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Q1HTSC Superconducting Bi-Pb-Sr-Ca-Cu-O and MgB_2 Compositions Fabricated by Hot Shock Wave Consolidation and Solar Melt Quenching Technologies

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ABSTRACT

The possibility of increasing of the critical temperatures T_c of superconducting precursors in samples of Bi-Pb-Sr-Ca-Cu-O and MgB_2 superconducting systems, fabricated using hot shock wave consolidation technology (HSWC) and solar energy for melting, and following superfast quenching of the melt, was investigated using vibrating torsional magnetometry methods. By using HSWC technology for the synthesis of Bi-Pb-Sr-Ca-Cu-O samples, the critical temperature T_c of potential superconducting precursor transition to a superconducting state was increased from T_c=107 K in the starting sample, to T_c=138 K.

In the Bi-Pb-Sr-Ca-Cu-O superconducting system samples, synthesized using solar energy for the melting and following superfast quenching of the melt, superconducting precursors with T_c more than 200 K were detected. The analysis of the nature of the obtained dependences, and their comparison with other available results associated with the processes in the vicinity of critical temperature T_c, allows one to conclude that there is a possibility for the existence of high-temperature superconducting precursors with T_c more than 200 K in samples of this system.

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Introduction

After the epoch-making discovery of high-temperature superconductors (HTSC) by Müller and Bednorz in 1986, significant efforts have been devoted worldwide to further increase the critical temperature of superconducting transition T_c, with the aim of reaching room temperature. The use of HTSCs with a T_c higher than those currently used (YBaCuO and MgB_2, for example) would lead to the development of new technological advances, opening up numerous opportunities in electronics and energetics.

From this point of view, the Bi-Pb-Sr-Ca-Cu-O system attracts particular interest, as it is characterized by high T_c=107 K and the record-high second critical magnetic field H_{c2} ~ 150 T. According to some studies (Yu *et al*., 2019; Pelc *et al.,* 2018; Pelc *et al.*, 2019), the universal behavior of the superconducting (SC) precursor was revealed, signifying the proliferation of SC clusters as a result of the inherent intrinsic inhomogeneity of cuprates. Understanding its nature is very important for the fabrication of new HTSC materials with a T_c close to room temperature.

The nature of the SC precursors in the cuprates has been the subject of numerous investigations. Different superconducting experimental methods have led to different conclusions on the temperature range of superconducting fluctuations. The main challenge was in the separation of the SC response from complex normal state behavior. For this aim a torque magnetometry method was used (Yu *et al*., 2019), which is a unique thermodynamical probe with extremely high sensitivity to SC diamagnetism. In torque magnetometry, the magnetization M is deduced from the mechanical torque $\tau = M\ H \sin\alpha$, where α is the angle between M and H, experienced by a crystal in an external magnetic field H. The torque is measured as a function of temperature (T), magnetic field strength (H), and orientation of the sample with respect to the field direction. This approach completely removes normal-state contributions, allowing one to trace the diamagnetic signal above T_c with great precision. As discussed in Yu *et al*. (2019), one could understand the unusual emergence of the SC precursors by noting that the cuprates are lamellar, perovskite-derived materials that are intrinsically inhomogeneous at the nanoscale distances. Evidence for the inhomogeneity was observed in scanning tunneling microscopy (STM) and nuclear magnetic resonance (Yu *et al*., 2019). Consequently, some of the spatially inhomogeneous SC gaps “survive” in the form of the SC precursor clusters at temperatures well above T_c. As the temperature decreases, these SC precursor clusters proliferate and grow in size, and eventually percolate near T_c.

In works (Chigvinadze *et al.*, 2018; Mamniashvili *et al.*, 2015; Gegechkori *et al.,* 2017; Gulamova *et al.,* 2012), two special technologies were discussed which were applied to synthesize HTSC samples with increased local inhomogeneities. The first of them is HSWC technology (Chigvinadze *et al.*, 2018), which was successfully applied for the fast fabrication of superconducting MgB_2 samples, avoiding long-time solid-state reaction procedures (Mamniashvili *et al.*, 2015; Gegechkori *et al.,* 2017). HSWC technology was used for the modification of microstructure, the introduction of efficient pinning centers, and the enhancement of the intrinsic inhomogeneity of HTSC samples.

One more special technology applied to synthesize HTSC samples with the increased local inhomogeneities is the solar fast alloy quenching technology (SFAQ-T) discussed in Gulamova *et al.* (2012). Based on glass-crystal and X-ray amorphous precursors, the HTSC samples were synthesized by quenching a melt produced by the heating of precursors with the solar radiation at low temperatures. The decomposition-resistant textured superconducting samples of $Bi_{1.7}Pb_{0.3}Sr_2Ca_{(n-1)}Cu_nO_{10-y}$ (n=2-30) systems with the critical temperatures of the superconducting transitions more than 200 K were fabricated (Chigvinadze *et al.*, 2017).

To determine the critical temperatures of the SC transitions Tc of the samples obtained by both technologies, the original torsional oscillation magnetometry method in applied magnetic fields was realized using an automated multipurpose device (Ashimov & Chigvinadze, 2002), having sensitivity comparable with that of a SQUID magnetometer. The investigation of the potential possibilities of the vibrating reed (VR) magnetometry method for similar aims was carried out in other works (Chigvinadze *et al.*, 2019; Esquinazi, 1991).

Results and Discussion

1. Superconducting Precursors in Bi-Pb-Sr-Ca-Cu-O Compositions Fabricated by HSWC Technology

Following the work Chigvinadze *et al.* (2018), the novelty of the proposed HSWC technology is in the consolidation of high-density bulk samples from the mixtures of the superconducting powders, with dimensions of the order of Æ~2-5 mm, L~ 50-70 mm. The process of consolidation was performed in two stages: First, the explosive pressing of powder precursor mixtures was made at

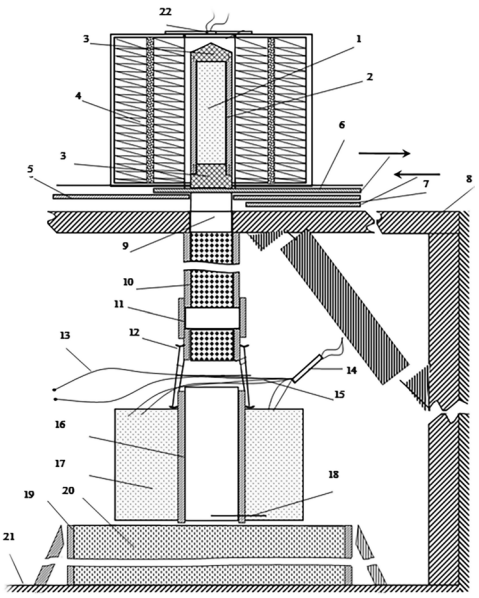

Fig. 1. Set-up of hot explosive consolidating device.

1. Consolidating powder material; 2. Cylindrical steel container, 3. Plugs of steel container, 4. Heating nichrome wires of furnace, 5. Opening and closing movement of furnace, 6. Opening sheet of furnace, 7. Closing sheet of furnace, 8. Basic steel construction of device, 9. Steel feeding tube for samples. 10. Movement tube for heated container, 11. Connecting tube from rub, 12. Accessory for fixing explosive charge, 13. Circle fixing passing of cylindrical ampoule, 14. Electric detonator to initiate, 15. Detonation cord, 16. Flying tube, thermo-isolator, 17. Explosive material charge, 18. Hard metal limiter for fixing the limit state of the ampoule, 19. Exploded cylindrical ampoule receptor, 20. Inert sand, 21. Experimental camera support floor, 22. Thermocouple.

room temperature, with 5-20 GPa loading to increase the initial density and to activate the surfaces of the mixture particles. At the next stage, an obtained cylindrical sample was pressed by an explosive wave pressure of 5-10 GPa at 700-800°C.

The experimental set-up is presented in Figure 1. (Gegechkori *et al*., 2017).

The study of superconducting characteristics shows that after the explosive wave, the material retains superconductivity and the explosive pressing of powder precursor mixtures at room temperature, with 5 GPa, 7 GPa, and 12 GPa pressure loading, does not significantly change the superconducting state of the material. After the explosion, a pronounced texture was formed, which, with the increased temperature of up to 700-800°C at the same applied pressures, could result in the increase of T_c.

The T_c of superconducting transitions were measured using the original supersensitive magneto-mechanical torsional method, through an automated multipurpose device (Ashimov & Chigvinadze, 2002), having sensitivity comparable with that of a SQUID magnetometer. The investigations were carried out operating at low-frequency axially-torsion oscillations (0.1÷1 Hz) in a permanent magnetic field with the strength H, and demonstrated a significant background effect on the experiment, the value of H, the initial orientation of the sample, and the direction of the temperature variation of a sample (cooling or warming) on the obtained results.

The method of axial-torsion oscillations magnetometry was firstly used for the investigation of energy losses (dissipation) in the mixed state of hard superconductors (Ashimov & Chigvinadze, 2002), when a high sensitivity of the torsion system (10^{-17} W) was shown. Using this method, the superconducting phase transition temperature T_c was determined not only by the frequency $\omega=2\pi/t$ of the superconductor oscillating in a permanent magnetic field H, but also by the character of the dissipative process $\delta(T)$ dependence, where δ is the logarithmic decrement of the attenuation of oscillations. These two characteristics t(T) and $\delta(T)$, being measured in parallel, complement each other and provide information on the presence or absence of the magnetic vortex threads in a sample within the study, allowing one to judge the SC state of a sample.

In Figure 2 the results of T_c measurements by the low-frequency torsional magnetometry method for the starting superconducting sample Bi-Pb-Sr-Ca-Cu-O (2223). As is seen, this method gives T_c=107 K. Figure 2 presents the temperature dependence of the oscillation period t of the suspension system, with a superconducting sample suspended by a thin elastic thread and performing axial-torsional oscillations in a magnetic field directed perpendicular to the axis of the superconducting cylinder for the HTSC system Bi/Pb (2223) sample, synthesized by HSWC technology at P≈5 Gpa, 7 gPa and 12 GPa.

Figure 3 shows that at the application of P≈5 Gpa, the critical temperature of transition into superconductive state T_c increases from T_c=107 K up to T_c=115 K (the increase by 8 degrees), the HSWC with P≈7 GPa makes T_c=130 K (the increase by 23 degrees) and the HSWC with P=12 GPa makes T_c=138 K (the increase by 31 degrees).

The use of the HSWC for the creation of new superconducting materials will allow one to synthesize such HTSC systems in which the

critical parameters of superconductors can be significantly increased.

The application of a shock wave method for induced enhancement of T_c in superconducting $Bi_{23}Sr_2CaCu_2O_{8+d}$ was also reported by Liu *et al*. (2017). It was further found that T_c increases from 84 K for a pristine sample to 94 K for the sample treated at temperature 1200 K and pressure 31 GPa.

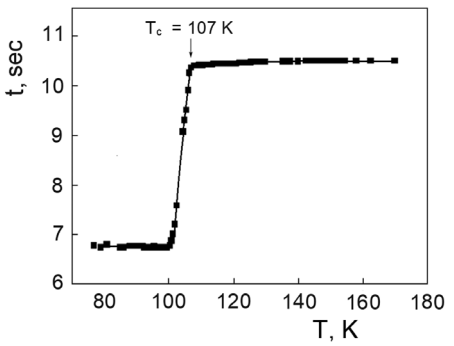

Fig. 2. The temperature dependence of the oscillation t of initial superconducting sample $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_{10-d}$ (2223) suspended by a thin elastic thread and making axial torsional oscillations in a transverse magnetic field, H = 250 Oe.

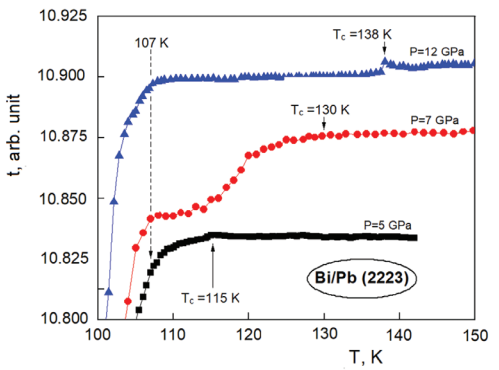

Fig. 3. Dependence of period t on temperature T of superconducting sample suspended on a thin elastic thread and making axial-torsional oscillation in a transverse magnetic field, at P~5 GPa, P~7 GPa and P~12 GPa.

2. Hot Shock Wave Fabrication of Hybrid Superconductive MgB_2 Composites

The rapid development of research of the conductors based on superconducting compound MgB_2 makes them a very real prospect for technical applications at temperatures below 30 K.

Reported achievements of all higher values of the critical current density in wires and tapes at moderate magnetic fields (Jiang *et al*., 2005; Holcomb, 2005) lay out strong hope that soon these conductors may be more economical at helium temperatures than industrial wires and cables based on NbTi and Nb_3Sn.

In the field of applied superconductivity, at temperatures 20–30 K MgB_2 based conductors may seriously push out industrial tape-based high-temperature superconductor (HTSC) materials.

The main way to obtain MgB_2 is a solid-phase synthesis in particular modifications. An example, and one of the most fruitful ones, is synthesis under high pressure (Priknha *et al*., 2003). As HTSC ceramics, compound MgB_2 is brittle and therefore cannot be directly manufactured in the form of wire or ribbon. The most widely used method now to manufacture conductors based on MgB_2 (as for HTSC ceramics) is the method "powder-in-tube" (PIT) (Mamalis *et al.,* 2004). It is mainly used in two ways: in situ and ex situ. In the PIT method, a thoroughly mixed stoichiometric mixture of magnesium and boron powders are pressed into a metallic tube, after which it runs into the wire. A superconducting core of MgB_2 wire is the final result of wire annealing in the average temperature range of 600-950°C. In ex situ PIT method,

in contrast, a metal tube filled with already provisionally synthesized compound MgB_2 is stretched into the wire. Both options have their advantages and disadvantages.

In the work of Daraselia *et al.* (2013), a novel method of photo-stimulated solid-state synthesis of oxide materials was developed, enabling a dramatic increase in the solid-state reaction speed. The rate of solid-state reaction appears to be approximately two orders of magnitude higher compared with an ordinary high-temperature solid-state reaction performed in a furnace. The experimental results given in the work of Daraselia *et al.* (2013), provide evidence of the photo-stimulated nature of the performed solid-state reaction, and demonstrate the possibility of production of HTSC and CMR oxides by way of light that is usually limited by the sample thickness - one can reasonably expect this method to be particularly effective in the preparation of oxide films of a high-technological importance.

The paper by Mamniashvili *et al.* (2015) presents the first results of the investigation of the properties of superconducting MgB_2 samples obtained through the hot shock-wave compaction (HSWC) method. Through this method, a similar effect for increasing the speed of solid-state reaction, as in case of using photo-stimulated solid-state synthesis, was obtained. Further, due to the high penetrating capability of shock-waves generated by explosion with intensity of compression 10 GPa, this method allows one to fabricate bulk, high-density and long-body cylindrical billets with a length near to 200 mm and diameter up to 30 mm. The HSWCs of cylindrical billets were conducted using a semi-automatic explosive device created at the Tsulukidze Institute of Mining, allowing one to consolidate different composition precursors near the theoretical density within the temperature range 20- 1200°C, and with an intensity of loading of 5-10 GPa.

The described HSWC method also allows one to produce multilayer cylindrical tubes (pipes) when the gap between the two metallic layers (e.g., Cu) is filled by superconducting MgB_2 composites, a fact which could have important applications in the production of superconducting cables for the simultaneous transport of hydrogen and electrical power in hybrid MgB_2-based electric power transmission lines filled with liquid hydrogen (Gegechkori *et al.,* 2017).

The novelty of the proposed nonconventional approach relies on the fact that the consolidation of solid high-density, long-body cylindrical MgB_2 billets from submicrometer-sized Mg and B powder blends is performed in two stages:

1. At the first stage, a preliminary explosive compression of the precursors is carried out at room temperature, with a loading intensity of 5-10 GPa to increase the initial density and to activate surfaces in the powder blend.

2. At the second stage, the same already pre-densified cylindrical sample is reloaded by a primary explosive shock wave, with a loading intensity of 10 GPa, but at temperatures of around 1000°C.

The first successful HSWC of Mg-B powder blends was performed at 1000°C, with the above-the-melting-point of Mg phase at loading intensity 10 GPa providing the critical temperature of the superconductive transition T_c near 37 K (Figure 4b).

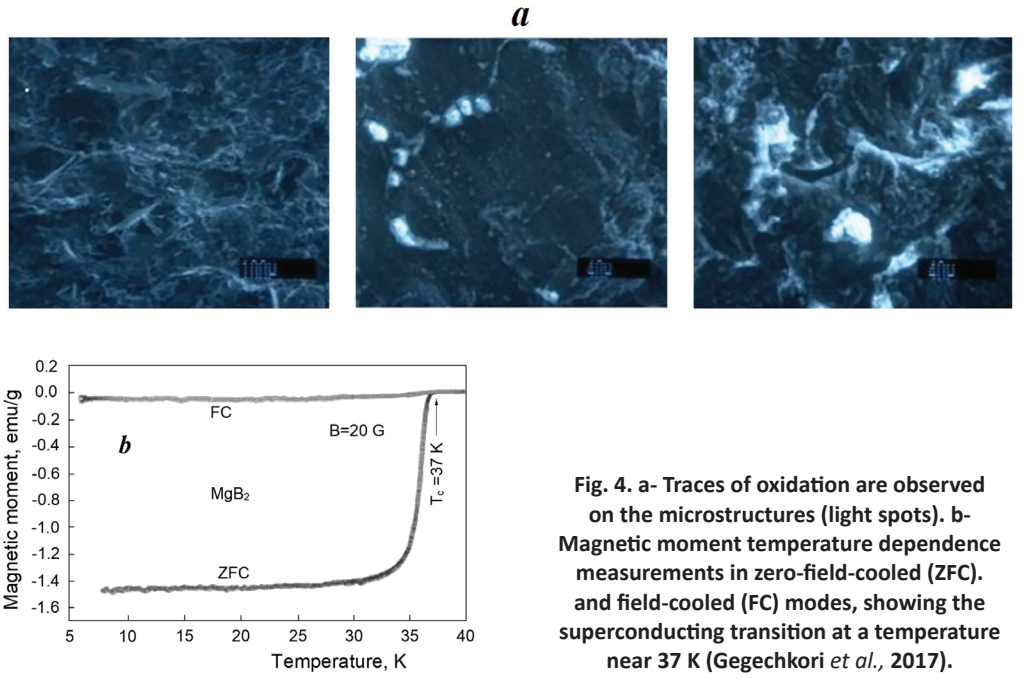

Fig. 4. a- Traces of oxidation are observed on the microstructures (light spots). b- Magnetic moment temperature dependence measurements in zero-field-cooled (ZFC). and field-cooled (FC) modes, showing the superconducting transition at a temperature near 37 K (Gegechkori *et al.,* 2017).

