IMPRESS-U: Renewable Energy for Bolstering Ukraine's Infrastructure by Learning and Design (REBUILD)

VISION AND GOALS

The Ukrainian people will need a strong workforce to rebuild their infrastructure after the devastation caused by Russia's invasion. The world must help them cultivate their human resources from the grassroots now. Renewable energy is crucial in Ukraine's path to become a sustainable, resilient, and prosperous nation after the war (United Nations Economic Commision for Europe, 2023). In this project, the **Institute for Future Intelligence** (IFI) of the United States, the **Institute of Renewable Energy** (IRE) of the National Academy of Sciences of Ukraine, and **Kaunas University of Technology** (KTU) of Lithuania will join forces to accomplish the following three goals: 1) develop innovative technology to support a learning-by-design educational approach in the context of renewable energy and energy efficiency, 2) organize extracurricular activities through afterschool programs designed for Ukrainian youth in the spirit of citizen science, and 3) provide professional development opportunities to engage Ukrainian STEM educators in international settings. Through this project, Ukrainian scientists, educators, and students will be involved in building a global cyberinfrastructure for tackling research and education challenges related to renewable energy. As the proposed project is based on the work done in the original NSF project *Science and Engineering Education for Infrastructure Transformation* (#2131097), supplemental funding is thereby requested to support the REBUILD project as its extension.

NOVELTY

The novelty of the REBUILD project stems from the following three aspects:

- **Learning by design**. Unlike many educational projects on climate change and renewable energy that focus primarily on teaching factual knowledge to children, this project will provide innovative technology and create actionable opportunities for them to take a step further to solve real-world problems with a learning-by-design (Kolodner et al., 2003) approach, as described later in the Specific Plans section. Such an approach is enabled by simulation-based engineering and science (Glotzer et al., 2011) for solar, wind, and other renewable energy sources, as well as their combinations in colocation projects (e.g., agrivoltaics that has enormous potential in Ukraine given the importance of agriculture in their economy). This is vital as the dire situation in Ukraine calls for urgent actions, which warrants unconventional learning-by-doing approaches (e.g., Zhang et al., 2023) to accelerate the development of a STEM-capable workforce in preparation for the reconstruction of Ukraine.
- **Citizen science**. By supporting Ukrainian youth to take on the renewable energy challenge in the real world in wartime, this project will contribute a unique model to the movement of citizen science (Bonney et al., 2014), now considered as an essential element in the European Green Deal approved by the European Commission in 2020 (Green Deal Projects Support Office, 2022). Rebuilding their country to achieve higher environmental standards and energy independence provides naturally a sociopolitical motivation for Ukrainian youth to engage in such citizen science programs. As these programs reach more young citizens over time, this approach can also consolidate a social consensus to drive the transition of their country to

renewable energy, according to various studies conducted by scholars across Europe (e.g., Fischer, Gutsche, & Wetzel, 2021; Sauermann et al., 2020; Wahlund & Palm, 2022).

- **Artificial intelligence**. AI, especially generative AI, is reshaping every field. Renewable energy and science education are no exception. For transformative AI to take root in these two fields in Ukraine, this project will 1) use generative AI to empower students to explore the solution space of an engineering problem more productively and creatively and 2) use machine learning to help teachers formatively and summatively assess students' design performance and learning outcomes. These applications of AI are especially important in this project as AI can, to some extent, serve as teaching assistants to compensate the shortage of instructional resources in out-of-school settings or disruptive situations caused by Russia's attacks.

