The objective of the proposed research is to test the hypothesis that power generation in a nanoscale-gap thermophotovoltaic (nano-TPV) device can be enhanced by a factor of 20 to 30 compared to conventional TPV systems. This implies that a nano-TPV device having a surface of a centimeter square could generate more than 30 Watts of electrical power. Such nano-TPV power generators will induce a paradigm change in the field of waste heat recovery. TPV power generation refers to direct thermal-to-electrical energy conversion of near infrared and infrared radiation emitted by a terrestrial source. Conventional TPV systems are limited by the blackbody spectrum. By separating the radiator and the cells by a nanosize gap, radiation heat transfer can exceed the blackbody predictions by a few orders of magnitude due to energy transport by waves evanescently confined within a distance of about a wavelength normal to the surface of a thermal source. Enhanced energy transfer by evanescent wave tunneling can thus lead to a significant increase of TPV power generation. The hypothesis underlying this proposal will be tested by measuring radiative heat flux and nano-TPV electrical power output and conversion efficiency in a device involving planar surfaces separated by a gap as small as 20 nm. The nanosize gap will be maintained via spring-like spacers. The application of an electrostatic force between the surfaces combined with the knowledge of the spring constant of the spacers will allow precise control and measurement of the gap thickness. Beyond the practical aspects of this project to waste heat recovery, the proposed research will enhance fundamental understanding of near-field radiative heat transfer between planar surfaces and evanescent wave-based energy conversion.

**Intellectual Merit:** This research will provide for the first time well-controlled radiative flux measurements between planar surfaces separated by a nanosize gap. This will allow the verification of the \( d^2 \) near-field thermal radiation regime, where \( d \) is the gap thickness, predicted for optically thick materials supporting resonant modes known as surface polaritons. Additionally, the project will demonstrate the newly discovered \( d^3 \) regime arising due to surface polariton coupling in optically thin layers. The research will provide the first quantitative experimental nano-TPV performance analysis at nanosize gaps. The spectral effects will be considered by testing various materials for the radiator. Indium tin oxide is of particular interest since it supports surface plasmon-polaritons in the near infrared band, thus matching the absorption bandgap of current TPV cells such as gallium antimonide. Nano-TPV performances will be systematically quantified as a function of the gap thickness and the temperatures of the radiator and the cells, and will be compared against predictions based on a coupled near-field thermal radiation, charge and heat transport model. The impacts of heat dissipation within the cells due to lattice and free carrier absorption, thermalization and non-radiative recombination of electron-hole pairs will also be analyzed in great detail.

**Broader Impacts:** This project will enhance fundamental knowledge in heat transfer, thermal radiation at nanoscale and evanescent wave-based energy conversion. The proposed research is a first step toward the establishment of miniature waste heat recovery devices that could be used in personal computers, and systems harvesting heat from the human body. Beyond its scientific and societal impacts, the project will promote training and learning through the involvement of high school, undergraduate and graduate students in the proposed activities. The departmental educational infrastructures will be enhanced via the integration of the nano-TPV experimental bench in the undergraduate and graduate curriculum. Fundamentals of near-field thermal radiation and specific research findings will be disseminated via the development of a new elective course dedicated to both undergraduate and graduate students. The lectures and class notes will be made available to the general public through thermalHUB and YouTube. Course feedback will result in a monograph on near-field thermal radiation that will be made freely available. Additionally, K-12 outreach will be performed via the Utah Science Olympiad. Departmental scholarships and research fellowships will be offered to high school students participating in this event. Direct thermal-to-electrical energy conversion will be promoted via the conception of an interactive, portable demo-kit that will be presented at the Utah Science Olympiad and in high schools. These activities will assist departmental efforts in recruiting high quality students in science and engineering programs.