The above confirms the important role of temperature in the formation of the superconductive MgB_2 phase in the whole volume of the sample, and corresponds with the literature data, where only after sintering processes above 900°C does the formation of MgB_2 phase with T_c =40 K take place. The difference of T_c between the HSWC and sintered MgB_2 composites may be explained by the rest period given to the non-reacted Mg and B phases or the existence of oxides in the precursors Figure 4a.

This could be checked by increasing the HSWC temperature or applying further sintering processes. The careful selection of the initial Mg and B phases is also important, and with the consolidation of the Mg-B precursors with the abovementioned corrections, the chance to increase T_c in the HSWC samples essentially increases.

In Figure 5, the views of MgB_2 billets in steel jackets after the previous densification (Figure 5a) and after the HEC procedure (Figure 5b), are shown.

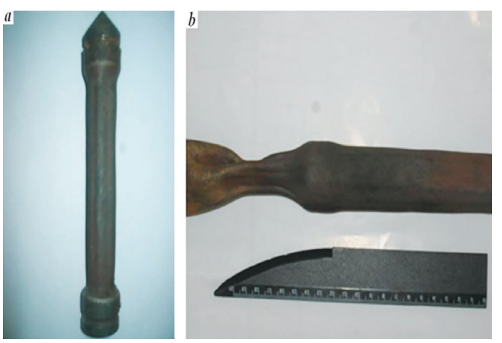

Fig. 5. Views of billets before (a) and after the HSWC procedure at 1000°C and loading intensity 10 GPa (b).

In further experiments, the application of pure Mg and a crystalline and amorphous B powder blend prevented the formation of

MgO in HEC billets and increased the T_c of the obtained MgB_2 composites up to 38.5 K., Figure 6, with pure amorphous boron powder without any post-sintering of the obtained samples.

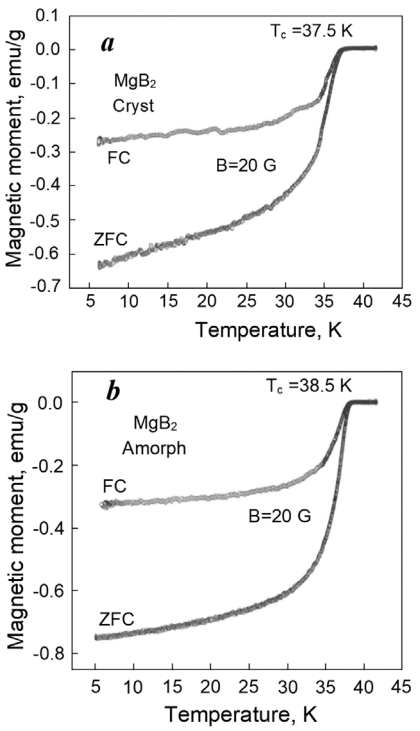

Fig. 6. Temperature dependences of the zero-field cooled (ZFC) and field-cooled (FC) magnetic moment for HSWC MgB_2 composites at 1000°C, with intensity of loading 10 GPa in magnetic field 20 Oe.

For these samples, traces of oxidation (light spots) on microstructures were not observed (Figure 7).

The experiments for the HSWC of precursors were performed under and above the melting point of Mg phase. The consolidation was carried out at 500, 700, 950, and 1000°C with a loading intensity of 10 GPa.

It was experimentally established that the comparatively low-temperature consolidations at 500°C and 700°C would give no results, and the obtained compacts would have no superconducting properties. The application of higher temperatures and consolidation at 1000°C provides the formation of MgB_2 composition throughout the whole volume of HSWC billets, with a maximal value of T_c =38.5 K, without further sintering procedures and corresponding to the literature where T_c =40 K takes place.

Finally, different types of superconducting Cu-MgB_2–Cu tubes for hybrid power transmission lines are demonstrated in Figure 8.

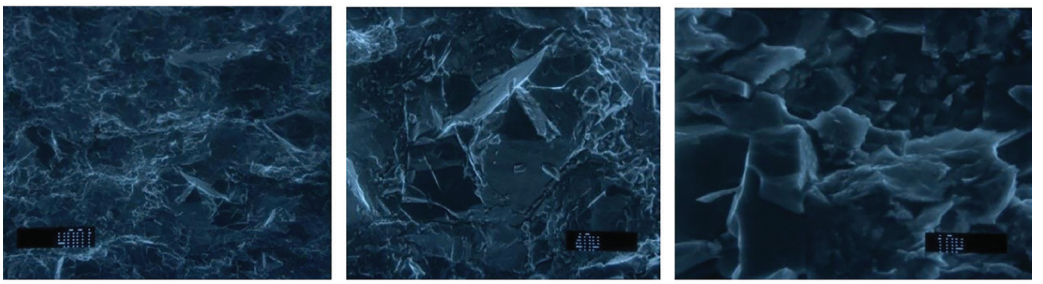

Fig. 7. Microstructures of the HSWC MgB_2 composites with HSWC at 1000°C and loading intensity 10 GPa from pure Mg and B powder blends (Gegechkori *et al.,* 2017).

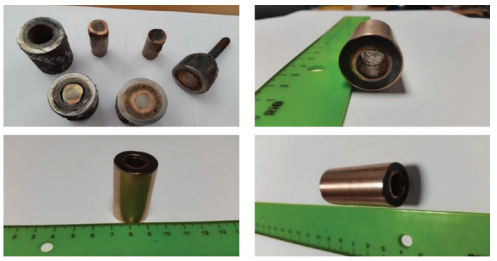

Fig. 8. Cu-MgB_2– Cu superconductive tubes

The novelty of the proposed nonconventional approach relies on the fact that the consolidation of solid high-density, long-body cylindrical MgB_2 billets from submicrometer-sized Mg and B powder blends is performed in two stages.

3. Superconducting Precursors in Bi-Pb-Sr-Ca-Cu-O Compositions Fabricated by SFAQ-T Technology

In the works of Gulamova *et al*. (2012) and Chigvinadze et al. (2019), precursors were synthesized using SFAQ-T technology, quenching the melt obtained by heating with solar radiation at low temperatures (Figure 9).

The characters of the t(T) and δ(T) dependencies for a monophase sample Bi/Pb (2-2-2-3) synthesized by the standard solid-phase reaction, with the critical temperature T_c= 107 K, are shown in Figure 10.

In Figure 11, the typical temperature dependences of the period t and the logarithmic decrement of damping δ of the Bi/Pb sample (2:2:19:20) are presented. All measurements were performed at increasing temperatures from T = 77 K to T = 180 K. As can be seen in Figure 10, the critical temperatures $T_c \approx$ 128 and 153 K clearly manifest in the dependences of both t(T) and δ(T). Moreover, the transition revealed through the oscillation period t(T) dependence are accompanied by peaks of the damping δ, which are typical for type-II superconductors during the processes of the release of "frozen" vortex filaments and their viscous motion, along with the matrix near the critical temperature. As the temperature rises, other attenuation peaks are also observed on the δ(T) dependence, indicating the presence of the other higher-temperature superconducting phases in this multiphase sample. Critical temperatures with up to T_c= 201 K were subsequently detected in a Bi/Pb sample (2:2:19:20), annealed at 846°C for 47 hours. A fragment of the result with the critical temperature 128 and 153 K is shown in Figure 10.

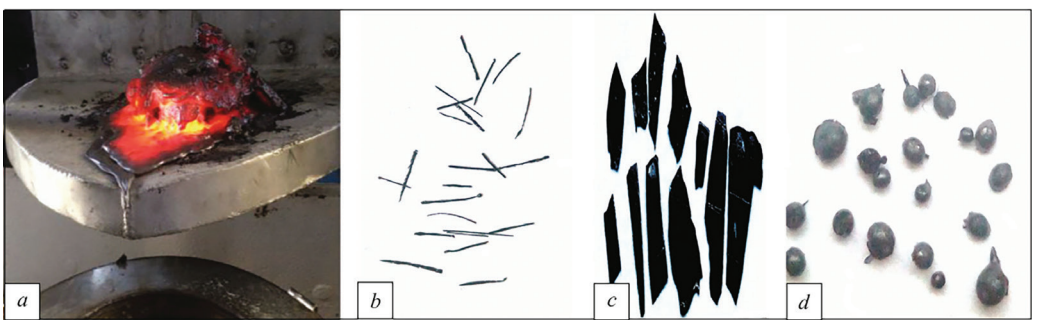

Fig. 9. Melting of a charge with the nominal composition $Bi_{1.7}Pb_{0.3}Sr_2Ca_{(n-1)}Cu_nO_y$ in the Large Solar Furnace (*a*), and precursors obtained through SFAQ-T technology: needles (*b*), plates (*c*), and spherulites (*d*).

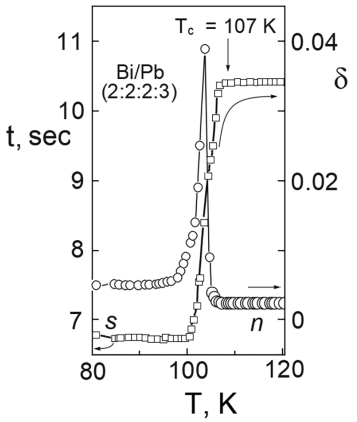

Fig. 10. Temperature dependence of the logarithmic damping decrement d and the period *t* of oscillation in the magnetic field of ceramic samples of the nominal $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_y$, obtained from precursors synthesized using solar technology.

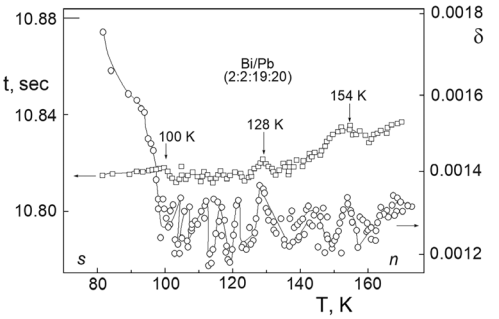

Fig. 11. Temperature dependence of the oscillation period t and the logarithmic damping decrement δ for multiphase Bi/Pb (221920), obtained from SFAQ-T precursors and annealing (846°C - 47 h). The results of measurements when the sample was held for 7 hours in liquid nitrogen in the magnetic field H=150 mT (n-state), as compared with AS-prepared samples (s-state).

It should be noted that, in the case of the multiphase for the Bi/Pb sample (2:2:19:20) in Figure 10, after increasing the temperature, additional attenuation peaks were also observed on the δ(H) dependence, indicating the presence of other HTSC phases in these multiphase samples.

Attention is drawn to the fact that the critical phase temperatures at T = 100, 128, and 154 K are most clearly manifested in peaks due to the attenuation, although closer examination, in particular of the dependence δ(T) in the interval 100 ÷ 170 K, indicates the presence in the sample of a significantly larger number of superconducting phase homologs with close T_c.

4. Superconducting Precursors in Bi-Pb-Sr-Ca-Cu-O Compositions Revealed by Vibrating Reed Magnetometry.

The electronic part of the VR acoustic spectrometer contains an acoustic spectrometer operating at a frequency of about 1 kHz, and instruments for powering a permanent magnet (Chigvinadze *et al*., 2019). The sensitivity of the spectrometer provides measurements of the natural frequency of the sample *f* with an accuracy of ~ 0.1%. In the VR acoustic spectrometer, the electrostatic method of exciting bending oscillations of a sample having the shape of a rectangular plate was used. The electronic equipment of the spectrometer allows measurements to be taken in the mode of the self-excitation of samples at their natural resonant frequencies. The electrode, located in the immediate vicinity of a

sample, makes up the capacitance included in the oscillating circuit of the high-frequency generator, and serves simultaneously to excite and detect the oscillations of a sample. Measurements of the resonant frequencies f_r of the sample oscillations make it possible to determine the elastic modulus *E* according to the relation:

$$f_r = k\frac{d}{L^2}\sqrt{\frac{E}{\rho}}$$

where d is the thickness of the sample, L is the length of the oscillating plate, E is the modulus of elasticity, ρ is the density of the sample, and k is a constant factor.

The variation of the square of the resonant oscillation frequency (f^2) of a sample can be considered in the framework of the so-called magneto-mechanical approach (Esquinazi, 1991), according to which, when a superconducting sample is displaced relative to the external magnetic field H, a restoring mechanical force acts on each "pinned" magnetic vortex. As a result, the oscillation frequency of the entire sample changes by Δf(H), depending on the density of the fixed vortices, the moment of inertia of the superconductor, and its volume. The dependence of the elastic modulus E of the substrate-sample system (in units of f^2) on the magnitude of the magnetic field gives information on the elastic interaction of the Abrikosov vortex lattice with the crystal lattice. This is a convenient method for determining the magnitude of the vortex pinning force. In addition, the f^2(H) dependence provides a simple method for determining the lower critical magnetic field H_{c1} value and the critical temperatures of the superconducting precursors in the multiphase HTSC samples.

The temperature dependences of the square of the natural frequency (f^2) of oscillations of Bi/Pb system (2-2-8-9) and (2-2-19-20) samples on a pure niobium substrate (Chigvinadze *et al.,* 2019) in a magnetic field were measured, Figure 8. In order to separate the effects associated with the penetration of AV into a superconducting sample from the effects of the niobium substrate, the temperature dependence of f^2 of pure niobium was measured.

Measurements were carried out in zero field cooled mode (ZFC-mode) in the magnetic field 300 mT, turned on after the cooling of a sample to 80 K.

It is seen that in the area of ~ 90 - 160 K, in sample (2-2-8-9), as well as in sample (2-2-19-20), there are features, near the temperatures of 95, 101, 115, 128, and 141 K. These features are associated with the existing superconducting high-temperature precursors

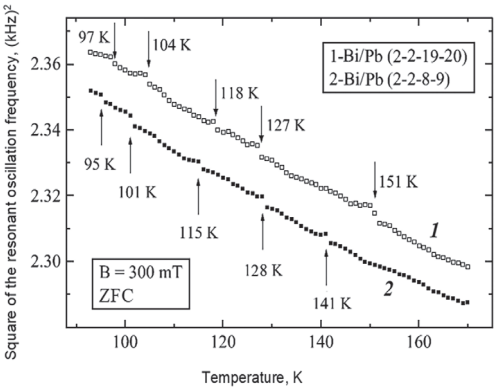

Fig. 12. Temperature dependence of the square of the natural frequencies of the multiphase samples (2-2-19-20) and (2-2-8-9) in the magnetic field of 300 mT.

in the multi-phase samples of the $Bi_{1,7}Pb_{0,3}Sr_2Ca_{n-1}Cu_nO_y$ system, which are absent in case of a single-phase sample (2-2-2-3) synthesized by solid phase technology. Thus, it can be concluded that in the (2-2-8-9) and (2-2-19-20), there are four different superconducting precursor phases. Comparing features in Figures 11 and 12, it can be seen that they are in definite correspondence, but in the case of Figure 12, these features are more clearly separated and visible. This observation could be considered as further confirmation, by the VR magnetometry method, of the existence of high-temperature precursors in multiphase samples of the $Bi_{1.7}Pb_{0.3}Sr_2Ca_{(n-1)}Cu_nO_y$ system, and, in addition, that it shows the potential advantages of application of the VR method to study superconducting precursors in multiphase HTSC samples.

Conclusion

1. The possibility of increasing T_c in HTSC samples of the Bi-Pb-Sr-Ca-Cu-O systems, fabricated using HSWC technology and measured by the vibrating torsional magnetometry method, was studied. The advantages of HSWC technology over traditional technologies for the synthesis of superconducting composites are shown. A critical temperature for the potential superconducting precursor T_c of transition to a superconducting state increased from T_c=107 K (starting sample) to T_c=138 K, using the HSWC technology for synthesis in a range of pressures from P=5 GPa up to P=12 Gpa, with a 31 K increase of T_c in the case of 12 GPa.

2. The liquid phase HSWC of Mg-B precursors at a temperature of 1000°C, provides the formation of the MgB_2 phase in a whole volume of billets, with a maximal T_c=38.5K. The consolidation of MgB_2 billets above the melting point of Mg, up to 1000°C in a partially liquid matrix of Mg-2B blend, powders. An evaluation and investigation of the structural property relations were made.

3. In the torsional low-frequency and vibrating reed dynamic experiments, in the course of investigating the magnetic properties of multiphase cuprate superconductors $Bi_{1,7}Pb_{0,3}Sr_2Ca_{n-1}Cu_nO_y$ (n=3÷5, 20), synthesized using solar energy and superfast quenching of the melt (SFAQ-T technology), the precursor phases with or near T_c=107-160 were detected. Analysis of the nature of the obtained dependences, and their comparison with other available results associated with the processes in the vicinity of critical temperature T_c, allows one to infer the existence of the high-temperature superconducting precursor phases.

The comparative study of torsional and vibrating reed magnetometries for the evaluation of T_c of the superconducting precursors in the multi-phase HTSC Bi-Pb-Sr-Cu-O system, fabricated by SFAQ-T technology, were also investigated for the first time. It was shown that the results obtained by both methods have sensitivity to the superconducting diamagnetism, making it possible to reveal new superconducting precursor phases above bulk T_c in those samples. Further, as compared with the low-frequency torsional spectroscopy method, the vibrating reed spectroscopy method has potential advantages for the study of the superconducting precursors in multi-phase HTSC ceramics.