PARTNERSHIPS AND ROLES

The three partners, IFI, IRE, and KTU, which will bring complementary expertise to this project (Figure 1), are ready to undertake this joint mission. IFI and IRE have signed a five-year Memorandum of Understanding to cooperate on renewable energy research and education. IFI's PI Charles Xie and IRE's PI Oleh Lysak communicate frequently to share ideas. Xie visited KTU in October 2023 to discuss with KTU PI Daina Gudonienė in person about collaborative research on smart learning technologies and international plans to support Ukrainian educators. The three partners will work closely with one another on the three goals stated at the beginning of this proposal, with the managerial responsibilities of each partner for each goal described as follows (Note: The fact that a leadership role for each goal is assigned to a partner does not mean other partners will not contribute to the corresponding work towards that goal):

- **Goal 1 (led by IFI)**: Develop a scientific inquiry and engineering design cyberinfrastructure to support citizen science for Ukrainian students by combining IFI's open-source, AI-enabled, and Web-based Aladdin CAD software (Xie, Ding, & Jiang, 2023), IRE's research in renewable energy in Ukraine, and KTU's expertise in smart learning technology optimized for the educational and cultural settings in the region (Gudoniene et al., 2023). For instance, the software will incorporate Ukrainian and Lithuanian locales (languages, currencies, scientific units, date formats, and so on). New features will be added to allow the modeling and design of architectural styles of cultural importance in the region. AI capabilities, such as generative design, learning analytics, and monitoring dashboards, will be enhanced or developed to meet the needs of this project. For instance, process mining will be used to glean students' learning dynamics from the event logs of the software (Xie et al., 2014). The results can be visualized on a dashboard to render the infographics of individual or group learning (Xie et al., 2022).
- **Goal 2 (led by IRE)**: Partner with established organizations in Ukraine such as the Junior Academy of Sciences (JAS)[1] and Sustainable Development Agency (SDA) Synergy[2] to create

[1] Launched in Kyiv in 1963, JAS is a national center in Ukraine that specializes in extracurricular science education. Each year, JAS sponsors nearly 170 out-of-school activities and more than 40 large-scale events for youth across Ukraine. JAS also offers professional development opportunities to STEM educators. **The current Minister of Education and Science of Ukraine Oksen Lisovyi served as the Director of JAS for 19 years**.

[2] Founded in 2021 by researchers from several universities, SDA Synergy promotes sustainable development of Ukraine by initiating and developing national and international programs that provide enterprises, municipalities, and communities with educational services on energy efficiency, renewable energy, and environmental protection.

extracurricular citizen science programs, referred to as *ecothons* when they are carried out in the format of hackathons, based on the content and technology developed by this project and offer these programs on the Internet free of charge to any Ukrainian youth interested in renewable energy. These programs are described in the Specific Plans section to shed light on how they can be realistically implemented in Ukraine given the current situation. The letters of support from JAS and SDA Synergy are attached in Other Supplementary Documents.

- **Goal 3 (led by KTU)**: Provide formal and informal science educators in Ukraine with opportunities to learn renewable energy content and technology through professional development workshops. To cast a wider net, these workshops will be offered online in the Ukrainian language to anyone. KTU PI Gudonienė is an expert in distance education and have trained many teachers on using technology to enhance teaching. She will work with the Ukrainian partners to develop these virtual workshops. To encourage participation, KTU will also offer paid trips for a 5-person Ukrainian educator delegation selected from qualified online participants to visit Lithuania and attend a three-day international workshop at KTU with colleagues from Baltic countries. Educators trained by this project can also help disseminate the information about the citizen science programs to a large number of pupils and students in Ukraine and other countries and even serve as their "Energy Coaches" in these afterschool programs initiated by this project. The Kaunas Regional Education Center, which has been facilitating the integration of temporarily displaced Ukrainian students into Lithuanian schools since the war started, will assist this project in recruiting local Ukrainian nationals to provide translation services as needed for the virtual and in-person workshops.

