Dynamics of Natural Gas Prices for Ukrainian Consumers*, Available online: http://www.naftogaz.com/files/Information/Dynamika-cina-2014-2018-Naselennya.pdf (in Ukrainian) (Accessed 27 December, 2020).

National (2019a) *National Energy and Utilities Regulatory Commission of Ukraine*, Available online: https://www.nerc.gov.ua/?id=15013 (in Ukrainian) (Accessed 27 December, 2019).

National (2019b) *National Energy and Utilities Regulatory Commission of Ukraine: Report on the results of National Energy and Utilities Regulatory Commission's activity in 2018*, decree No. 440, 29.03.2018, Available online: http://www.nerc.gov.ua/data/filearch/Catalog3/Richnyi_zvit_NKREKP_2018.pdf (in Ukrainian) (Accessed 28 December, 2019).

Newell, R.G. and Siikamäki, J. (2014) 'Nudging energy efficiency behavior: the role of information labels', *Journal of the Association of Environmental and Resource Economists*, Vol. 1, No. 4, pp.555–598.

Nova Poltava (2016) *About 90% of Multiapartment Stores need Thermomodernization in Ukraine*, Available online: http://www.nova.poltava.ua/v-ukra%D1%97ni-blizko-90-bagatopoverxivok-potrebuyut-termomodernizaci%D1%97/ (in Ukrainian) (Accessed 26 December, 2019).

Okushima, S. (2016) 'Measuring energy poverty in Japan, 2004–2013', *Energy Policy*, Vol. 98, No. C, pp.557–564.

Papada, L. and Kaliampakos, D. (2016) 'Measuring energy poverty in Greece', *Energy Policy*, Vol. 94, pp.157–165, https://doi.org/10.1016/j.enpol.2016.04.004.

Petrova, S., Gentile M., Mäkinen, I.H. and Bouzarovski, S. (2013) 'Perceptions of thermal comfort and housing quality: exploring the microgeographies of energy poverty in Stakhanov, Ukraine', *Environment and Planning*, Vol. 45, pp.1240–1257, doi:10.1068/a45132.

Phimister, E., Vera-Toscano, E. and Roberts, D. (2015) 'The dynamics of energy poverty: evidence from Spain', *Econ. Energy Environ. Policy*, p.4, doi: 10.5547/2160-5890.4.1.ephi.

Poputoaia, D. and Bouzarovski, S. (2010) 'Regulating district heating in Romania: legislative challenges and energy efficiency barriers', *Energy Policy*, Vol. 38, No. 7, pp.3820–3829, https://doi.org/10.1016/j.enpol.2010.03.002

Prokopenko, O., Toktosunova, C., Sharsheeva, N., Zablotska, R., Mazurenko, V. and Halaz, L. (2021) 'Prospects for the Reorientation of Investment Flows for Sustainable Development under the Influence of the COVID-19 Pandemic [Perspektywy reorientacji przepływów inwestycyjnych na rzecz zrównoważonego rozwoju w warunkach pandemii covid-19]', *Problemy Ekorozwoju*, Vol. 16, No. 2, pp.7–17, http://doi.org/10.35784/pe.2021.2.01

Pye, S., Dobbins, A., Baffert, C., Brajkovi'c, J., Grgurev, I., Miglio, R.D. and Deane, P. (2015) *Energy Poverty and Vulnerable Consumers in the Energy Sector across the EU: Analysis of Policies and Measures*, INSIGHT_E, Brussels, Belgium.

SAEE (2019) *State Agency on Energy Efficiency and Energy Saving of Ukraine. State Support for Energy Saving*, Available online: http://saee.gov.ua/uk/consumers/derzh-pidtrymka-energozabespechenya (in Ukrainian) (Accessed 29 December, 2019).

Sardianou, E. and Genoudi, P. (2013) 'Which factors affect the willingness of consumers to adopt renewable energies?', *Renewable Energy*, Vol. 57, pp.1–4.