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Scaling up Inclusive Education for Sustainable Development in Africa

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ABSTRACT

Inclusive education plays a key role in achieving sustainable development. Its impact ripples across many dimensions, fostering reduced fertility, morbidity, and mortality rates, while empowering women and enhancing workforce quality. Beyond these aspects, it influences individual learners, shaping their personal development and prospects in the job market. The significance of inclusive education goes beyond individuals, contributing to achieving five of the United Nation's Sustainable Development Goals (SDGs). It plays a significant role in realizing SDG1: No Poverty, SDG4: Quality Education, SDG5: Gender Equality, SDG10: Reduced Inequalities, and SDG16: Peace, Justice, and Strong Institutions.

The global commitment outlined in the 2030 Agenda for Sustainable Development and the African Union's Agenda 2063 highlights the need to enhance educational outcomes and foster knowledge accumulation for developmental progress. To concretize this vision, the Education 2030 Framework for Action stands as a testament to drive advancements aligned with the objectives of SDG4 and its specific targets. Central to this framework is an emphasis on eradicating all forms of exclusion, recognizing inclusivity as the cornerstone for achieving educational equity and sustainable development.

This study aims to propose key policy actions for an inclusive education agenda, empowering urban and rural youth in Africa, amplifying their role in socio-economic transformation, combating persistent inequality, and fostering inclusive growth.

[1] United Nations Economic Commission for Africa, Office for North Africa, Rabat, Morocco; Mansoura University, Egypt.

"If you plan for a year, plant a seed. If for ten years, plant a tree. If for hundred years, teach the people. When you sow a seed once, you will reap a single harvest. When you teach the people, you will reap a hundred harvests".

K'UAN-TZU, 551-479 BC (as cited in World Development Report, 1991, P.52).

Introduction

The concept of inclusive education embodies different dimensions, shaped by a tapestry of practices, traditions, and contexts. Notably, where inclusive education thrives, it becomes a catalyst for exceptional academic achievements among students (Galkiené & Monkevicienė, *eds.,* 2021). As outlined by UNESCO, inclusive education signifies the obligation of schools to support all children, irrespective of their physical, intellectual, social, emotional, linguistic, or other unique conditions. Therefore, inclusive education is a coherent and unifying factor for sustainable development (UNESCO, 2016).

The definition of inclusion involves four key elements: a) A search for ways to respond to diversity; learning how to learn from differences, b) Is concerned with the identification and removal of barriers, c) Is about the presence, participation and achievement of all students, and d) Involves a particular emphasis on those groups of learners who may be at risk of marginalization. The approach intertwines quality, equality, equity, and diversity, forming an interdependent web that underpins an inclusive educational paradigm. It is not merely about coexistence, but about creating an environment where each element reinforces and enhances the others, fostering an educational landscape that supports the richness of individual differences (Ainscow & Messiou, 2017).

Inclusive education stands as a cornerstone in the journey towards achieving sustainable development. By enhancing inclusive education, we witness a ripple effect that paves the way for reduced fertility, morbidity, and mortality rates, and boosts women's empowerment. This approach also serves as a catalyst for enhancing the overall quality of the workforce (PROSPECTS, 2011). Beyond these aspects, it influences individual learners, shaping their personal development and prospects in the job market (Ainscow, 2016, a, b). The significance of inclusive education extends beyond the individual, contributing to achieving five of the United Nation's Sustainable Development Goals (SDGs). It plays a key role in realizing SDG1: No Poverty, SDG4: Quality Education, SDG5: Gender Equality, SDG10: Reduced Inequalities, and SDG16: Peace, Justice, and Strong Institutions.

Africa's youth encounter significant challenges in accessing an inclusive education that equips them with the requisite skills and knowledge essential for the demands of the labour market. Consequently, the transition from schooling to employment often proves challenging, resulting in many young Africans either suffering from unemployment, or settling for underemployment in the informal sector. This trend exacerbates prevailing inequalities within societies.

Over the years, African youth have had access to more formal education. However, educational systems across Africa have

faced a decline in quality at all levels. They are geared toward providing basic literacy and numeracy, and not industrial skills, and are yet to adjust to the changing demands for knowledge and skills required by the labour market. This mismatch between education and market requirements has led to a concentration of youth unemployment among those who have received some level of education, but who lack the specific industrial skills sought by employers. Consequently, these individuals find themselves less appealing to labour markets that prioritize skilled and experienced workers. Furthermore, educated youth prefer wage jobs in the formal sector and tend to remain unemployed until they find their ideal job.

The global commitment outlined in the 2030 Agenda for Sustainable Development and the African Union's Agenda 2063 highlights an urgent call to enhance educational outcomes and foster a culture of knowledge accumulation. A clear manifestation of this vision is embodied in the Education 2030 Framework for Action. Central to this framework is the emphasis on eradicating all forms of exclusion, recognizing inclusivity as the cornerstone for achieving educational equity and sustainable development (AUC and UNICEF, 2021).

This study seeks to propose key policy actions for an inclusive education agenda benefiting youth in urban and rural areas, aiming to enhance their involvement in Africa's socio-economic transformation to overcome persistent inequality and foster inclusive growth.

1. Drivers of Inequality in Education

1.1. Access to skills through education

Increased educational attainment in Africa does not deter from the challenges of inequitable access to quality education. Inequalities of outputs- completion and quality, are mirrored in outcomes- learning achievements and skills. As a result, the inadequate skills acquired by many young Africans partly limit their access to more formal employment opportunities.

Compared to other developing regions, Africa has not improved its gender parity in access to skills through education. This remains a serious challenge and reinforces a gender disadvantage in employment opportunities (Marcos, 2022).

In Africa, a clear deficiency in the provision of marketable skills lies in the marginalization of Technical and Vocational Education and Training (TVET), concerning both resource allocation and policy emphasis. This neglect undermines the capacity to equip individuals with the necessary skills required by the job market. Consequently, the educational needs essential for the demands of the labour market remain largely unmet. The stock of technical workers could be increased by upgrading technical education, and further training low-trained technicians to acquire greater knowledge in polytechnics[1].

More young Africans learn through on-the-job traditional apprenticeships, rather than through the formal TVET channels. Yet,

[1] https://acetforafrica.org/research-and-analysis/insights-ideas/articles/the-paradox-of-technical-and-vocational-education-in-africa/

while this on-the-job apprenticeship increases supply, the demand for such skills is small, and as such, exposure remains limited. This in turn limits the career path of the majority of on-the-job trained professionals. Among the reasons for young people to choose on-the-job channels is that access to formal skill-acquisition favors those with a relatively high income. However, even in informal (on-the-job) training, there is income bias.

To escape the low productivity/informal employment trap, TVET requires urgent promotion. Achieving this goal demands the reduction of barriers that hinder access to education. Lowering the cost of acquiring this education is pivotal. Furthermore, there is a pressing need for innovative approaches to effectively incentivize and encourage young people to pursue TVET programs. These measures will be instrumental in directing individuals towards acquiring the skills essential for enhanced productivity and more secure employment prospects.

Access to education exhibits substantial disparities across income brackets, genders, and geographical locations (Atsebi *et al.,* 2022). Unfortunately, these disparities perpetuate a vicious cycle of inequality, poverty, and exclusion. Those marginalized or excluded from educational opportunities often find themselves constrained to low-productivity, low-paying, and often "dead-end" informal job prospects, further deepening prevailing inequalities. The presence of private institutions has a direct effect on increasing inequity of access and an indirect effect on the role of the State (Bennell, 2022a).

According to the African Union (AU), the expansion in enrolments "masks huge disparities and system dysfunctionalities and inefficiencies" in education subsectors, among them preprimary, technical, vocational, and informal education, which are severely underdeveloped. Most of Africa's education and training programs suffer from low-quality teaching and learning, as well as inequalities and exclusion at all levels. Even with a substantial increase in the number of children with access to basic education, a large number remain out of school.[2]

1.2. Quality and relevance

The barriers preventing young people from accessing employment opportunities extend beyond limited access due to factors like low income, gender, and geographical constraints. They are also rooted in the pervasive issue of substandard skills imparted through education. Supply-side challenges play a key role in compromising the quality of skills gained in educational settings. Among these challenges, the quantity and quality of teachers emerge as among the most critical bottlenecks, significantly impacting the educational landscape, and ultimately the skills acquired by students (Olanrewaju O., 2022).

The primary aim of educational curricula is to furnish young individuals with the knowledge and skills necessary for their functionality and contribution to society. These skills serve as a foundation for further education and application across diverse job roles (McClellan, 2010). In the secondary school system, these skills are more generic than

[2] https://www.un.org/africarenewal/magazine/december-2017-march-2018/africa-grapples-huge-disparities-education

specific, even though some courses are expected to endow the students with specific skills and knowledge that are applicable to certain occupations. In today's evolving landscape, knowledge stands as a critical driver of development, underscoring the growing dependence of labour productivity on high-level non-cognitive skills like analysis, problem-solving, and communication, as well as behavioural skills such as discipline and work ethics (Montenegro & Patrinos, 2014). As economies develop, more employers consider skills a key factor in business development, and are increasingly prioritizing them. Consequently, there is a need for an effective educational system that delivers these vital skills to meet the demands of employers and the changing dynamics of the workforce (Ionescu, 2012).

The necessary skills for employment emphasized in the curricula include cognitive skills like literacy, numeracy and scientific literacy, which are delivered through English, mathematics, and science. More time is allocated to these subjects, as they are designated as core subjects that require special attention and success to enable one to progress in one's academic carrier. Conversely, non-cognitive skills such as creativity, persistence, reliability, and effective communication, or more specialized skills, receive less emphasis when preparing individuals for employment. Despite their critical relevance in professional settings, these skills receive less attention within the educational framework (Oxford Economics Africa, 2022).

The essence of TVET diverges slightly from conventional education. TVET encapsulates the study of sciences and technology, while focusing on acquiring practical skills, and fostering a deep understanding related to occupations across diverse sectors of economic and social spheres. A fundamental hallmark of TVET lies in its direct alignment with the professional realm, emphasizing a curriculum designed to impart employable skills. This vocational education is distinguished by its orientation toward preparing individuals for the demands and expectations of the workforce (UN, 2022).

The curriculum of TVET, while in principle linked to very specific skills, has many challenges. The first is that TVET courses seem decoupled from labour market demands. Technology skills, particularly IT, which are becoming imperative in modern society, are absent. Furthermore, akin to secondary education, TVET often overlooks the teaching of non-cognitive skills, despite the high demand for them in the labour market. This oversight results in TVET graduates possessing inadequate skill profiles, leading to them failing to meet the multifaceted requirements of modern employment opportunities.

Additionally, TVET perpetuates gender stereotypes, thus exacerbating the inequality of opportunities. Historically, TVET was predominantly considered a domain reserved for males. Institutions catering to girls often hesitate to offer courses in traditionally male-dominated fields, like mechanics and engineering. In cases where such subjects are available, the resources and emphasis allocated to them are notably inadequate. This disparity in resources and attention further entrenches gender-based barriers, limiting girls' access and participation in these crucial skill areas within TVET (Baten et al., 2021).

Like secondary education, tertiary education has traditionally focused on public sector employment, with insufficient attention being paid to specific skill sets. Furthermore, technical subjects tend to be more expensive, and hence more inequitable towards lower incomes. The choice of "non-technical" subjects results in difficulties for graduates to find employment opportunities and contribute to the mismatch of skills required by the labour market. The insufficient focus on the relevance of technical subjects is complemented by the quality concerns of tertiary institutions.

Quality and relevance are interrelated with the structural challenges faced by the educational system in Africa. The drivers of access to skills provided in the secondary, TVET and tertiary educational systems are vital in understanding the skills mismatch in Africa.

1.3. Completion and learning outcomes

Completion rates have often been used as a proxy for quality provided (UNESCO, 2017), and portray similar inequities across income, gender, and location. Thus, low, and inequitable completion reinforces exclusion of the poorest rural households, with a negative bias towards gender. Consequently, their inadequate representation in learning achievements transitions to secondary level skills (Bennell, 2023).

Completion rates are influenced by location and income disparities. Urban residents tend to exhibit higher rates of school completion compared to their rural counterparts, mirroring a similar trend among the wealthiest compared to the poorest quintiles (Buckner & Abdelazis, 2023). Consequently, the poorest rural inhabitants, particularly women, face challenges in attaining the robust skill set necessary for active participation in labour markets. This disparity in educational outcomes accentuates the obstacles faced by these individuals in securing the skills vital for engaging effectively in the workforce.

Secondary school education poses a greater challenge than that of primary education. Yet, to enter the labour markets and obtain decent jobs, secondary education is paramount. Students with secondary school education increase their chances of formal employment and improved livelihoods, as many unfilled jobs require education and training above the primary level. Hence, the attainment of secondary school education stands as an imperative milestone (Holsinger D., Cowell R., 2000). Completion rates at the secondary level of schooling pose a multifaceted challenge. The increased imposition of tuition fees for secondary education across many African households has notably intensified the issue of lower completion rates (Bennell, 2022b).

While completion rates pose a persistent challenge, the correlation between completion (as outputs) and learning achievements (as outcomes) holds great significance. Learning achievements as an outcome and its conversion to increased employment opportunities for young people is a key factor in a household's investment in education. Learning achievements of the fundamental skills in Africa face a serious challenge. Insufficient levels of learning achievement stem not only from school dropouts, but also from

the quality of education received by those who do complete the schooling cycle. A critical deficiency lies in inadequate fundamental skills, particularly in literacy. This deficiency significantly hampers transitions to lower secondary education and the acquisition of higher-level skills. Furthermore, even among those transitioning to secondary education, low completion rates, especially among women and rural low-income groups, pose substantial barriers in acquiring the necessary skills for progression beyond school. These disparities in learning achievements are perpetuated by inequities in enrollment and completion, continuing disparities based on income, location and gender (Mastercard Foundation, 2019, 2020, 2022).

Secondary school plays a key role in equipping young individuals with skills that enhance their job prospects. While lower secondary skills extend and consolidate the basic skills learnt in primary school cycles, upper secondary deepens general education and adds technical and vocational skills. In summary, improvement in access and quality is also linked to the relevance of the curriculum to labour demand, and influences household decisions to invest in children's secondary learning and skills (OECD, 2019).

2. Key Policy Actions for a More Inclusive Educational System

Addressing the inequities in accessing education stands as a great challenge throughout Africa. Despite the introduction of free tuition, mainly at the primary level, but in some instances extending to secondary schooling, household income remains a critical determinant influencing access. Moreover, gender and geographical location continue to exert negative influences on both access to education and completion rates.

Crafting an inclusive educational policy in Africa presents a multifaceted challenge. The complexity is given by the expected outcome of productivity gains and employment creation, contributing to growth and improved livelihoods for young people. The suggested policy directions operate across three levels: macroeconomic, meso, and micro levels. The integration and alignment of policies across these levels are crucial for fostering an inclusive educational landscape capable of empowering Africa's youth and propelling sustainable development.

Macro

The pace and character of Africa's economic growth partly drives the inability to generate productive jobs. This results in capacity underutilization and increasing numbers of low-paid, informal jobs; a situation that hampers economic growth in the long-run. The relationship between employment and economic growth therefore suggests job creation in Africa can only be increased by:

- Ensuring increases in quantity and quality issues of educational spending for efficient allocation;
- Shifting the sources of growth from capital-intensive, low employment generating sectors to labour-intensive, high productivity sectors;
- Strengthening the role of the State, since private provision of education requires the State to be a strong regulator on matters of accreditation, costs,

quality control, and standards. The State should also be actively involved in strategically directing information flows from industrial and labour needs to education curriculum design;
- Targeting pro-employment policies, including incentives for private sector development and skills upgrading, particularly for rural and informal sector workers.

Meso

In Africa, the education system has demonstrated constraints that cut across quality, relevance, and equity. The policy instruments need to be customized to country priorities and specificities, while the policies themselves need also to take cognisance of the global and regional frameworks concerned.

Quality

- Assessing quality through the establishment of regional exam centres at the end of each schooling cycle;
- Ensuring that youth organizations are involved in the design and implementation of the policy direction;
- Establishing learning achievements centres that use skills at different levels in the learning cycle to assess outcomes, rather than output;
- Involving the private sector in educational policy, such as, for example, productivity councils in East Asia;
- Scaling-up on-the-job training for teachers, with innovations in teaching, techniques and areas taught; providing incentives for remote areas assignments;
- Targeting teacher-student ratios in classrooms to international standards.

Relevance

- Focusing on Science, Technology, Engineering, and Mathematics (STEM) across all levels;
- Re-focusing on technical and vocational training at the lower level (post-junior secondary) and upper levels (tertiary); creating incentives for uptake by students, with the participation of the private sector and apprenticeships;
- Re-focusing on cognitive and non-cognitive skills demanded by labour markets;
- Re-orienting tertiary institutions towards technical and technological areas and teacher training.

Equity

- Creating incentives for retention and completion across levels through the introduction of social protection programmes, such as school feeding, cash transfers for transport, and other ancillary, water, and sanitation facilities in schools;
- Enhancing social assistance schemes that strengthen access and facilitate completion of schooling cycles, with affirmative action for girls, for example school feeding, transport, and gender sensitive infrastructure;
- Ensuring that equity cuts across all levels of education by minimizing cost sharing with households for all costs, affirmative actions for gender participation and rural households, including training and recruitment of more female teachers;
- Exercising positive discrimination towards promoting girls' education, since the poor living in rural/remote areas, especially girls, are disadvantaged;

- Increasing teacher-pupil ratios, especially in rural areas, by offering adequate incentives.

Micro

Ultimately, household decisions on educational investment are dependent on perceived rates of return. The policy proposals emanating indicate many areas that require attention:

- Incentivizing the enrolment and retention of women in school through social protection programmes;
- Introducing active labour market policies, such as differentiated packages for informal sector skill upgrades, contractual status information and wage policy;
- Introducing a Labour Market Information System that links labour skill demands to educational production.

The assigned role of young people as torchbearers of Agenda 2030 relies heavily on their inclusion in the political, social, and economic activities of a nation. The vulnerability of young people in terms of (i) higher unemployment (ii) lower quality jobs for those who do find work (iii) greater market inequalities across income, gender, and location, hinges also on the quality education that provides the necessary skills for employment. Equitable access to education, ensuring a level playing field in labour market participation, can contribute to addressing the inequalities of outcomes on the continent.