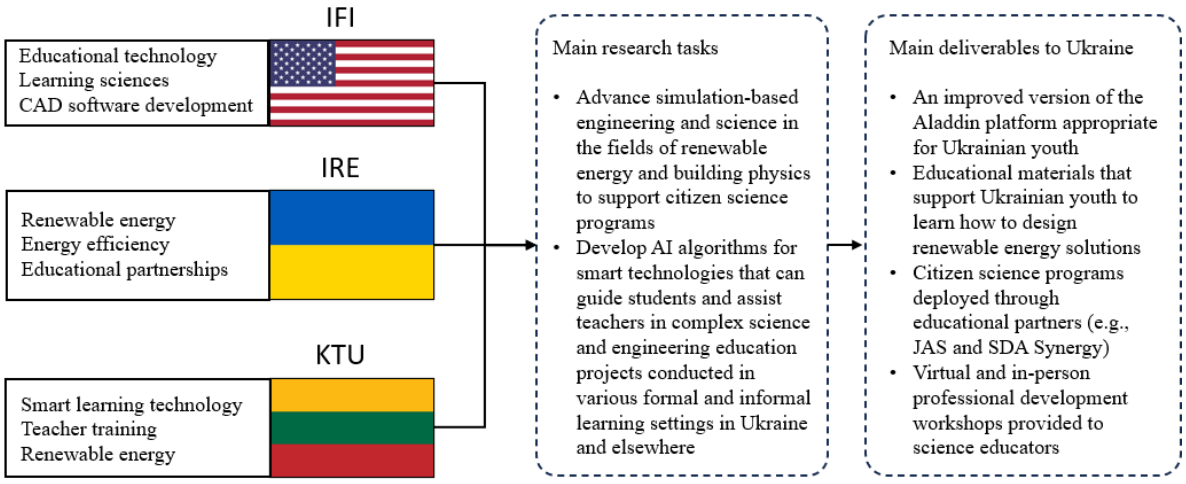

Figure 1: A simple logic model that illustrates how the three partners will collaborate based on their combined expertise to conduct the research tasks and achieve the project goals.

While this project focuses primarily on aiding Ukraine, the proposed educational technologies, materials, and programs are also applicable to America, Lithuania, and other countries. We will ensure that all the end products will be freely available in English, Ukrainian, and Lithuanian. This international collaboration will also provide graduate students at KTU with research opportunities to explore the applications of AI in developing next generation educational technology.

Specific Plans

In this project, we will create the following two citizen science programs related to renewable energy and energy efficiency to foster STEM education and green transition in Ukraine.

Citizen Science Program One: Solar Energy to the Rescue

The Washington Post reported that solar energy is helping the Ukrainians power their schools and hospitals during the constant Russian airstrikes that damage the electric grid (Birnbaum, 2023). However, only a small number of schools in Ukraine have received solar panels donated by the

