Energy harvesting is a topic which has been developed for years in terms of pollution reduction and green environment. Energy can be harvested from several different resources, sun, water, wind are classical examples. The development of new materials which due to mechanical deformations may produce electrical potential gives possibility to harvest energy from ambient vibrations. The space and aircraft vehicles, automotive, marine or robotic systems, machine tools etc. require wireless sets of sensors, data transmitters, controllers and other electronic devices which must be regularly charged by small amount of power. They require batteries which must be regularly replaced or recharged. Therefore, energy harvesters offer a solution for continuous power supply of many electronic devices. To fully exploit energy harvesters their unique properties in linear and nonlinear regimes, couplings of mechanical and electrical loads, amplitude and bandwidth of frequencies of loadings etc. must be taken into account.

The scientific problem of the project is to propose original nonlinear systems which after proper tuning to excitation conditions exhibit dynamical response useful for energy harvesting. Two type of structural elements will be taken under investigations: (1) nonlinear beams made of composite or isotropic materials subjected to excitations under selected internal and external resonances, (2) composite shells with specific laminate configurations producing two or more steady states. In both cases active elements will be applied for energy harvesting.

The challenge is the development of mathematical models of the structures which will consider an integrated smart electro-mechanical system. The governing equations of motion representing the system mechanical domain will be derived in a form of nonlinear partial differential equations additionally coupled with an equation comprising terms representing properties of active elements. The partial differential equations will be solved directly by the multiple scale method. The analytical results will be validated by direct numerical computations in FEM and by experimental tests. An elaboration of reduced models of nonlinear beams and multi-stable shells with active elements which will adequately represent nonlinear effects observed in nonlinear harvesters and confirmed by real experimental tests is the purpose of the research.

The project will be carried out by means of various methods. The mathematical models of the system will be derived on the basis of a theory of elasticity using the extended Hamilton's principle. Kinetic and potential energies of both mechanical and electrical domains fields will be formulated. The analytical part of the project will be done by means of symbolic computations performed in Wolfram Mathematica package. Analytical studies will be verified by a finite element method. The elaborated PDEs will be solved directly by the multiple time scale method. The second approach is to reduce the PDEs by normal modes projection to get a set of ordinary differential equations. The developed theoretical models will be validated experimentally.

A new full complete nonlinear electro-mechanical model of the harvester based on the piezo-composite beam and shell together with its detailed parametric study will be the project contribution to the state-of-the-art. It is expected that active elements will produce much larger energy than reported in the literature. Regular and chaotic dynamics, and bifurcation paths based on a reduced order models will be investigated. The model should capture the most important dynamical phenomena taking into account mechanical properties of beams or shells and electrical properties of the of the active elements and electrical circuits.