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Approaches for Integrating Sustainability in Business Schools – Challenges and Opportunities in the Digital Age

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ABSTRACT

The paper presents opportunities for integrating sustainability into business schools' educational and management models in this era of digital transformation, seeking to increase their capacity for innovation, and the role of academia as a driver for boosting the potential of regional ecosystems for sustainable development. Contemporary trends and factors driving the need for higher education's response to the environmental changes caused by digital technologies, and efforts to achieve sustainability on a global scale, are examined, while the benefits of applying a multidisciplinary and intersectoral approach in sustainability education, supplemented with a research-based approach to engage students, two-eyed seeing and competence-oriented educational models, are characterized.

Arguments are given that balancing innovation and sustainability in business schools implies applying an ambidextrous approach. It reflects on the one hand the need for business schools to adapt, taking into account changes in the environment, with an emphasis on digitization, internationalization, partnerships, multidisciplinarity and multisectorality to achieve academic sustainability. On the other hand, a need for a balance is recognized between established traditions, organizational culture, the specific features of business schools, and the introduction of innovations in them, including digital and social innovations.

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Introduction

The issues of achieving sustainable development are being discussed more and more actively by the business, private and non-governmental sectors today. Higher education institutions react to the growing public interest in problems of sustainability by offering ever more varied courses and programs in order to contribute towards providing knowledge and building student competences so as to accomplish the United Nation's Sustainable Development Goals (SDGs). Thus, universities foster a positive desire to share sustainable and responsible practices among present day students and future participants in the labour market, be they future employees, managers or employers.

The topicality of this research is defined by the need to bring highlight possibilities for improving business schools' educational models in view of achieving the synergy of joint efforts for sustainable development in the business, private and non-governmental sectors, and the role of higher education institutions in the process. A specific modern trend in the European Commission's policies and funding programs is the idea of uniting the efforts of representatives of all three sectors so as to multiply the effects of applying sustainable policies in various spheres. Here, the European Commission declares its objective of 'developing synergies not only among the spheres of science, education and innovation, but also among the local authorities, private sector and academia' (European Commission, 2021). This requires that higher education institutions seek to consistently improve their educational models and approaches to support the achievement of this synergy by combining their inner resources with external opportunities, and their established good practices with innovative educational approaches.

The aim of this research is to present the possibilities for modifying business schools' educational models that focus on the formation of student competences in sustainable development. It suggests the use of new as well as existing educational approaches. These should correspond to modern technologies in the processes of scientific research and teaching, as well as the opportunities for funding through EC programs, which stimulate the role of universities in creating regional innovative ecosystems. However, transformations in business schools' educational models have to be carried out in accordance with the specifics of the national and international educational environment, as well as with the established traditions in the higher education sector and the specific characteristics of the particular higher education institution.

1. Driving Forces for Changing Sustainability in Educational Approaches

Towards the end of the 20th century and the beginning of the 21st century, more and more universities started introducing the issue of sustainability into their curriculums and syllabuses, in various forms. Nearly twenty years ago, UNESCO initiated a 'Decade of Education for Sustainable Development 2005 – 2014', stating as its main objective 'to integrate principles, values and practices of sustainable development in all

aspects and levels of education' (UNESCO, 2011). Since then, education for sustainable development has been gaining in popularity, not only as a research field or in the forms and methods of teaching pupils and students, but also as initiatives concerning various processes in universities and on campuses. As a result, business schools have applied various educational methods and approaches. These, however, need to be constantly modified in order to respond to the trends and challenges in the contemporary business and educational environment.

One of the key factors making it necessary for business schools to modify their educational approaches in educating students on sustainable development are *the constantly developing ideas of sustainability,* characterized by *multidisciplinary and inter-sectoral dimensions*.

Fig. 1 sums up the most popular contemporary ideas reflecting the endeavour for sustainability, which are grouped according to similarity, depending on their essence and forms of manifestation. In Fig.1, the first top left quadrant illustrates the two most recognizable- and perceived as fundamental- concepts, dating back to the 1960s-70s, which are most actively present in teaching students about sustainable development. Apart from the 'classical' concept of *sustainable development*, business schools' educational models often include courses on *Corporative Social Responsibility* (CSR). The two concepts arise for different reasons and have different theoretical foundations at the initial stages of their development, but, eventually, their contemporary interpretation comes to present them as being very close, even synonymous. At the beginning of the 21st century, both concepts included the three basic dimensions – economic, social and environmental, with possibilities for finding a balance between them being perceived as a criterion of sustainability in the work of organizations in the business, public, and nongovernmental

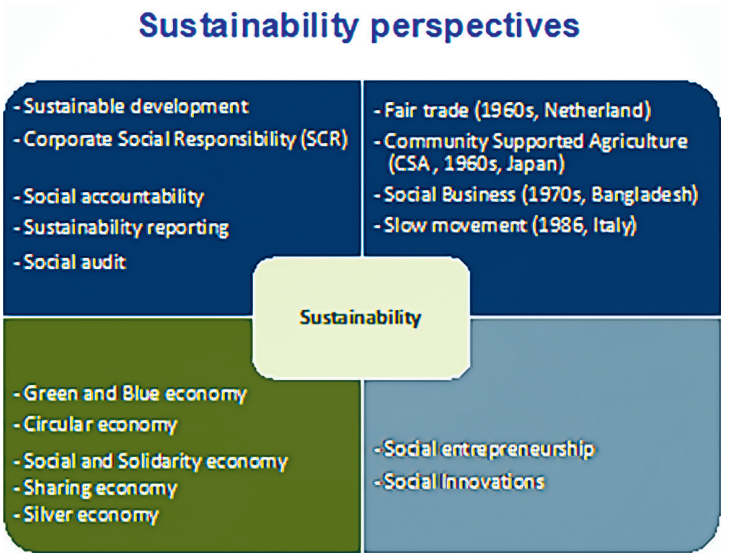

Fig. 1. Developing Ideas on Sustainability

sectors. These days, the idea of CSR, as a constituent element of the overall efforts made for sustainable development, is supported by an increasing number of international institutions, including the European Commission. It is a fact, however, that the concept of sustainability continues to develop in various directions, including the addition of new dimensions, such as its fourth dimension – cultural factors (James, 2015).

The logical continuation of the ideas of sustainable development and CSR is based on the need for greater transparency in organizations by the disclosure of non-financial information about their activities. As a result, the concepts of *social accountability, sustainability reporting* and *social audit* are being developed and included in university curricula.

In the top right quadrant, we see specific and less popular concepts than CSR and sustainable development, but all of them, under one form or another, include economic, environmental, and social dimensions. These are the concepts of *Fair Trade,* Community Supported Agriculture (CSA), Slow Movement and the concept of microcredits developed by Professor Muhammad Yunus, known as *Social Business* (Serafimova, 2017).

These concepts arise in different countries, reflecting the search for solutions to specific local social problems, and subsequently gradually spread on an international scale. Fair Trade arose in response to the unfair treatment by goods producers (originally of coffee, cocoa and bananas) of their poor employees in African and Asian countries, who received low remuneration for their work. The first Fair Trade store started in The Netherlands in 1969, and, in Europe and the USA, it gained popularity in the early 1990s. Today, Fair Trade is an international network of distributors of various products produced in different countries. Its mission is to improve the working conditions of producers, promising dignified payment for their work at the expense of reducing intermediaries in the chain, preventing forced labour, avoiding the exploitation of female and child labour, eliminating discriminatory practices, etc. Fair Trade strives to contribute to the sustainable development of poor regions and environmental protection.

Community-Supported Agriculture (CSA) originated in Japan in the 1960s, spreading very quickly to other Asian countries, and then to America and Western Europe. Its social role is to create mutual benefits between people living in the big cities, and producers from the small villages around them, contributing to the region's sustainable economic development. Local small farms deliver organically produced fruits, vegetables, and livestock products to households in large cities for an upfront payment. The mutual benefit for both parties, and the idea of the sustainable development of this concept, are based on the idea of mutually beneficial cooperation and risk-sharing between consumers and producers. People from big cities get natural food products, produced according to local traditions, and farmers get a guarantee of employment and a sustainable and fair income source. Middlemen in the logistics chain are avoided, allowing producers to be paid fairly. Mutual trust replaces the need for product certification with organic and natural product certificates, which otherwise make it unnecessarily expensive.

The basis of the Social Business concept is the creation of innovative business models in the search for solutions to social problems. It is associated with the name of Muhammad Yunus and Grameen Bank he founded in Bangladesh for micro-crediting to very poor people to help them create independent businesses that will become their long-term livelihoods. Micro-loans (up to a few dollars per person) are granted, relying on the joint responsibility of the recipients, without requirements for additional guarantees. Today, Grameen Bank has over 2,700 branches and is popular worldwide, serving as a model for many micro-finance initiatives on different continents. Grameen Bank is not a charity organization; it is built as a profitable business, but instead of aiming to maximize profit, it has a social focus, seeking to provide as many benefits as possible to the region's poor. According to the idea of the founder M. Yunus, the profit from the business is used for social purposes, and the people who invested in it later receive only their investments back, without dividends, and this is their personal social responsibility. However, the specific variety of social business expressed in the activities of Grameen Bank in Bangladesh is difficult to implement in its original form in many European countries. In fact, in Europe, only in Albania is it applied in its original form. This means that teaching this concept in business schools requires an educational approach to help adapt it to the particularities of the business environments in different countries.

The Slow Movement concept protests against global companies and their collision with small local businesses and entrepreneurial culture when they enter regions with a strong tourist identity. It is also a reaction to the trends towards increasingly hectic lifestyles and busy work schedules of people striving for a successful career. It was born in opposition to the "fast-food" culture, the desire to consume large quantities of products and services, and the possession of more and more objects and belongings by people in consumer society. Its birth marks a protest by local restaurateurs, organized by Carlo Petrini in Rome in 1986, against McDonald's' desire to open a restaurant near the Spanish Square - one of Rome's most typical landmarks. Thus, the slow movement started as a "slow food concept," but, gradually, other varieties were created – slow cities (aiming to slow down globalization and the depersonalization of cities by contributing to happier and more satisfied citizens), slow tourism/travel, slow science, slow money, slow aging, etc. Thus, the varieties of the Slow Movement contribute to the presentation of diverse points of view and their potential benefits for achieving sustainable development - a return to the natural way of life and production, conservation of natural resources, and preservation of the environment, keeping local traditions, customs and culture, stimulation of local production and employment, and a healthy and sustainable lifestyle.

The lower left quadrant of Fig.1 presents concepts with a strong focus on the economic dimension of integrating sustainability into business and people's lives. The first three – *Green, Blue and Circular Economy* – can be singled out as an independent sub-group due to their strong emphasis on the environmental dimensions of responsible business and sustainability. In the same quadrant, other

contemporary, state-of-the-art concepts related to sustainability are indicated – *Social, Solidarity and Sharing Economy*. They are mainly caused by the impact of technological and cultural factors related to the development of digital technologies and social media, and changes in people's attitudes to practicing a more sustainable lifestyle. The last and least popular concept so far is the *Silver Economy*, which reflects the strong influence of demographic factors due to the aging population of most European countries. In 1990, the average age of the EU population was 35.2 years, while in 2019, it grew to 43.1 years. Forecasts estimate the average age will have reached 47 by 2050 (Eurostat, 2019). As a result, the European Commission started developing the ideas for the Silver Economy (European Commission, 2018), which have to be covered in business schools' syllabuses and curriculums, and which have to be taught to students by means of relevant educational approaches and methods.

The bottom right quadrant of Fig.1 shows the latest sustainability-related concepts – *Social Entrepreneurship and Social Innovations*. The idea of Social Business by Nobel laureate M. Yunus can be perceived as a specific variety of the more general concept of Social Entrepreneurship, which is gaining more and more popularity today. In their businesses, social entrepreneurs try to combine profit with fulfilling a mission aimed at solving specific social problems. Similarly, understanding Social Innovation is generally associated with opportunities to offer innovative business solutions to social issues.

A specific factor to be taken into consideration by business schools when they modify their educational models are the peculiarities and expectations of *Generation Z* (those born between 1996 and 2012). In addition to being very demanding about using modern digital technologies in all spheres of social life, education included, they are also more sensitive to the issues of applying socially responsible practices and striving for sustainable development.

A particular question associated with achieving the objectives of sustainable development which has not yet become a popular business school practice in certain countries in Eastern Europe, is providing *an equal chance and managing variety* in the sphere of education, research and innovation. This is demonstrated in taking initiatives and applying educational approaches that support access to higher education for various social groups, avoiding any forms of discrimination in the educational, research and labour environments. These ideas are backed by various international initiatives, as well as by different policies and programs of the European Commission. One of them aims to include genders in the European research space. In order to participate in the Horizon Europe program, for instance, higher education institutions in EU member states must commit to compliance with the Gender Equality Plan, and explicitly state this on their websites. As of 2022, the European Commission defines this pledge as an eligibility criterion when such schools apply with project proposals for research funding (European Commission, 2020). Activities featuring in the plan should refer to all major stakeholders, including students, doctoral students, academia, and

administrative personnel, as well as relationships with external stakeholders.

The need to apply new approaches in education for sustainability in business schools also results from the constantly changing educational environment, owing to the *development of digital technologies and globalization.* As an outcome, new jobs appear, new skills, knowledge and competences are sought by employers, and all this requires that they are included in the processes of student education. In this, Europe's business schools need to comply with European Commission policies that regulate the acquisition of digital competences, for example the Digital Competence Framework for European Citizens (European Union, 2017), which contains descriptions of the most important digital competences, classified into five areas. They comprise: Information and data literacy, communication and collaboration, digital content creation, and safety and problem solving competencies.

Another document that suggests the updating of the curriculums of European Union business schools is the European Framework for Key Competences (The Council of the European Union, 2018). It contains eight key competences which are essential for students' future realization, for their healthy and sustainable lifestyle, their aptitude for employment, active citizenship and social inclusion. The eight groups of competences cover: Literacy, multilingual competence; mathematical competence; competence in science and technology; digital competence; personal, social and learning to learn competence; citizenship competence; entrepreneurship competence, and cultural awareness and expression competence. Of these, the one most strongly focused on the acquisition of knowledge and skills for sustainable development is "citizenship competence," defined by the European Commission as 'the ability to act as a responsible citizen and provide a valuable contribution to society.' In some of the remaining groups of competences, there are also knowledge and skills directly or indirectly connected with achieving sustainable development. Among them, for instance, are 'cultural awareness and expression competence', 'personal, social and learning to learn competence' and 'entrepreneurship competence'. In the above mentioned documents, the European Commission recommends applying "*competence-orientated educational approaches*" in schools and universities.

2. Applicable Educational Approaches for Sustainable Development in Contemporary Business Schools

Responsible and sustainable business ideas are constantly evolving, and universities should include them in their curricula and programs to promote their application among students. Some are taught as standalone courses, while others are included as separate topics in more general classes. This demonstrates the need for a *multidisciplinary approach* to sustainability education in business schools.

At the same time, by the guidelines of the European Commission, business schools should apply *competence-oriented educational approaches* which focus on including enough topics and courses dedicated to sustainable development in as many majors and academic degrees as possible, contrib-

uting to forming sustainability competencies in students.

However, this process also needs to be taken into account with the growing popularity of alternative forms of education, such as Massive Open Online Courses (MOOCs), developed thanks to digital technologies and offered by various organizations, among them *Corsera, Udemy, edX, LinkedIn*, etc. These tend to be short, lasting a mere few months, and the trainees receive specific knowledge and skills in a particular, narrower, field, which is why there is an opportunity for their faster assimilation and application in practice. This educational approach corresponds to the expectations of Generation Z for shorter-term and more practically-oriented training, aiming for speedier career realization.

The competition caused by short-term alternative forms of education can also be seen as one of the reasons for the observed trend in Europe towards moving from 4-year to 3-year bachelor's degree studies. This again necessitates a change in the educational models of business schools, which also affects the opportunities for students to acquire sustainability competencies. Reducing training time requires finding a new approach to provide sufficient knowledge for sustainable development within the shortened time frame, which also implies shortening individual topics or entire courses in the training period. In this connection, the so-called T-shaped educational approach (Saviano et al., 2016), which allows students a shorter time to form a specific theoretical basis, giving the general idea of sustainable development, and subsequently, at their discretion, for students to choose individually from a narrow area of the various aspects of sustainability in which to gain more profound knowledge.

A number of more pragmatically oriented concepts of sustainable development arise in different countries, and are strongly directed towards solving regional social problems closely related to local culture and the peculiarities of the individual business environments (such as M. Yunus's Grameen Bank in Bangladesh, and his understanding of social business). This requires applying an educational approach that will support adaptation to the business environment in different countries and cultures. In this regard, some scientists propose using the so-called *Two-Eyed educational approach* for sustainable development (Zeyer 2022). This approach was inspired by Canadian science educators who used it in teaching their Aboriginal students, combining the scientific perspective of sustainable development knowledge with the traditional environmental knowledge practices of the region (Zeyer 2022: 5). Subsequently, this educational approach for sustainable development began to be developed experimentally, mainly for pedagogical education. The reason for this is the understanding that creating a culture for sustainable development in various social spheres needs to start at an early age and continue through the different stages of people's education. Thus, issues related to sustainability need to find a place in educational models, first in schools and then further developed in universities. However, it is crucial that the

various aspects of sustainability are taught in an understandable and motivating way to students of different ages. This means that it is necessary to have prepared teachers, who combine the scientific perspective of sustainable development knowledge with traditional local understandings and practices for a sustainable lifestyle; that is, to apply the Two-Eyed educational approach. In this way, questions related to, for example, the personal lifestyle of learners, could be taught with an emphasis on health; ecological dimensions could be taught with a focus on protecting the environment and life on the planet, through examples of native plant and animal species; and social dimensions could be taught in the context of overcoming economic inequalities and giving equal chances by combating discrimination, focused on social groups from local communities.