Real World Photo | Aladdin Model Screenshot

Design and analysis of rooftop solar panel arrays in Aladdin

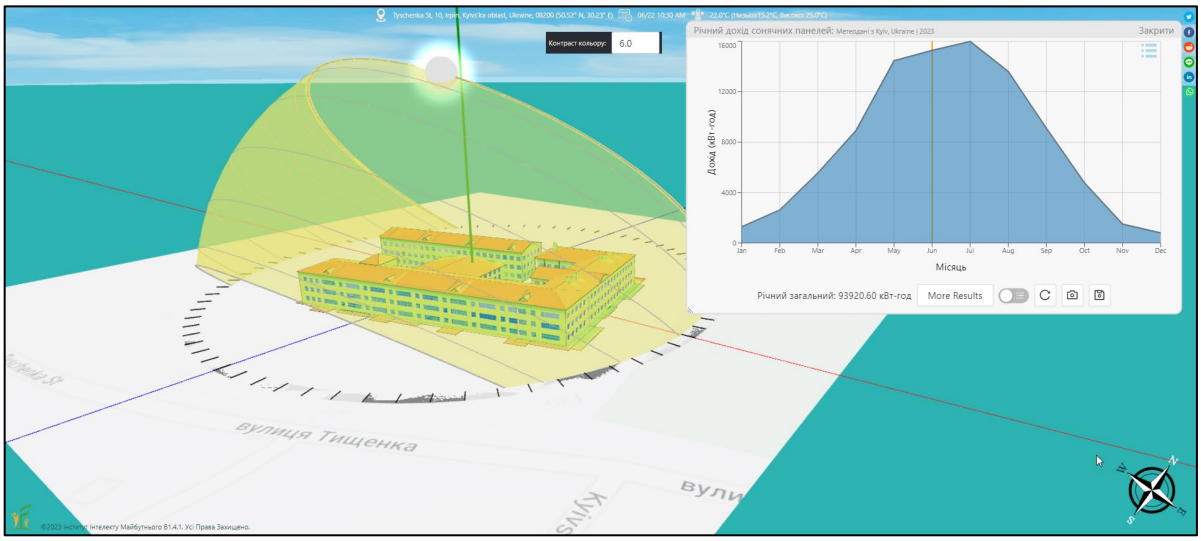

Figure 2: These images show the feasibility for pupils to use Aladdin to model their school buildings and design solar energy solutions to power their own schools using School No. 17 in Irpin, a town in outskirt Kyiv, as an example. The American version of this student project has been successfully pilot-tested in high schools and colleges under the program title "Solarize Your School"(Jiang, Ding, & Xie, 2023).

international community. For example, the “100RESforSchools” initiative by the Energy Act For Ukraine Foundation aims to equip 100 schools with solar panels—out of thousands of schools that have been damaged or are under threat in the war. Far more solar panels will be needed to keep Ukrainian schools open during the war and continue to provide clean electricity after the war.

This citizen science program will challenge Ukrainian children to design solar power solutions for their own schools using STEM knowledge and skills taught by this project, including how to use generative AI to create novel and optimal designs. These solutions will provide details about the numbers of photovoltaic modules and DC-AC inverters needed, their positions and layouts on the roofs and land of the schools drawn on top of satellite images, the size of the battery storage system