Shkola, V., Prokopenko, O., Stoyka, A., Nersesov, V. and Sapiński, A. (2021) 'Green project assessment within the advanced innovative development concept', *Estudios de Economia Aplicada*, Vol. 39, No. 5, https://doi.org/10.25115/eea.v39i5.5135

Sineviciene, L., Kubatko, O.V. and Sotnyk, I.M. (2017) 'Determinants of energy efficiency and energy consumption of Eastern Europe post-communist economies', *Energy & Environment*, Prepublished 9 October, 2017, DOI: 10.1177/0958305X17734386.

Sklyarov, R. (2019) *Warm Loans: Should the Government Continue to Pay*, Available online: https://www.epravda.com.ua/rus/publications/2019/11/6/653367 (Accessed 26 December, 2020).

Sotnyk, I., Dehtyarova, I. and Kovalenko, Y. (2015) 'Current threats to energy and resource efficient development of Ukrainian economy', *Actual Problems of Economics*, Vol. 11, No. 173, pp.137–145.

Sotnyk, I., Kurbatova, T., Dashkin, V. and Kovalenko, Y. (2019) 'Green energy projects in households and its financial support in Ukraine', *International Journal of Sustainable Energy*, https://doi.org/10.1080/14786451.2019.1671389

State (2019) State Statistics Service of Ukraine. Available online: http://www.ukrstat.gov.ua. (Accessed 20 December, 2019).

Thomson, H., Snell, C. and Bouzarovski, S. (2017) 'Health, well-being and energy poverty in Europe: a comparative study of 32 European countries', *Int. J. Environ. Res. Public Health*, Vol. 14, No. 6, doi: 10.3390/ijerph14060584.

Thonipara, A., Runst, P., Ochsner, C. and Bizer, K. (2019) 'Energy efficiency of residential buildings in the European Union – an exploratory analysis of cross-country consumption patterns', *Energy Policy*, Vol. 129, No. C, pp.1156–1167, DOI: 10.1016/j.enpol.2019.03.003.

Trofymenko, O., Shevchuk, O., Koba, N., Tashcheiev, Y. and Pavlenco, T. (2021) 'Knowledge and innovation management for transforming the field of renewable energy', in Solanki, A., Sharma, S.K., Tarar, S., Tomar, P., Sharma, S. and Nayyar, A. (Eds.): *Artificial Intelligence and Sustainable Computing for Smart City. AIS2C2 2021, Communications in Computer and Information Science*, Vol. 1434, Springer, Cham, https://doi.org/10.1007/978-3-030-82322-1_6

Trotta, G. (2018) 'Factors affecting energy-saving behaviours and energy efficiency investments in British households', *Energy Policy*, Vol. 114, No. C, pp.529–539.

UKEEP (2019) *Ukraine Energy Efficiency Programme*, Available online: http://www.ukeep.org (Accessed 14 December, 2019).

UNECE (2009) *Toward Energy-Efficient Housing: Prospects for UNECE Member States*, Committee on Housing and land Management, United Nations Economic Commission for Europe, Geneva.

Urge-Vorsatz, S. and Tirado Herrero, D. (2012) 'Building synergies between climate change mitigation and energy poverty alleviation', *Energy Policy*, Vol. 49, pp.83–90.

USELF (2019) *Ukraine Sustainable Energy Lending Facility*, Available online: http://www.uself.com.ua (Accessed 12 December, 2019).

Vasylieva, T., Lyulyov, O., Bilan, Y. and Streimikiene, D. (2019) 'Sustainable economic development and greenhouse gas emissions: the dynamic impact of renewable energy consumption, GDP, and corruption', *Energies*, Vol. 12, No. 17, doi: 10.3390/en12173289.

Verkhovna (1997) *Verkhovna Rada of Ukraine: Law of Ukraine "On electric power industry"*, No. 575/97, Available online: http://zakon3.rada.gov.ua/laws/show/575/97-%D0%B2%D1%80 (in Ukrainian) (Accessed 24 December, 2019).

Voitko, S., Trofymenko, O. and Pavlenco, T. (2021) 'Decarbonisation of the economy through the introduction of innovative technologies into the energy sector', *E3S WebConf., Vol. 255, International Conference on Sustainable, Circular Management and Environmental Engineering (ISCMEE 2021)*, pp.1–11, https://doi.org/10.1051/e3sconf/202125501016