To increase students' interest in the topic of sustainable development, higher education schools need to apply a *research-based educational approach*, involving students in teams of scientists implementing scientific research projects, stimulating them to participate in national and international student conferences, competitions and mobilities, with a focus on sustainable development. The *entrepreneurial approach* in sustainable development education is also applicable, stimulating students to develop their entrepreneurial ideas in search of business solutions to the social problems of local communities, and stimulating their development into real business projects. The role of business schools is to support students through mentoring and funding sources for student entrepreneurial projects through business incubators, accelerator programs, and other relevant initiatives.

Business schools can benefit from European Commission funding programs to expand the training practices in Sustainable Development. They aim to develop cooperation between educational, scientific, business, and public institutions, and aim to create new educational models seeking synergy between science, technology, cultural and creative industries, architecture, and ecology (Serafimova, 2021). This necessitates the application of intersectoral educational approaches - intersectoral educational models. This idea corresponds with Responsible Education in Business and Management (Laasch and Gherardi, 2019) and practices of Responsible Management Learning and Education (Moosmayer et al., 2020).

Sustainability training in higher education can also be linked to the transformation of higher education in the direction of increased connectivity and the possibilities of European university alliances. The European Commission perceives these alliances as "an engine towards constructing a modern and sustainable, more digital and environmentally friendly higher education, able to ensure high achievements with an inclusive approach." In this way, students are included in pan-European values and efforts to enforce culture and values supporting the Sustainable Development Goals. They, in turn, turn business schools into an engine for regional and business development, supporting the realization of a digital and ecological transition and sustainable management of regions.

Conclusion

The following conclusions can be drawn by summarizing the outlined trends and features in sustainable development training in business schools.

First, sustainable development education is characterized by a multidisciplinary approach that covers the various elements of sustainability in different study courses, in whole or in part, emphasizing the individual aspects. Sustainability issues are included as parts of separate topics in more significant foundational business and management courses, or can be taught as different courses through more narrowly profiled academic disciplines.

Second, business schools in the European Union apply the competence-oriented educational approach recommended by the European Commission, and it is appropriate to upgrade it through the application of the T-shaped educational approach. In this way, they would be more flexible and competitive in response to increasing competition from alternative higher education forms, offering shorter-term learning opportunities, such as MOOCs.

Third, implementing the two-eyed educational approach would facilitate educators' efforts to adapt some concepts and practical initiatives for sustainable development to the specificities of the business environment in different countries and cultures.

Fourth, research-based and entrepreneurial-oriented educational approaches need to be applied to form more practically oriented skills in students to search for business solutions to social problems.

Fifth, the training for sustainability in business schools is also related to the application of an intersectoral educational approach, in which synergies are sought from the mutual participation of representatives from the business and public sectors, academic institutions, and non-governmental organizations, in achieving sustainable development.

The diverse approaches to integrating sustainability into higher schools' educational and management models outline the possibilities for increasing their innovative activity and their role as a driver for the sustainable development of regional ecosystems. However, the new educational approaches must be appropriately combined with the established promising educational approaches and practices of business schools. This could be achieved by applying an ambidextrous approach.

This reflects the need for business schools to change, taking into account changes seen in the environment, with an emphasis on digitization, internationalization, partnerships, multidisciplinarity and multisectorality to achieve academic sustainability. On the other hand, there is the need for a balance between established traditions, organizational culture, specific features in the functioning and management of business schools, and the introduction of digital and social innovations.

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Ethiopian Programs, Strategies and Agreements for Sustainable Development: A Study of the Oromia Region

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ABSTRACT

This study examines Ethiopia's efforts, strategies, and programs for sustainable development, with an emphasis on the Oromia regional state. The economy of Ethiopia is growing at one of the fastest rates on the continent, and it has made significant progress towards achieving the United Nation's Sustainable Development Goals. The country has initiated several policies, agreements, and initiatives to promote sustainable development for the Oromia people. The development of sustainable farming practices, land-use planning, renewable energy sources, and forest preservation are all prioritized in the majority of the government's projects, decreasing greenhouse gas emissions and strengthening resistance to climate change as a result. The initiatives have also been successful in promoting economic growth, improving food security, and reducing poverty. A number of noteworthy projects that have been implemented in the Oromia region. Through the promotion of renewable energy sources like solar and wind power, these projects aim to reduce reliance on fossil fuels and mitigate the consequences of climate change. In order to ensure the population's general development and well-being, efforts have also been undertaken to increase access to healthcare and education. The Oromia region has many obstacles in the way of achieving sustainable development, despite boasting a diverse population and an abundance of natural resources. This paper examines the initiatives undertaken by the federal government, state and local governments, and other stakeholders to address these problems and promote sustainable development. The research findings enhance comprehension of the challenges faced by the Ethiopian government in defending its long-term objectives for both the country's citizens and the global community.

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Introduction

With its distinct socio-economic and environmental issues, Ethiopia, a country known for its historical significance, cultural richness, and ancient civilization, is negotiating the difficult path towards sustainable development. Ethiopia, a nation in the Horn of Africa, has gained attention as a focal point for talks on sustainable development worldwide in recent years, due to its dedication to tackling complex problems like social inequality, poverty, and environmental degradation. The country's will to reverse its long-standing cycles of poverty and reliance on conventional farming methods and to combat the negative effects of climate change, periodic droughts, and population expansion, further heighten the need for sustainable development measures in the nation (UNDP, 2021).

The realization of its interconnected goals, which are embodied in national policy frameworks like the Growth and Transformation Plans (GTPs), is one of the main factors propelling Ethiopia's commitment to sustainable development. According to the Government of Ethiopia (2010), these programs place a strong emphasis on the need for inclusive economic growth, social fairness, and environmental sustainability as interrelated foundations for achieving lasting development. Ethiopia demonstrates its commitment to international collaboration and shared responsibility in tackling global concerns by aligning itself with global sustainability agendas, especially the United Nations Sustainable Development Goals (UN SDGs) (United Nations, 2015).

Ethiopia's varied ecosystems and rich cultural legacy highlight the significance of sustainable development even more. An essential part of Ethiopia's sustainable development story is the preservation and exploitation of the country's natural resources and cultural heritage. National identity and international stature are enhanced by initiatives that support eco-friendly tourism, biodiversity conservation, and cultural heritage preservation, in addition to environmental sustainability.

Given Ethiopia's demographic profile, where a sizable section of the populace depends on agriculture for a living, sustainable development is essential so as to reduce poverty and guarantee food security. The country's dedication to adopting sustainable farming methods and improving rural livelihoods is indicative of an integrated strategy that acknowledges the interdependence of social, economic, and environmental aspects (FAO, 2016).

Ethiopia is a nation that is deeply committed to ending the cycle of poverty, tackling environmental issues, and promoting inclusive and fair growth, which makes sustainable development extremely important. In order to develop effective policies and strategies that are in line with Ethiopia's particular context, it is crucial to comprehend the contextual nuances of the opportunities and difficulties facing the country as it navigates its path towards sustainability.

The Importance of Agreements, Plans and Tactics

Implementing targeted initiatives, strategic frameworks, and international agree-

ments are all integral parts of Ethiopia's path towards sustainable development. Ethiopia's dedication to resolving the intricate relationship between social justice, economic development, and environmental protection is seen in this coordinated endeavour. We may learn more about the dynamic interactions that influence Ethiopia's trajectory towards sustainable development by looking at each of these components' functions:

Programs for Inclusive Development: Ethiopia's sustainable development is driven by comprehensive policies intended to promote inclusive growth and the reduction of poverty. Notably, programs like the Productive Safety Net Program (PSNP) seek to break the cycle of poverty, improve food security, and lessen the effects of climate change on people that are already at risk (World Bank, 2018). These initiatives demonstrate Ethiopia's dedication to building a resilient and sustainable society.

Strategic Frameworks for Holistic Growth: Sustainable development in Ethiopia is mapped out using strategic frameworks like the Growth and Transformation Plans (GTPs). The Government of Ethiopia (2010) states that the GTPs have a strong emphasis on social development, industrialization, and economic diversification. They also set high goals. Sustainable development principles are adhered to by a strategic strategy that combines economic goals with social and environmental aspects.

International Agreements for Global Collaboration: Ethiopia actively engages in international agreements, recognizing the global nature of sustainable development challenges. Ethiopia's signing of the Paris Agreement on climate change is a testament to its commitment to mitigate environmental risks and promote sustainable practices (United Nations, 2015). By participating in these agreements, Ethiopia acknowledges the interconnectedness of its development with global efforts, and seeks collaborative solutions. The Oromia Region, as a microcosm of Ethiopia's diverse challenges, requires specialized strategies for sustainable development. Localized efforts, such as the Oromia Regional Development Plans, demonstrate a tailored approach to addressing regional nuances (Oromia Regional Government, 2019.). These strategies acknowledge the significance of context-specific interventions for sustainable outcomes.

Challenges and Adaptations

There exist issues associated with the role of programs, strategies, and agreements. Strategies for adaptation are required due to gaps in implementation, institutional limitations, and changing global dynamics. The refinement of methods and maintenance of the relevance of sustainable development programs depend on an understanding of these problems (Kaplinsky, 2019). Programs, strategic frameworks, and international agreements are purposefully integrated, which emphasizes the importance of sustainable development in Ethiopia. Ethiopia's dedication to an inclusive and holistic development model, which recognizes the interdependence of social, environmental, and economic aspects, is reflected in the dynamic synergy between these components.

Research Objectives and Goals

Among the research objectives and goals for the study 'Ethiopian Programs, Strategies, and Agreements for Sustainable Development: A Study of the Oromia Region' is the aim to critically assess the effectiveness of various sustainable development programs implemented in the Oromia region of Ethiopia, considering their impact on economic growth, social equity, and environmental sustainability.

Programs for Poverty Alleviation and suitability

The Productive Safety Net Program (PSNP) is one of the key initiatives in addressing vulnerability, by providing cash and food transfers to households during periods of food insecurity. This targeted approach seeks to enhance community resilience, improve livelihoods, and ultimately contribute to long-term food security. The effectiveness of the PSNP in the Oromia region underscores the importance of targeted interventions in addressing poverty and promoting sustainable development, as is evident in the evaluation of poverty alleviation programs (World Bank, 2018).

Analysis of Agricultural Development Initiatives

The Oromia region's agricultural development initiatives are essential to its economic structure, as they boost production, encourage sustainable farming methods, and help the region become more resilient to climate-related shocks. This study delves into the results of these initiatives, analysing their influence on the agricultural environment. Programs for agriculture that are based on sustainability principles try to promote eco-friendly behaviours. Organic agricultural practices, conservation tillage, and agro-ecological techniques all improve soil health and biodiversity (Pretty *et al*., 2018). Through improved crop types, effective irrigation systems, and contemporary farming practices, agricultural interventions aim to increase productivity, while using drought-resistant and high-yielding crops increases agricultural productivity and ensures community food security (IFAD, 2020).

Resilience to Climate-Related Challenges

Recognizing the vulnerability of agriculture to climate change, new programs tend to emphasize climate-smart practices. Diversification of crops, water management strategies, and early warning systems enhance the sector's resilience to erratic weather patterns and extreme events (FAO, 2016). Successful outcomes hinge on empowering farmers with knowledge and skills. Training initiatives on sustainable practices, modern technologies, and risk management contribute to the resilience of farming communities (IFPRI, 2019). The integration of innovative technologies, such as precision agriculture and remote sensing, fosters efficiency and informed decision-making. Technology-driven solutions play a pivotal role in adapting agriculture to changing climatic conditions (FAO, 2021).

Economic Empowerment and Market Access

Agricultural development programs extend beyond the farm gate, incorporating

measures to boost market access for farmers. The creation of value chains and market linkages ensures that increased productivity translates into economic empowerment for rural communities (Diao *et al*., 2019). This assessment draws on a combination of quantitative indicators, field surveys, and expert interviews to comprehensively evaluate the outcomes of agricultural development programs in the Oromia region.

Sustainable Development in National Policy

For comprehensive and long-lasting success, it is essential that national and regional policies fall in line with the principles of sustainable development. Examining how closely these frameworks follow the concepts of sustainable development, this study focuses on Ethiopia's national Growth and Transformation Plans (GTPs) and the Oromia Regional Development Plans, specifically, GTP I (2010/11–2014/15) and GTP II (2015/16–2019/20). As interrelated pillars, these strategies prioritize social justice, economic prosperity, and environmental sustainability (Government of Ethiopia, 2010).

Oromia Regional Development Plans

At the regional level, the Oromia Regional Development Plans articulate strategies tailored to the specific needs and context of the Oromia region. These plans outline initiatives for economic development, social services, and environmental management. Examining the alignment of Oromia's plans with sustainable development principles provides insights into the region's commitment to addressing local challenges, while contributing to broader national and global sustainability goals.

Economic, social, and environmental dimensions must be integrated. Harmonizing social, economic, and environmental goals is essential for sustainable development. The study evaluates the ways in which national and regional policies incorporate these elements, guaranteeing inclusive economic growth, prioritizing social fairness, and protecting environmental resources for posterity (United Nations, 2015).

Inclusivity and Stakeholder Engagement

The participatory nature of the policies can be understood by analyzing policy documents to determine the level of community involvement, particularly in the creation and execution of development plans (Cohen & Uphoff, 1980). In order to evaluate the policy papers' compliance with sustainable development principles, a comprehensive review of the documents was undertaken, including of the GTPs and Oromia Regional Development Plans.

Ethiopia's commitment to sustainable development extends beyond national borders, involving active participation in international agreements. In order to assess this international collaboration, the study looks at Ethiopia's engagement in international agreements related to sustainable development, focusing on their impact on the Oromia region in particular, considering the region's unique socio-economic and environmental dynamics.

The Paris Agreement on Climate Change

Ethiopia's ratification of the Paris Agreement on Climate Change demonstrates its dedication to addressing climate change. The objectives of the agreement are essential for tackling environmental issues in the Oromia region, where water supplies and agriculture are impacted by climate change (United Nations, 2015).

The UN Sustainable Development Goals (SDGs)

Ethiopia addresses poverty, education, health, and environmental sustainability through coordinating its sustainable development initiatives with the UN SDGs. The analysis focuses on how the Oromia region is impacted by the integration of SDGs into national and regional policies and programs (United Nations, 2015).

African Union's Agenda 2063

Ethiopia's involvement in the African Union's Agenda 2063 reflects a continental commitment to socio-economic transformation. Investigating the implementation of Agenda 2063 in the Oromia region sheds light on its contributions to regional development aspirations (African Union Commission, 2015).

International Monetary Fund (IMF) and World Bank Agreements

Engagements with international financial institutions like the IMF and World Bank influence economic policies. Assessing the impact of such agreements on Oromia's economic development provides insights into the region's financial resilience and capacity building (IMF, 2020; World Bank, 2021).

Global Environmental Conventions

Adherence to conventions such as the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity has an impact on conservation activities aimed at protecting biodiversity. Understanding how international commitments translate into local action is made easier by looking at their effects in the Oromia region.

Trade Agreements and Economic Partnerships

Investigating Ethiopia's engagements in trade agreements and economic partnerships provides insights into the economic dimensions of sustainable development. The study assesses how these agreements contribute to trade, investment, and economic growth in the Oromia region (UNCTAD, 2020).

Implementation Challenges in Sustainable Development Initiatives

Achieving long-term economic, social, and environmental improvement in the Oromia region depends on the effective implementation of sustainable development projects. The present analysis aims to identify and investigate the obstacles and problems that impede the efficient implementation of these initiatives.

Limited Access to Resources and Infrastructure

Inadequate electricity, water, and transportation infrastructure is a major barrier to sustainable development initiatives (Ay-

enew, 2019). Projects meant to enhance livelihoods and foster economic progress are hampered by inadequate access to necessary resources.

Climate Variability and Environmental Degradation

According to the NMSA (2020), the Oromia region is susceptible to climate-related issues, such as periodic droughts and land degradation. Adaptive methods are required because these environmental stressors make sustainable agriculture difficult and heighten worries about food security. The region's economic imbalances make it difficult to raise money for programs aimed at sustainable development. Small-scale farmers and business owners are less able to invest in sustainable practices due to limited access to financing and financial services (World Bank, 2020).

Political and Social and Governance Challenges

Development endeavours may encounter disruptions due to historical political tensions and societal unrest in the region. According to Megersa & Beyene (2020), maintaining stability and encouraging community involvement are essential for the effective execution of sustainable initiatives. Initiatives for sustainable development are difficult to implement and monitor because of weak institutional capacity and governance issues, such as bureaucratic inefficiency and corruption (Mohammed & Yimam, 2015).

Limited Awareness and Community Involvement

The success of sustainable development efforts may be hampered by low levels of community involvement and awareness. Long-term project viability depends on increasing community capacity and guaranteeing active involvement (Kibret, 2019). Adoption of some sustainable techniques may be hampered by societal attitudes and traditional cultural conventions. Success depends on coordinating projects with regional traditions and encouraging community acceptance (Lemma & Negatu, 2019). A diversified strategy that takes into account the particular circumstances of the area is needed to address these issues. The Oromia region should employ strategies, including capacity building, policy reforms, and community participation, to enable the successful execution of sustainable development programs and to overcome obstacles.

Policy Recommendations

Top priority should be given to developing infrastructure, especially in remote regions, in order to enhance accessibility to vital services like markets, healthcare, and education. Investments in electricity, water supplies, and transportation networks can boost the general standard of living and promote economic activity.

Climate-resilient farming methods should be created and carried out to tackle environmental issues. To increase agricultural output and guarantee food security, this involves supporting sustainable land-use planning, water management, and the deployment of climate-smart technologies.

The Oromia region needs to implement evidence-based policy suggestions in order to maximize the effectiveness of sustainable development initiatives. It is recommended by policy that economic, social, and environmental objectives be aligned using integrated development planning. This calls for the alignment of national and regional development plans, such as the Growth and Transformation Plans and the Oromia Regional Development Plans, in order to guarantee a coherent and well-coordinated approach (Government of Ethiopia, 2010; Oromia Regional Government, 2019).

To increase production and efficiency, the adoption of cutting-edge technologies should be encouraged in all areas.

To improve service delivery and generate chances for economic growth, digital solutions should be embraced in the fields of education, healthcare, and agriculture.

The institutional capabilities of regional governance structures should be developed. Combating corruption, promoting openness, and addressing bureaucratic inefficiencies are part of this. According to Mohammed and Yimam (2015), successful policy implementation requires strong and capable institutions.