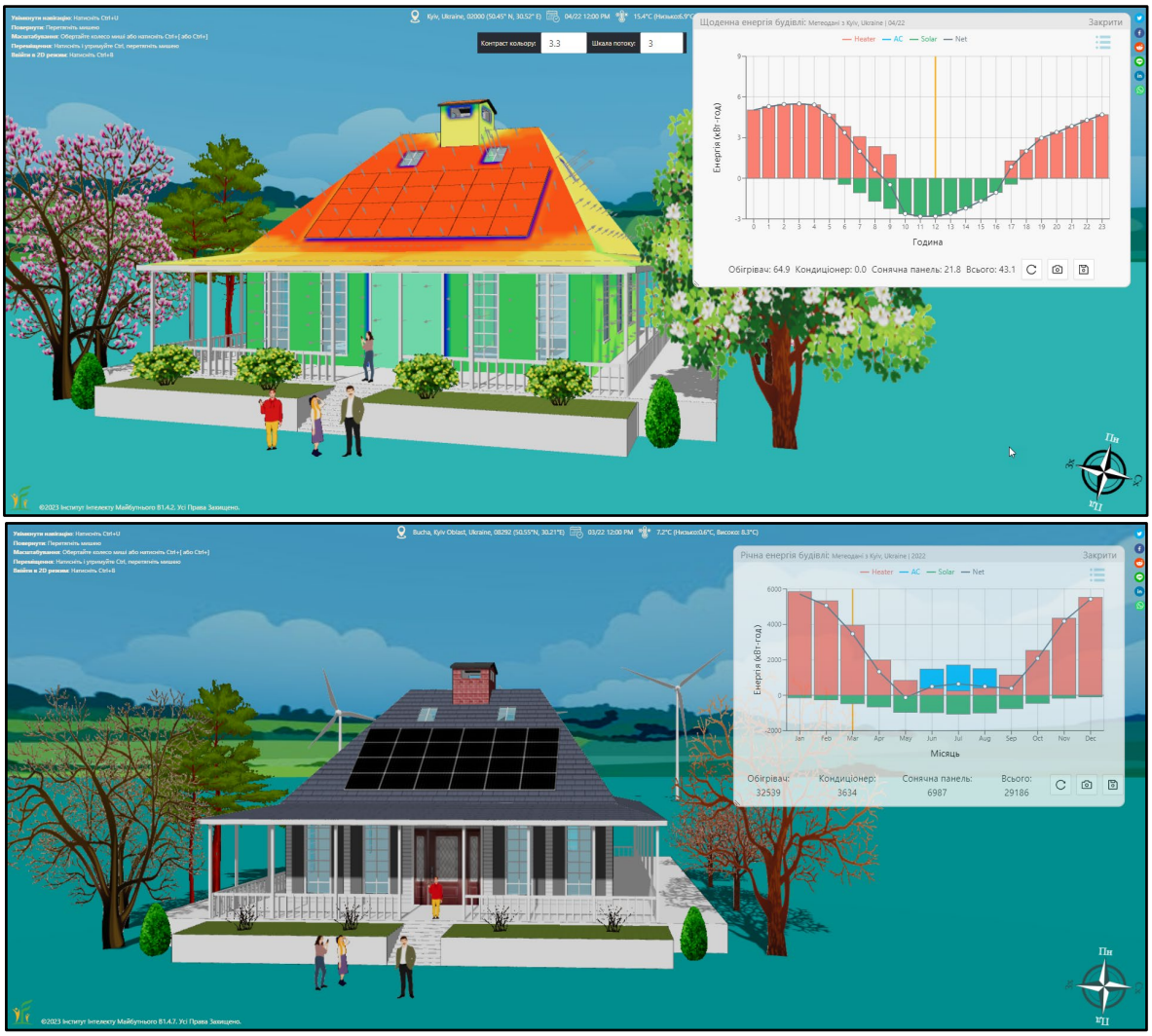

Figure 3: Aladdin can be used to design a house and analyze its energy usage throughout a day or a year. This citizen science program, The Net Zero Energy Challenge, will engage students in exploiting renewable energy generation and energy efficiency measures to reduce the energy consumption of a building as much as possible. The upper image shows a heatmap visualization of solar irradiance on a house in a traditional Ukrainian “khata” style and the vectorial visualization of daily heat transfer through its building envelope. The lower image shows the energy generation (with the rooftop solar panels, but not wind turbines in the distance) and consumption of the house over the course of a year in the Kyiv region.

to power a microgrid in case of emergency, the estimated material and labor costs, the predicted electricity generation, and so on. With the technology developed by this project, children can share their solutions in the form of interactive 3D models with the world on social media and call for help to crowdfund their eventual construction, creating **a novel mechanism on a scientific basis to connect the specific needs in Ukraine and the potential supporters abroad**. The three project partners will also explore various media opportunities so that the engineering work by Ukrainian children can reach out to a large audience to garner wide international support. Such a citizen science program will provide a powerful motivation for Ukrainian youth to learn STEM and, to some extent, an opportunity for them to contribute to the defense and reconstruction of their own country in a meaningful way. Figure 2 shows a concrete example using School No. 17 in Irpin, which was featured in the Washington Post report.

Citizen Science Program Two: The Net Zero Energy Challenge

A net zero energy building itself generates renewable energy no less than the total amount of energy that it consumes over the course of a year. In recent years, highly energy-efficient buildings are becoming a reality—even in high-latitude areas. For example, Winthrop Center, the fourth tallest skyscraper in Boston, was just certified in 2023 as the world's largest "passive house" office building. Inspired by the Solar Decathlon sponsored by the U.S. Department of Energy for more than two decades, we will create a simplified virtual version (i.e., "ecothons") on the Internet to support Ukrainian youth to learn how to design sustainable housing to achieve energy independence and reduce carbon footprints. This is vital to the future of Ukraine as the Ukrainian people are planning to rebuild their country with higher environmental standards to meet the requirements of the European Union (United Nations Economic Commision for Europe, 2023).