Investment in education and skills development should be prioritized to build a capable and adaptable workforce. This includes initiatives to improve the quality of education, vocational training programs, and aligning educational curricula with the needs of emerging industries.

Conclusion

Ethiopia, as a whole, has implemented several successful sustainable development initiatives that have had a positive impact. These initiatives often address economic, social, and environmental aspects. Among the most notable examples are:

- Premier social safety program 'the Productive Safety Net Program (PSNP),' which gives food and cash handouts to households that are at risk. Beneficiary communities have benefited from PSNP through greater shock resistance, decreased poverty, and improved food security.
- Community-based health insurance programs. In order to improve access to healthcare in rural areas, Ethiopia has put in place community-based health insurance programs which have improved health outcomes, increased health coverage, and decreased out-of-pocket costs. They have also notably improved vulnerabilities.
- Investing in renewable energy projects like wind and hydroelectric power, an area in which Ethiopia has made several investments. Sustainable development goals have been aided by these measures, which have increased access to electricity and decreased dependency on non-renewable resources.

In conclusion, the study provides a comprehensive overview of sustainable development initiatives in the Oromia region, highlighting successes, challenges, and potential areas for improvement. The findings underscore the importance of a multi-dimensional and collaborative approach so as to achieve lasting and inclusive sustainable development.

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Sustainable Development in the Conditions of the Russian-Ukrainian War: The Local and Global Dimension

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ABSTRACT

The escalation of the Russian-Ukrainian war poses a serious threat to achieving the United Nations Sustainable Development Goals (SDGs). The challenges to meeting the SDGs by 2030 will be even greater, considering the current conditions. The consequences have spread not only to the countries directly involved in the war, but also to a global level.

Before the full-scale invasion in 2022, Ukraine had made progress in 15 of the 17 SDGs. However, the war nullified all previous achievements in Ukraine's development progress. Yet, despite these negative tendencies, the SDGs provide a good basis for determining Ukraine's development priorities, and are also an effective way to attract financial support to increase the country's resilience and recovery. Although war complicates the movement toward the goals of sustainable development, it necessitates the socially responsible position of different states, businesses, and international organisations.

The paper aims to assess the impact of the Russian-Ukrainian war on indicators that characterize the economic dimension of SDGs, based on a comprehensive analysis of the available data, a literature review, and empirical estimations. Ordinary Least Squares (OLS) methodology for time series data was used to estimate the main functional dependencies. The investigation proves the destructive impact of war on the global economy, seen mostly through increases in commodity prices, trade, and supply chain distraction. The obtained results confirm the need to support sustainable development as a foundation for peaceful societies, national resilience, and recovery at the local and global levels.

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Introduction

The Russian-Ukrainian war which erupted in 2014 has not only had profound consequences for Ukraine and the immediate region, but has also reverberated around the globe. Sustainable development, a universal goal set by the United Nations, seeks to balance economic, social, and environmental progress. The war in Ukraine has had a far-reaching global impact on the pursuit of that development.

This article explores how the conflict affects sustainable development goals not just in the region, but also globally. The main focus is on the economic dimension.

1. Economic Dimension of the SDGs

The proposal from the Stockholm Resilience Centre suggests that the conflict is affecting the Sustainable Development Goals (SDGs) associated with the biosphere, economy, and society. SDG 17, which focuses on Partnerships for the Goals, encompasses all dimensions, including the biosphere, society, and economy (Stockholm Resilience Centre, 2017). Preliminary analysis of the literature shows that the biggest global impact is felt through the economic dimension (Pereira et al, 2022; de Groot et al., 2022; Jenkins, 2023). The armed conflict between Russia and Ukraine triggered an economic recession, damaged the global economy, and impeded the post-COVID recovery (World Bank, 2022).

According to Pereira et al (2022, p.284-286), the Russian-Ukrainian war has made it impossible to achieve the following SDGs within the economic dimension: SDG 8, SDG 9, SDG 10, and SDG 12. The impossibility of SDG 8 comes as a result of the global recession and GDP loss, the decrease in economic upgrading due to the sanctions, destruction of business development and increased unemployment, the risk of human trafficking, reduction in tourism, and domestic financial institution crises. Obstacles in the way of achieving SDG 9 include infrastructure destruction and inflation, reduction of industry, unemployment, financial market disruptions, and sanctions reducing industry capacity. The levelling of progress toward SDG 10 is caused by reduced economic growth, increased inequalities and repression, and evidence of forced child and adult mobilisation to Russia. And of course, the full-scale invasion influences SDG 12 because the increase in demand for fossil fuel, environmental pollution, and economic crisis can reduce the establishment of sustainable practices.

In analysing obstacles to SDG 17, we recognise that: Economic crises reduce the resources for developing countries and their GDP (UNCTAD, 2022, Ruta, 2022); the war affected the trading environment and macroeconomic stability (Guenette et al, 2002); the war blocked the global partnership between countries (Pereira et al, 2022, p.286).

2. Ukraine

Ukraine has experienced a degree of destruction unprecedented in Europe since World War II, and the recovery process back then for Germany and the United Kingdom took two to three decades following on from the end of the war (Jenkins, 2023).

Fig. 1. Ukraine: Real GDP growth, 1991-2022.
Source: International Monetary Fund (IMF)

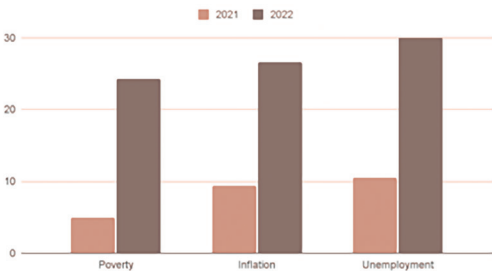

Fig. 2. Ukraine: Poverty, Inflation, Unemployment
Source: World Bank Database

Apart from the humanitarian disaster, the Russian invasion has inflicted severe damage on Ukraine's economy. This has resulted in a sharp drop in GDP and a significant increase in unemployment, as reported in various sources (Kyiv Independent 2022, National Bank of Ukraine 2022, Ministry of Economy of Ukraine 2023). Ukraine's economic output is now at a fraction of its pre-war levels. In the first year of the conflict, the country lost 30-35% of its GDP, leading to the largest recession in Ukraine's history (see Figure 1). Its GDP is projected to grow in 2023, if only by 0.5%. Results of some investigations show that losses in total factor productivity are expected to plummet by about 7% by 2035, and that the negative effects will fade away only slowly over the following decades (Egert et al., 2023). The cost of reconstructing the damaged and destroyed physical infrastructure is estimated to be between 130% and 330% of Ukraine's GDP before the COVID-19 pandemic, as indicated by Becker et al. (2022).

For the people of Ukraine, incomes have dropped against a background of high inflation and unemployment. Poverty in the country increased from 5.5% of the population to 24.2% in 2022 (Figure 2), and the number could rise to as high as 55% by the end of 2023, according to the World Bank overview (World Bank, 2023). The war pushed 7.1 million more people into poverty, undoing 15 years of progress (Kilfoyle, 2023).

3. Global Consequences

The war has unfolded during a challenging period for the global economy. The world has been striving to recover from the economic downturn caused by the pandemic, but this recovery is slowed by persistent COVID-19 outbreaks and reduced governmental assistance, the World Bank (2022) noted. Moreover, inflation rates are on the rise in numerous nations, prompting major economies to raise interest rates to control it. The disruptions in global trade and investment are anticipated to hinder the growth of developing countries and intensify inflationary pressures, espe-

cially if governments opt to implement trade restrictions to protect their domestic economies (Ruta, 2022).

According to research by Kammer et al, impacts will flow through three main channels:

1. Higher prices for commodities like food and energy will push inflation up further, in turn eroding the value of incomes and weighing on demand;
2. Neighbouring economies will grapple with disrupted trade, supply chains, and remittances, as well as a historic surge in refugee flows;
3. Reduced business confidence and higher investor uncertainty will weigh on asset prices, tightening financial conditions and potentially spurring capital outflows from emerging markets (Kammer *et al.*, 2022).

Russia and Ukraine are major commodities producers, and disruptions have caused global prices to soar, especially for oil and natural gas. Food costs have jumped, with wheat, for which Ukraine and Russia make up 30 percent of global exports, reaching a record high (Kammer *et al*., 2022). Similar channels are defined in the Ruta investigation. This report outlines five specific trade and investment channels that will be impacted by the conflict in Ukraine. These include disturbances in commodity markets (especially food and energy), logistic networks, supply chains, foreign direct investment, and other specific sectors (Ruta, 2022).

From a macroeconomic standpoint, increased prices for food and energy will lead to a decline in real incomes and a reduction in global import demand. Sanctions will not only impose economic burdens directly on Russia, but also on its trade partners. Apart from Russia and Ukraine, the negative effects on gross domestic product (GDP) are being particularly felt in Europe due to the region's geographical proximity and reliance on Russian energy. Trade expenses were increased due to sanctions, export limitations, elevated

Table 1. Indicators and channels of the global influence of the Russian-Ukrainian War: Economic dimension

Chanel	*Macroeconomic indicator*	*Effects*
Trade	Trade Balance	Commodity market distraction (especially food and energy), global import demand depression, global supply chains (GVC), and logistic networks.
Investment and Financial Stability	Foreign Direct Investment	Tightening global liquidity, let down in credit quality, corporate and sovereign debt elevation, and decline in renewable energy investment.
Global Inflation	Commodity prices	Increasing commodity prices (especially agricultural and energy).
Labour market	Unemployment rate	Declining real wages, and decreasing demand for workers because of uncertainty
Inequality	Income inequality	Higher prices, unemployment, debt escalation, increase in the level of poverty

Source: Developed by the author

energy costs, and transportation disruptions. Consequently, the war's impact on global trade in 2022 surpassed its impact on the overall global GDP (WTO, 2022).

Based on an analysis of previous studies on the topic, and reports of international organisations, we have systematised channels of global economic influence and the corresponding macroeconomic indicators which are primarily affected by the war and will be used for further research (Table 1).

The estimated decline in global income is 0.7 percent, with low-income countries losing 1 percent and high-income countries losing 0.6 percent (Figure 3). Given the relative size of energy in GDP, the expected impact from the increase in energy prices as compared with the impact of prices of crops and stylised sanctions on total income are much higher (Ruta, 2022).

The pandemic exposed the weaknesses of just-in-time supply chains, and the economic repercussions of the war in Ukraine have emphasised the extra risks inherent in such a system (Jenkins, 2023). The Russian invasion of Ukraine is already beginning to cause extensive and debilitating supply chain disruption around the globe. Experts believe that the war will likely cause supply chain disruption in four major areas: commodity price increases, firm-level export controls and sanctions, cyber security collateral damage and supply chain turmoil, and geopolitical instability (Interos Report, 2022).

UNCTAD's World Investment Report 2023 shows a widening annual investment deficit that developing countries face as they work to achieve the SDGs by 2030. The gap is now about $4 trillion per year – up from $2.5 trillion in 2015 when the SDGs were adopted. The report shows that global foreign direct investment (FDI) fell 12% in 2022. The report highlights that developing countries need renewable energy investments of about $1.7 trillion each year, but attracted only $544 bil-

Fig. 3. Real GDP growth (Annual percent change)

Source: IMF, World Economic Outlook, October, 2023.

lion in clean energy FDI in 2022 (World Investment Report, 2023).

The Russian invasion of Ukraine has led to a substantial increase in the prices of energy and food since the start of the war, as Russia and Ukraine were major suppliers of energy and food for European countries. Global inflation has increased to 8.6 percent.

The influence of the war on inequality may vary somewhat depending on the financial situation of each country, but those with very high debt may suffer much more complex consequences if the conflict continues. It was found that inequality increases during violent conflict, and will do so in particular in the five years following the end of conflict. Previous investigations on this issue show that income inequality increased by around 1.7 Gini points during the war (Bircan, 2017).

Earlier research showed that the impacts of the armed conflict on inflation and unemployment would be global (Ruiz-Estrada, 2022), and that this will likely be translated into the loss of purchasing power, and poverty. The effects are being felt through food and energy inflation, declining real wages, growing inequality, shrinking policy options, and higher debt in developing countries. A slowdown in economic growth and aggregate demand will also reduce demand for workers as uncertainty and worsening expectations affect hiring.

Currently, on the base of secondary data analysis, we can observe more negative tendencies in Ukraine, where the unemployment rate has increased to 30%. More than five million jobs in Ukraine have been lost. The global unemployment rate did not rise when the full-scale invasion began, but by the end of 2022, the unemployment rate in the world had decreased by 0.4 percentage points (-6.45 percent) on the previous year. Unemployment rates continue to decrease in neighbouring European countries. For the European Union as a whole, the unemployment rate stood at 5.9% in August, the same as in May and June.

4. Data and Methodology

The annual data for the period of 2000-2023 was used to study the impact of the Russian-Ukrainian war. The analysis includes a sample covering global and Ukraine statistics. The data is transformed into logs to prevent the influence of outliers.

The selected list of dependent variables corresponds to the results of the previous analysis of the channels through which the war influences the global economic dimension of sustainable development (Table 2). The dependent variables are as follows: gdp_g_t – world GDP growth (%), $energy\_pr_t$ – World Bank energy commodity price index (2010=100); agr_prt – World Bank agricultural commodity price index (2010=100), $ineq\_g_t$ – difference in the income share for bottom 40% and top 10%, world average, World Inequality Database; $unempl\_g_t$ – global unemployment rate (as a share of the total labour force); $trade\_g_t$ – external balance of goods and services (% of GDP); and inv_g_t – global FDI (in millions of US dollars).

For independent variables characterizing the impact of the Russian-Ukrainian war, we used both variables that describe the direct influence of military actions, and economic indicators reflecting the participation of Rus-

sia and Ukraine in global trade. The indicator of involvement of the conflicting countries in global value chains closely correlates with the military actions and sanctions against Russia.

The list of explanatory variables includes military_ukr$_t$ – military expenditures in Ukraine (% of GDP); war_ukr$_t$ – dummy variable (4– period of full-scale invasion from 2022 till 2023, 2– preparing for full-scale invasion, 2021, 1– period of invasion 2014-2020); gvc_ukr$_t$ – Ukrainian GVC-related trade (% gross trade), gvc_rus$_t$ – russian GVC-related trade (% gross trade).

The data were obtained from the World Bank Database, World Inequality Database, World Integrated Trade Solution Database, and UkrStat Database[1].

The following base model is used to study the relationships between war characteristics and the main macroeconomic indicators:

$$\log(X_{it}) = a_0 + a_1 \log(X_{it-1}) + a_2 \log(\text{mil\_}ukr_t) + a_3 \text{ war\_}ukr_t + a_4 \log(\text{gvc\_}ukr_t) + a_5 \log(\text{gvc\_}rus_t) + \varepsilon \quad (1)$$

where $\boldsymbol{X_{it}}$ represents the seven groups of dependent variables: energy_pr$_t$, agr_pr$_t$, ineq_g$_t$ unempl_g$_t$, trade_g$_t$, and inv_g$_t$, while ε_{it} is the error term.

We also performed the Variance Inflation Factor (VIF) analysis to assess the extent of multicollinearity in the Ordinary Least Squares (OLS) regression. This analysis aids us in preventing correlations among multiple explanatory variables within our regression equations.

[1] The data didn't include variables from Ukrainian regions currently occupied by Russia.

5. Results

Firstly, a tests for stationarity for time series were used to ensure that no variable is stationary. The Augmented Dickey-Fuller Test (ADF), introduced by Dickey and Fuller in 1981, is a widely used approach in the analysis of time series data (Dickey and Fuller, 1981). Phillips and Perron Test (PP) is employed to verify the precision of the obtained results (Phillips & Perron, 1988). The results of these tests are shown in Table 2. In accordance with ADF and PP tests variables are stationary at I (0).

Table 2. Unit root test

	ADF (trend and intercept)	PP (trend and intercept)	Oder of interpretation
log(agr_pr$_t$)	-3,62**	-3,52*	I(0)
log(energy_pr$_t$)	-3,78***	-3,62*	I(0)
log(ineq_g$_t$)	-3,16**	-2,13	I(0)
log(unempl_g$_t$)	-3,95***	-3,80**	I(0)
log(gdp_g$_t$)	-5,50***	-5,25***	I(0)
log(trade_g$_t$)	-4,39***	-4,42**	I(0)
*log(*inv_g$_t$*)*	-4,62**	-4,85***	I(0)
log(*mil_ukr$_t$*)	-5,91***	-5,91**	I(0)
log(gvc_*rus$_t$*)	-5,94***	-5,46***	I(0)
log(gvc_*ukr$_t$*)	-3,36**	-2,86*	I(0)

*Notes: ***, ** and * respectively showed for the significance level of 1%; 5% and 10%*

The verification of the main functional dependencies is performed by the method Ordinary Least Squares (OLS) for time series data. The results are presented in Table 3 for seven regression models (1-7), each for every dependent variable.

Table 3. Results of empirical investigation

Explanatory variables	***Dependent variables/regression model number***						
	log(agr_pr$_t$)	*log (energy_pr$_t$)*	*log(ineq_g$_t$)*	*log (unempl_g$_t$)*	*log(gdp_g$_t$)*	*log (trade_g$_t$)*	*log(*inv_g$_t$*)*
	1	2	3	4	5	6	7
Constant	-	-	-0.084 (1.26)	5.035*** (5.89)	-	6.62 (1.87)**	-5.184 (0.95)
Lagged dependent variable	0.882*** (9.54)	0.898*** (5.78)	1.02*** (17.9)		-	0.934*** (6,83)	0.429** (2.14)
log (*mil_ukr$_t$*)	0.242*** (2.60)	0.289* (1.72)	0.005 (1.07)	0.134* (2.02)	-0.742 (-1.29)	- 0,385** (-2.03)	- 0.247 (-0.68)
war_*ukr$_t$*	0.119* (1.61)	0.147* (1.65)	0.003 (0.74)	0.021 (0.97)	-0.228 (-0.65)	-0.149* (-1.67)	-0.127 (-0.75)
log (gvc_*ukr$_t$*)	-0.931** (-2.08)	-3.235*** (-2.20)	0.022 (1.49)	-0.44* (-1.78)	5.710*** (2.01)	0.721* (1.657)	2.80* (1.61)
log (gvc_*rus$_t$*)	-0.831** (-1.92)	-3.425*** (-2.62)	-0,043* (-1.89)	-0.382* (-1.94)	6.20*** (2.15)	0.937* (1.82)	0.612 (0.49)
R^2 Adjusted R^2 BPG (P-value) DW	0.89 0.87 0.49 1.68	0.72 0.65 0.60 1.81	0.90 0.89 0.34 2.13	0.56 0.45 0.28 2.42	0,20 0.08 0.59 2.03	0.83 0,78 0.39 1.73	0.62 0.50 0.52 1.63

*Notes: 1) ***, **, and * represent the levels of significance of 1%, 5% and 10% respectively.*
2) The values of t-statistics are in parenthesis. 3) All variables are used in logarithms.

Source: Authors' calculations.

The statistically significant Durbin-Watson coefficient (DW) indicates the absence of an autocorrelation between the residuals of the regression equations. Also the residuals were tested for heteroscedasticity through the Breusch-Pagan-Godfrey Test (BPG). According to test results, we can assume that there is no evidence of heteroscedasticity (we cannot reject the null hypothesis of homoscedasticity as P-value is greater than 0.05). The rejection of autocorrelation and heteroscedasticity hypothesis provide grounds for further analysis of the obtained results. The coefficient of determination (R^2) indicates a high proportion of the variation in the dependent variable that can be predicted from the independent variable. According to the values of the adjusted R^2 indicator for multiple regression, the percentage of explanation of the dependent variable by the independent variables ranges from 8 to 89%. The highest level of significance is in case of inequality dependency (model 3), the lowest – for GDP dependencies (model 5). The percent of the variance in the response variable can be explained by the explanatory variables are 89% and 8% respectively.

The highest impact of the war is observed on commodity prices and global trade, a fact

confirmed by the statistical significance of the result and higher coefficients for explanatory variables. In particularly, the results indicate that the escalation of military actions (represented by variables log(mil_ukr_t) and war_ukr_t) led to a 0.2% and 0.1% increase in prices of agricultural products respectively, and a 0.3% and 0.1% increase in energy prices. The opposite impact of these explanatory variables on global trade is observed, as their growth contributes to a deterioration of the dependent variable by 0.4% and 0.1% respectively. This result is in line with the previous assumption that the impact of the war on global trade exceeds its influence on the global GDP (WTO, 2022).

The independent variables used to characterize the economic impact of war (log(gvc_ukr_t) log(gvc_rus_t)) are characterized by influencing almost all dependent variables. Thus, a decrease in Ukraine's involvement in global value chains leads to an increase in prices of agricultural products and energy resources, an increase in unemployment, a deterioration of global GDP, world trade, and FDI volumes (by 0.9%, 3.2%, 0.4%, 5.7%, 0.7%, 2.8% respectively, according to regression results). The impact of Russia's reduced participation in global value chains is even more significant, as a 1% change in this indicator leads to: an increase in global prices of agricultural products and energy resources, an increase in global inequality and unemployment levels, as well as a deterioration of global GDP and trade balance (by 0,8%, 3,4%, 0,04%, 0,3%, 6,2%, 0,9%correspondingly, based on the outcomes of the regression analysis).

The influence on energy, agricultural prices and global trade was observed in the case of both the economic characteristics of the impact of the war (participation in Russia and Ukraine in GVC) and in military terms (defence spending, intensity of attacks). In the case of global inequality and investments, the direct impact of war-related characteristics is negligible. This can be explained by the fact that global data do not allow for the consideration of characteristics specific to individual regions and the level of economic development. For instance, the decrease in investments due to the war is more pronounced for developing and low-income countries, while in some advanced economies and emerging markets (OECD Report, 2023; Crapps, 2023), investment volumes have increased. Countries with weak institutional and economic characteristics are disproportionately affected by income inequality. A similar explanation can be given for the minor impact on global unemployment, which corresponds with our previous analysis of secondary data.

6. Opportunities for Global Cooperation and Sustainable Development Goal Achievement

Due to the war, the world is becoming more and more disconnected and economically weaker. Yet, there exist several Opportunities for Global Cooperation and Sustainable Development Goal Achievement:

1. *Diplomatic Initiatives.* Diplomatic efforts to resolve the conflict are vital, not just for Ukraine but for global peace and stability. These efforts can open the door to sustainable development opportunities.
2. *International Aid and Support.* International aid and support can promote

sustainable development and humanitarian assistance.

3. *Energy Transition.* The conflict highlights the need for a global transition to renewable and sustainable energy sources to reduce dependence on volatile regions.
4. *Environmental Cooperation.* Collaborative environmental efforts can mitigate the ecological consequences of the conflict and promote sustainable practices worldwide.

Conclusions

The Russian-Ukrainian war has had world-level implications for the economic SDGs. The main channels of global economic influence are: Increases in commodity prices, trade, and supply chain distraction. On the one hand, the obtained results confirm the need to move in the direction of SDG achievement as a foundation for peaceful societies, national resilience, and recovery at the local and global levels. On the other hand, they point to the impossibility of achieving them without putting an end to the war.

Enhancing the comprehension, analysis, and surveillance of how war affects trade and development in developing nations and among vulnerable groups is of great significance for the international trade and development community. It is equally crucial to help countries to harmonise their trade policy responses. Only when we have a thorough grasp of these consequences can we establish resilient supply chains, minimise additional losses in trade and development, and prevent the widening disparities between developed and developing countries.

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Economic Losses from Russia's Missile Attacks on Ukrainian Critical Infrastructure with the Aim of Destroying the Ukrainian Nation

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ABSTRACT

The author examines objects that were targeted by missile attacks, and their significance in the context of defining the concept of "critical infrastructure". The aim of the analysis is to assess the economic damage caused to Ukraine and the extent of the destruction. The article raises the issue of genocide of the Ukrainian people in the context of attacks on Ukrainian critical infrastructure being carried out. The study shows that Russia's shelling and destruction of Ukraine's infrastructure are aimed at deliberately impacting living conditions in the Ukrainian nation, calculated to bring about its partial destruction as referred in Part. 6 (c) of the Statute of the International Criminal Court. Restoring infrastructure and creating safe living and working conditions in the country is an important task for Ukraine and its international partners. Restoration of critical infrastructure, energy systems, housing, and demining, will facilitate the return of Ukrainians home and will help prevent a rapid demographic crisis and the destruction of the Ukrainian nation, as planned by the Russian Federation when it launched the missile attacks.

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Introduction

The Russian military aggression, which has been going on for nine years, has caused extensive damage to Ukraine's critical infrastructure, electricity sector, industry, and the country's economy as a whole. The greatest damage was caused after the full-scale invasion that started on 24 February 2022[1]. Armed conflict always stands in extremely negative correlation with the economic situation of the country where it occurs (Serneels & Verpoorten, 2015), however, its intensity, objects and the infrastructure destroyed will define the process and cost of recovery. According to preliminary estimates by the Ministry of Economy of Ukraine, the decline in Gross Domestic Product in 2022 amounted to 30.4%[2]. Similar assessments are conducted by the World Bank, which estimates a 29.2% drop in GDP[3]. However, the real economic losses caused by the Russian aggression are much higher, as Ukraine is also losing the lives of its citizens (defenders and civilians), namely the working population, due to the mass emigration of its people abroad, and Russia continues to destroy residential buildings, enterprises, energy and transportation facilities, cultural, medical, administrative, educational and scientific institutions. With regards environmental and subsoil damage, the Department of Environmental Control and Methodology of the Ministry of Environmental Protection and Natural Resources has already estimated the environmental damage at UAH 10 trillion[4]. It is critical to accurately calculate all economic losses caused by the Russian aggression and acts of the Russian armed forces, as this data can be used as evidence in international courts to compensate for the damage. It is important to note that Russia is not only trying to gain a military advantage through this destruction, but also to destroy the Ukrainian nation itself. This is evidenced by the targeted shelling of critical infrastructure. In the first weeks of the full-scale invasion, the main strikes targeted military objects; however, having failed to achieve military success due to the resistance of the Ukrainian armed forces and Ukrainians themselves, Russia then turned to the tactic of "missile terror" by launching missile strikes on civilian targets, seeing missiles deliberately aimed at residential buildings, shopping and entertainment centers, railway stations, and seaports.

According to the Head of the Office of the Prosecutor General of Ukraine, the main purpose of these attacks on the civilian population was to intimidate, create conditions for constant tension in society, and to pressure the Ukrainian leadership to make territorial and political concessions favorable to the Russian Federation[5]. The long-term goal of

1 The full-scale military invasion that started on 24 February 2022 was a continuation of Russian aggression since 2014, however, on 24 February 2022, Russian armed forces initiated attacks (with the use of its aviation and missiles) targeting every big city in Ukraine.

2 Official information available on: https://www.kmu.gov.ua/news/minekonomiky-poperedno-otsiniuie-padinnia-vvp-v-2022-rotsi-na-rivni-304 (Last accessed on 23 April 2023).

3 Information available on: https://www.worldbank.org/en/news/press-release/2023/04/06/russian-invasion-of-ukraine-and-cost-of-living-crisis-dim-growth-prospects-in-emerging-europe-and-central-asia (Last accessed on 23 April 2023).

4 Information available on: https://www.radiosvoboda.org/a/news-mindovkillia-zbytky-nadram/32338768.html (Last accessed on 24 April 2023).

5 Information available on: https://www.gp.gov.ua/ua/posts/raketni-udari-po-budinku-u-dnipri-tc-u-kremenchuci-ta-insix-civilnix-objektax-povidomleno-pro-pidozru-

the Russian Federation is the partial destruction of the Ukrainian nation. Since the beginning of fall 2022, the main target of Russia's missile attacks has been energy facilities: Thermal and hydroelectric power plants, substations, and power lines. Such acts at the beginning and during the heating season were aimed at destroying the Ukrainian economy and creating unfavorable conditions for the civilian population. In general, according to the Kyiv School of Economics, direct damage to Ukraine's infrastructure (based on the replacement cost method) as of March 2023, amounted to USD 144 billion[6]. However, the real figure of losses is much higher, since the replacement cost method used by the Kyiv School of Economics experts estimates only the minimum value of assets that can replace the destroyed ones, and does not estimate economic losses from lost opportunities, such as job losses, business cuts and closures, and the departure of the working class abroad. For example, World Bank President David Malapas estimates the cost of rebuilding Ukraine's destroyed infrastructure at $350 billion[7]. The 2020 military conflict in Syria was the largest ongoing conflict in the world (Iacovoiu & Panait, 2020), however, the Russian military aggression against Ukraine seems to have changed the *status quo*.

The aim of this article is to analyze and assess the economic damage caused by Russia's shelling of Ukraine's critical infrastructure with the aim of destroying the Ukrainian nation. To achieve this goal, the following tasks need to be accomplished: To analyze which infrastructure facilities were destroyed by missile attacks, the results and extent of the destruction, and to establish the economic damage caused and its impact on the civilian population of Ukraine. Such analysis will enable us to prove that the actions of the Russian Federation are aimed at deliberately inflicting on the group conditions of life calculated to bring about its physical destruction in part, which, according to Article 6 (c) of the Statute of the International Criminal Court, can be qualified as a crime of genocide (Rome Statute of the International Criminal Court).

The abovementioned analysis was based on synthesis and a statistical method that permitted us to summarize and process the collected data and draw conclusions.

1. Analysis of Critical Infrastructure Facilities Damaged by Missile Attacks

Since 24 February 2022, Russia has launched almost 5,000 missile strikes (including of the S-300 and S-400 systems) on the territory of Ukraine, and about 3,500 air strikes. Additionally, 1,100 launches of unmanned aerial vehicles were carried out. This data was reported as of 23 February 2023, by the Deputy Chief of the Main Operational Directorate of the General Staff of the Armed Forces of Ukraine, General Oleksiy Hromov[8]. Most of these strikes targeted

komandiru-rosiiskogo-aviapolku (Last accessed on 1 May 2023).

6 Official report available on: https://kse.ua/ua/about-the-school/news/za-rik-povnomasshtabnoyi-viyni-rosiya-zavdala-zbitkiv-infrastrukturi-ukrayini-na-mayzhe-144-mlrd/ (Last accessed on 1 May 2023).

7 Information available on: https://www.reuters.com/markets/imfs-georgieva-sees-rising-cost-keep-ukraines-economy-going-2022-12-01/ (Last accessed on 2 May 2023).

8 Information available on: https://www.ukrinform.ua/rubric-ato/3674032-rosia-za-rik-zavdala-po-ukraini-majze-85-tisaci-raketnih-ta-aviacijnih-udariv.html (Last accessed on 27 April 2023).

residential buildings and critical infrastructure. The concept of "infrastructure" appeared in the works of economists back in the 1940s. The term was first coined by P. Rosenstein-Rodan, who considered it a set of basic economic sectors, including roads, railways, dams, sewers, and other public utilities (Rosenstein-Rodan, 1961). P. Nurkse believed that the main purpose of infrastructure is to ensure a rational and uninterrupted process of servicing production, distribution, exchange and consumption in the structure of the national economy (Nurkse, 1966). Infrastructure is also interpreted as a tool for meeting the needs of the country's population (Rostow, 1962). Regarding the definition of the term "critical infrastructure," the U.S. Cybersecurity and Infrastructure Security Agency, according to the Presidential Political Directive, identifies 16 sectors of critical infrastructure, whose assets, systems and networks, both physical and virtual, are considered so significant that their disruption will have a debilitating impact on security, economy, health, and the social sphere[9]. The Ukrainian law "On Critical Infrastructure" defines such infrastructure as being of critical importance for the economy, national security and defense, and whose disruption may harm vital national interests (Закон України "Про критичну інфраструктуру", 2021). Therefore, critical infrastructure is a set of facilities intended primarily to ensure the vital activity of the country's civilian population. Such facilities include the energy sector, healthcare facilities, communications and telecommunications, food, transportation infrastructure, water supply and sewerage, the pharmaceutical industry, financial sector, civil defense and rescue services. It can be assumed that the destruction of critical infrastructure threatens the survival of the civilian population of the state, especially those directly dependent on it.

The shelling and destruction of such facilities is aimed at the destruction of the Ukrainian nation, and constitutes a war crime against the civilian population. By launching missile attacks on Ukraine's critical infrastructure, Russia is grossly violating international humanitarian law, as Article 48 of the Protocol Additional to the Geneva Conventions relating to the Protection of Victims of International Armed Conflicts of 8 June 1977, and other conventions,[10] requires that in the conduct of hostilities, the parties must always distinguish between civilian and military objectives and, accordingly, direct their actions only against military objectives[11]. The Protocol also prohibits "attacking or destroying, withdrawing or rendering unusable objects essential for the survival of the civilian population". Russia has been deliberately targeting such objects.

According to the statistics of the 'Damaged in UA' project, which collects information from citizens, the government and local governments on losses and damage across the country, 207,500 private cars, 153,900

9 Official report of Cybersecurity and Infrastructure Security Agency of United States, available on: https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/critical-infrastructure-sectors (Last accessed on 26 April 2023).

10 For instance, Geneva Convention Relative to the Protection of Civilian Persons in Time of War (Fourth Geneva Convention), 12 August 1949, 75 U.N.T.S. 287.

11 Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977, 1125 U.N.T.S. 3.

residential buildings, 16,000 public transport units, 3,170 educational institutions, 1,216 healthcare facilities, and 1,800 cultural institutions were destroyed during the first year of full-scale aggression[12]. In addition, 340 bridges and other road structures and 25,000 kilometers of both local and national roads were destroyed or damaged.

The largest attack on Ukraine's critical infrastructure involved missile strikes to the energy system that began on 11 September 2022, seeing Russia launch 12 Kalibr and X-101 cruise missiles that hit the Zmiivska Thermal Power Plant, Kharkiv CHPP-5, and three high-voltage substations. It should be added that since 4 March 2022, the Zaporizhzhia Nuclear Power Plant, which is the largest nuclear power plant in Europe with 6 power units and a total capacity of 6000 MW, is under the occupation of the Russian armed forces. As a result of the seizure, the plant is no longer supplying electricity to the unified energy system of Ukraine.

On 10 October 2022, the first massive missile attack on the country's energy infrastructure took place, during which 84 cruise missiles were fired. The shelling damaged 11 critical infrastructure facilities in eight regions and the capital[13]. Following the attack, the National Energy Company 'Ukrenergo' introduced the first emergency and rolling blackouts in Ukraine. Electricity exports to the European Union were also restricted. The biggest missile attacks, in terms of the number of missiles launched, and the most destructive to the energy system, occurred between 15-23 November 2022, destroying almost half of Ukraine's power grid. The main missile attacks targeted high-voltage substations and power lines, causing emergency protection to be activated at all nuclear power plants under Ukrainian control, leading to automatic shutdowns of power units, and shutting down most thermal and hydroelectric power plants. According to energy experts, Ukraine experienced the first blackout in its history[14]- some cities and regions were completely de-energized, and a significant power deficit occurred in the energy system. As a result, the National Energy Company 'Ukrenergo' was forced to introduce blackout schedules for all regions of Ukraine over the following few months.

According to the data provided on the official websites of the General Command of the Armed Forces of Ukraine, the Air Force Command of the Armed Forces of Ukraine, during the entire period of shelling of energy facilities and infrastructure (which lasted from 11 September 2022 to 9 March 2023), launched 908 cruise missiles of X-101, X-555, X-59, X-22, X-32, Kalibr, Iskander, Tornado, and Oniks, 648 of which were intercepted and shot down. However, the share of missiles that were not shot down by the Air Defense Forces caused significant damage to both the energy infrastructure and the civilian critical infrastructure of Ukraine as a whole.

12 Information available on: https://damaged.in.ua/damage-assessment (Last accessed on 1 May 2023).
13 Information available on: https://biz.censor.net/news/3372646/rosiyiski_viyiskovi_poshkodyly_11_vajlyvyh_infrastrukturnyh_obyektiv_u_8_regionah_ta_kyyevi_shmygal (Last accessed on 2 May 2023).
14 Information available on: https://www.epravda.com.ua/publications/2022/11/28/694331/ (Last accessed on 3 May 2023).