The current version of Aladdin already supports rudimentary design, simulation, and analysis of building energy (Figure 3). In this project, we will leverage the expertise of Dr. Lysak of IRE, Prof. Viktor Mileikovskyi of the Kyiv National University of Construction and Architecture (KNUCA), and Prof. Valančius of KTU to add the modeling and design capabilities for HVAC systems and geothermal heat pumps into Aladdin, given the importance of geothermal energy in achieving the net zero goal in the region (Birnbaum, 2022). These experts from IRE, KNUCA, and KTU will also ensure that the simulation results can more accurately match the climate conditions and cultural traditions in Ukraine. Finally, this citizen science program ("ecothons") can be easily fit into the existing organizational frameworks and operational formats of hackathons or competitions currently run by JAS and SDA Synergy.

TEAM

The Institute for Future Intelligence

The IFI part of this project will be led by **Dr. Charles Xie**, the PI of the NSF project (#2131097) that this supplemental funding is requested for. A computational scientist, Dr. Xie has over 25 years of research and development experience in STEM research and education, particularly in simulation-based engineering and science. He has created many scientific and engineering software widely used by students, teachers, and scientists around the world, including Aladdin that provides a technical foundation for this project. **Andriy Kashyrskyy** is a junior software engineer

and data scientist originally from Ukraine. His work involves mining Aladdin's event logs of student actions to provide insights to teachers for guiding student learning and to developers for creating smart learning technologies. **Elena Sereiviene**, the Director of Outreach and Dissemination of IFI, will serve as the project manager to coordinate and facilitate this international cooperation. She is originally from Lithuania. **Xiaotong Ding** is a senior full-stack software engineer who is another main developer of Aladdin. He and Dr. Xie will work with the rest of the ream to add new features to Aladdin as needed by this project.

The Institute of Renewable Energy of the National Academy of Sciences of Ukraine

The IRE part will be led by **Dr. Oleh Lysak**, a research scientist at the Geothermal Energy Department. He studies solar energy systems, in particular seasonal thermal storage of solar energy. He is also the head of the Young Scientists Council at IRE. He has published over 50 scientific papers. **Drs. Mykola Kuznietsov** and **Oleskii Zurian** are IRE's Deputy Directors for Scientific Work who will oversee this project as senior advisors. **Prof. Mileikovskyi** at the Department of Heat-Gas Supply and Ventilation of KNUCA, a Member of the Ukrainian Green Building Council and an Academician of the Academy of Technical Sciences of Ukraine, will also join the team to provide further scientific and educational expertise. IRE's partners, JAS and SDA Synergy (led by **Dr. Viktoriia Vostriakova** who is also affiliated with the Vinnytsia National Technical University), have a lot of experience developing educational programs across Ukraine. For example, funded in part by the Ministry of Foreign Affairs of Germany, SDA Synergy is working with the WECHANGE Cooperative on a two-year project entitled "Civil Society Energy for Resilient Ukraine," designed to support the creation of renewable energy communities in Ukraine.

Kaunas University of Technology

The KTU part will be led by **Prof. Dr. Daina Gudonienė**, the PI of the Smart Educational Technologies and Applications Research Group at KTU. Her research involves models, systems, platforms, and architecture. She has many years of experience in project management and implementation and is also an expert in distance education and educational technology. She is the author or coauthor of more than 60 research papers and eight books. **Prof. Dr. Rokas Valančius** from KTU's Department of Civil Engineering and Architecture will provide the expertise in building science to ensure that the smart educational technologies developed by this project are scientifically accurate and disciplinary relevant. KTU will also support a number of graduate students as research assistants to this project.

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