2. Assessment of Economic Losses Caused by Shelling of Critical Infrastructure In Ukraine

The replacement cost method (see more about application of the replacement cost method in: Jackson *et al.*, 2014) is most commonly used when assessing economic damage to critical infrastructure. The method allows us to calculate direct damage to infrastructure, and involves estimating the cost of constructing or creating an object that will be equal or equivalent to the destroyed one in terms of its properties, as defined in the Ukrainian National Standard No. 1 'General Principles of Property and Property Rights Valuation' (Постанова Кабінету Міністрів України, 2022). A similar method, called the cost approach, is proposed to be used in the absence of any relevant market evidence of the value of the damaged property, in order to put the injured party in the same position as it was before the damage occurred. This approach is proposed for use as a method of damage assessment by the European Valuation Standards Council (Guidance on Applying EVS in Wartime Circumstances, 2022). The method of estimating direct costs at replacement cost is being actively used by the Kyiv School of Economics to assess the damage to Ukraine's infrastructure. As mentioned above, the total amount of damage caused by March 2023 was USD 144 billion, of which the largest amount of damage was caused to residential infrastructure (USD 53.6 billion), transport infrastructure (USD 36.2 billion), and industry ($11.3 billion). The distribution of direct damage to Ukraine's infrastructure in value terms by replacement cost is shown in Figure 1.

At this stage, there is no single realistic assessment of the damage to critical infrastructure, primarily because the war is still ongoing and Russia continues to strike and cause destruction in Ukraine. However, open sources provide figures for the damage from the

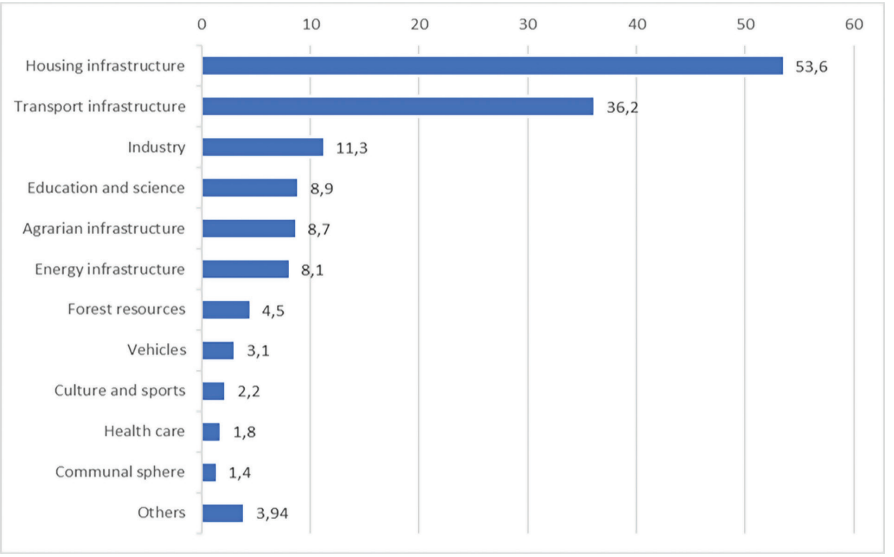

Fig. 1. Direct losses to Ukraine's infrastructure by replacement cost method (USD billion).

statements of Ukrainian leaders, politicians, and heads of international organizations. As part of the Recovery Plan for Ukraine, the National Council for the Restoration of Ukraine from the Consequences of the War prepared a draft 'Audit of the Damages Incurred as a Result of the War'[15]. According to this report, the total economic damage caused by Russian aggression and the destruction of infrastructure, including losses from a decline in gross national product, reduced foreign direct investment, labor outflow, and increased defense and social support costs, ranges from USD 564 to 600 billion. At the same time, according to the World Bank, Ukraine's gross national product in pre-war 2021 was only USD 200.1 billion[16].

If we consider the economic damage to Ukraine's infrastructure caused solely by the shelling of the energy system during the heating season, according to the United Nations Development Program (UNDP), the amount of damage to the energy sector was more than USD 10 billion[17]. Transformer substations and power plants suffered the most damage among energy facilities. According to a preliminary estimation by the Ukrainian hydroelectric generating state-owned company 'Ukrhydroenergo,' the damage caused by missile attacks to hydroelectric facilities alone amounted to about 40 billion UAH[18]. State Thermal Energy Company (DTEK), a private power generating company, estimates the damage caused by Russian missiles targeting its thermal power plants at 6 billion UAH [19]. The National Energy Company 'Ukrenergo' and the National Nuclear Energy Generating Company 'Energoatom' have not yet provided their final calculations for the damage caused by mass missile attacks. In general, the amount of direct damage from the destruction of energy infrastructure should be supplemented by the loss of income from electricity generation by state and private generating companies, green energy, a drop in income of the National Energy Company 'Ukrenergo,' and regional distribution operators from the provision of electricity distribution services to consumers, and the loss of foreign exchange earnings of Ukraine from energy exports abroad.

The power outages and restrictions imposed throughout Ukraine had a negative impact on the economy as a whole. The National Bank of Ukraine, in its commentary on changes in Ukraine's real gross domestic product, noted that in late spring and during the summer of 2022, the first signs of economic recovery after the shock caused by the start of the full-scale military invasion appeared. However, the recovery was abruptly interrupted by an electricity shortage that forced some businesses, organizations and individual entrepreneurs to either suspend

15 Official assessment of losses due to Russian aggression: https://www.kmu.gov.ua/storage/app/sites/1/recoveryrada/ua/audit-of-war-damage.pdf (Last accessed on 22 April 2023).
16 Data Commons. Ukraine: https://datacommons.org/place/country/UKR?utm_medium=explore&mprop=amount&popt=EconomicActivity&cpv=activitySource%2CGrossDomesticProduction&hl=en (Last accessed on 20 April 2023).
17 Ukraine Energy Damage Assessment: https://www.undp.org/ukraine/publications/ukraine-energy-damage-assessment (Last accessed on 21 April 2023).
18 Information available on: https://finbalance.com.ua/news/ukrhidroenerho-otsinyu-zbitki-cherez-raketni-udari-rosi-na-40-mlrd-hrn (Last accessed on 14 April 2023).
19 Information available on: https://forbes.ua/news/v-dtek-energo-otsinyuyut-shkodu-vid-rosiyskikh-atak-mayzhe-v-6-mlrd-grn-22032023-12562 (Last accessed on 19 April 2023).

their operations entirely, or significantly reduce production and services. Thus, the electricity shortage caused by Russia's attacks on the energy infrastructure led to a deepening of the decline in the Gross Domestic Product in the fourth quarter, to 31.4% year-on-year[20]. It is worth noting that some Ukrainian businesses and civilians have gradually adapted to the power outages by purchasing generators, inverters, and other autonomous power sources. In 2022, imports of generators to Ukraine increased more than 50 times, and the total number of officially imported generators amounted to 669.4 thousand units[21].

When assessing the damage caused to the country's critical infrastructure, according to the methodological recommendations of the European Valuation Standards Council, the amount required for demining and clearing explosive ordnance from infrastructure facilities and territories should also be added. According to estimates by the 'CASE Ukraine' project, funded by the International Solidarity Fund under the Polish Development Cooperation Program of the Ministry of Foreign Affairs of the Republic of Poland, the estimated area contaminated by mines and ammunition ranges from 132,000 to 300,000 square meters. Accordingly, in relation to the contaminated area, the cost of complete demining of the territory will cost from USD 400 to 900 billion[22].

The scale of damage from the crimes of the Russian army seriously increased after 6 June 2023, when Russian forces provoked an explosion on the dam of the Kakhovska Hydroelectric Power Plant[23]. The war crime and act of ecocide committed by the Russian occupation forces is another crime that deliberately impacted living conditions, and which was calculated for the partial physical destruction of the Ukrainian nation in the region of the Kakhovska Hydroelectric Power Plant.

3. The Impact of Economic Losses from the Destruction of Ukraine's Critical Infrastructure

The constant shelling of civilian infrastructure and residential buildings by Russian forces is a gross violation of international treaties, and can be qualified as a crime of genocide of the Ukrainian nation. The resulting destruction of housing, educational, medical and cultural institutions, and the energy sector, do not provide Russia with any military advantages on the battlefield. The fact that the actions committed by the military forces of the Russia against Ukrainian people can be qualified as genocide is evidenced by a large number of factors, including mass killings of civilians because of their nationality, deportation, and deliberate missile attacks on critical infrastructure. According to the Convention on the Prevention and Punishment of the Crime of Genocide, adopted by the United Nations General Assembly in 1948, genocide means any of the following acts committed with intent to destroy, in whole or in part, a

20 Information available on: https://bank.gov.ua/ua/news/all/komentar-natsionalnogo-banku-schodo-zmini-realnogo-vvp-u-2022-rotsi (Last accessed on 13 April 2023).
21 Information available on: https://biz.censor.net/news/3391662/import_generatoriv_v_ukrayinu_zris_za_rik_u_ponad_50_raziv (Last accessed on 2 May 2023).
22 Information available on: https://cost.ua/tsina-rozminuvannya-do-900-mlrd-i-desyatky-rokiv (Last accessed on 2 May 2023).
23 Information available on: https://www.ukrinform.ua/rubric-other_news/3720776-pidriv-rosianami-kahovskoi-ges-usi-novini.html (Last accessed on 15 June 2023).

national, ethnical, racial or religious group: Killing members of the group; causing serious bodily or mental harm to members of the group; deliberately inflicting on the group conditions of life calculated to bring about its physical destruction in whole or in part; imposing measures intended to prevent births within the group; and forcibly transferring children of the group to another group (Convention on the Prevention and Punishment of the Crime of Genocide, 1948).

The Convention provides for an explanation of the concept of genocide, but does not provide for jurisdiction to prosecute individuals who have committed the crime of genocide. The document that provides for jurisdiction and, at the same time, qualification of the crime of genocide is the Statute of the International Criminal Court. According to Art. 6(c) of the Statute, for the purposes of this Statute, "genocide" means any of the following acts committed with intent to destroy in whole or in part a national, ethnic, racial or religious group as such: "[…] c) deliberately inflicting on the group conditions of life calculated to bring about its physical destruction in whole or in part" (The Statute of the International Criminal Court, 1998). It is important to clarify that the crime of genocide is not only the intentional act itself, but also the intent to destroy a group in whole or in part. Missile attacks on critical infrastructure definitely impact the living conditions of Ukrainians, and therefore lead to the physical destruction of the Ukrainian nation. The intentionality of the missile attacks is undoubtedly evident, as the accuracy of the attacks cannot be accidental. It should be emphasized that all the missile attacks occurred in the fall and winter, and the scale and timing of the shelling, proves the purpose of such actions – to create conditions for the partial destruction of Ukrainians, since such conditions turned their lives into a process of survival.

Constant missile attacks on peaceful cities and civilian infrastructure, and destruction of the energy system during the cold season when heating is required, are actions that violate a number of international treaties. By launching missile attacks on critical infrastructure, Russia is deliberately killing Ukrainians, exerting psychological pressure on the Ukrainian people, and creating living conditions aimed at their complete or partial destruction. In parallel, having occupied a part of the country's territories, Russia is carrying out repressions; killing, torturing and committing violent acts against Ukrainians; carrying out the forceful deportation of Ukrainian children; stealing grain and agricultural products; destroying agricultural machinery; and mining fields. All these actions are direct evidence of the aggressor's deliberate destruction of the Ukrainian people.

Russia has spent USD 7.5 billion on launching massive missile strikes against Ukraine[24]. The total cost for Russia of waging its military invasion on Ukraine as of March 2023 reached 115 billion USD[25]. However, there currently exist no accurate assessments

24 Information available on: https://focus.ua/uk/voennye-novosti/554103-rf-za-5-mesyacev-potratila-na-udary-po-ukraine-7-5-mlrd-analitiki (Last accessed on 2 May 2023).

25 Information available on: https://forbes.ua/war-in-ukraine/rosiya-vitratila-na-viynu-z-ukrainoyu-mayzhe-115-mlrd-i-vsi-tanki-yaki-mala-pered-vtorgnennya-rozrakhunki-forbes-24022023-11970 (Last accessed on 4 May 2023).

as to the total cost of Ukraine's destroyed critical infrastructure, which includes the aerial bombardment and artillery shelling of residential buildings in cities. It is estimated that the damage caused to such infrastructure amounts to USD 500-600 billion. And yet it did not result in the complete collapse of the Ukrainian economy (as noted before, the decrease in gross domestic product during the first year of the military conflict was approximately 30%), nor did it disrupt the implementation of the state budget and the financing of the military needs of the Ukrainian Armed Forces. Further, complete economic collapse is not likely, as Ukraine receives significant support from the Allied countries.

Still, the main goal of these attacks is the destruction of the Ukrainian nation by creating survival-like conditions for the Ukrainians. Russia has been able to cause a humanitarian crisis in some regions of Ukraine. According to analysts' assessments, based on data from the Ministry of Communities and Territories Development of Ukraine, more than 2.4 million Ukrainians lost their homes during Russia's full-scale invasion, while the total number of applications for compensation submitted through the Diia app and administrative service centers exceeded 300,000, submitted from the region with an area over 23 square kilometers[26]. The Ukrainian government is currently unable to solve the problem of destroyed housing due to ongoing military activities, or to deal with the need to finance defense expenditures. A significant problem in the context of deliberately impacting on living conditions of Ukrainians, calculated to bring about their physical destruction, is the number of internally displaced persons (IDPs). According to the report of the Ministry of Social Policy, over 4.9 million Ukrainians have officially become internally displaced persons due to the military activities and missile attacks. This phenomenon created an additional challenge for the Ukrainian government and local governments, seeing them having to deal with thousands of additional inhabitants flooding into their municipalities[27]. Yet, the biggest difficulty for the Ukrainian nation has been the massive outflow of Ukrainians abroad. According to the UN High Commissioner for Refugees, around 8,174,189 people have left Ukraine, while 5,044,033 registered for temporary protection in the European Union member states[28], especially Poland.

The number of internally displaced persons and Ukrainians who moved abroad has resulted in a significant reduction in Ukraine's population, loss of employees (in both the public and private sectors), and the loss of skilled workers. According to the research conducted by the Center for Economic Strategy in cooperation with the Ukrainian mobile operator 'Kyivstar' and the National Bank of Ukraine, 87% of migrants are women with children. 65% of these women are of working age, while nearly 70% have higher education[29]. Some of these people do not plan to

26 2.4 мільйони українців втратили домівки за час війни: https://www.epravda.com.ua/publications/2022/11/7/693516/ (Last accessed on 19 May 2023).

27 Міністерство соціальної політики України. Внутрішньо переміщені особи: https://www.msp.gov.ua/timeline/Vnutrishno-peremishcheni-osobi.html#

28 Operation data portal. Ukraine refugee situation: https://data.unhcr.org/en/situations/ukraine

29 Наскільки масштабною буде демографічна криза в Україні і як повернути біженців: https://texty.org.ua/fragments/109074/yakym-ye-masshtab-majbutnoyi-demohrafichnoyi-kryzy-v-ukrayini/ (Last accessed on 21 May 2023).

return to Ukraine even after the attacks on Ukraine's infrastructure stop and the Russian aggression ends, and the gradual integration of Ukrainians into foreign labor markets and educational processes will only increase the percentage of people who will not return to the country.

The deliberate missile attacks and destruction of that critical infrastructure, on which the survival of the Ukrainian nation depends, are aimed at the partial destruction of the Ukrainians. The economic and social development of every nation is an important factor for its future growth and progress within its own state. The substantial number of internally displaced persons, the migration of millions of Ukrainians abroad, and the humanitarian crisis in many regions of Ukraine are a notable obstacle to the nation's growth. The aggravation of the demographic crisis in Ukraine, due to the wave of forced migration of Ukrainians caused by the military activities and missile attacks on residential areas and critical infrastructure, may in the near future make the economic consequences much worse for the Ukrainian nation.

Conclusion

Missile attacks on Ukraine's critical infrastructure have caused significant economic losses for the Ukrainian nation. Direct losses from the destruction, according to the replacement cost method, currently amount to more than USD 114 billion, while the total losses, according to various estimations by Ukrainian think tanks, government authorities, and international financial organizations, amount to USD 500-600 billion. In total, 207,500 private cars, 153,900 residential buildings, 16,000 units of public transport, 3,170 educational institutions, 1,216 healthcare facilities and 1,800 cultural institutions were destroyed during the first year of Russian aggression. One of the largest international crimes against Ukrainians are the missile attacks on critical infrastructure that began on 11 September 2022. Due to missile attacks on thermal and hydroelectric power plants, substations and power lines, some cities and regions were completely de-energized, and a significant power shortage was created in the energy system, leading to blackout schedules having to be introduced for all regions that lasted several months. The shelling of the energy system caused significant damage to the country's economy as a whole, although its main goal was to deliberately destabilize the living conditions of Ukrainians, a move calculated to physically destroy the nation in part and to put those living there under such psychological pressure that some Ukrainians were forced to migrate abroad.

It has been established that missile attacks of critical infrastructure violate not only a number of international treaties, but can also be qualified as a crime of genocide under Article 6(c) of the Statute of the International Criminal Court. The destruction carried out by Russian armed forces is aimed at the destruction of the Ukrainian nation, as by launching missile strikes on critical infrastructure, the Russian armed forces deliberately kill Ukrainians, exert psychological pressure on the Ukrainian people, and impact living conditions.

By shelling and destroying Ukrainian infrastructure, Russia has caused significant

economic and humanitarian damage to the Ukrainian nation. About 2.4 million Ukrainians have lost their homes, 4.9 million have been internally displaced, and more than 8 million have moved abroad seeking legal protection. All these factors may cause a demographic crisis in Ukraine. It is therefore important to restore the critical infrastructure, energy systems, and housing destroyed by the Russian armed forces, and to demine Ukrainian territory so as to ensure safe living and working conditions in the country.

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Постанова Кабінету Міністрів України «Про внесення змін до Національного стандарту № 1 "Загальна засади оцінки майна і майнових прав"» від 09.08.2022 р., № 886.

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Strunk, W., Jr., & White, E. B. (1979). The elements of style. (3rd ed.). New York: Macmillan, (Chapter 4).

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