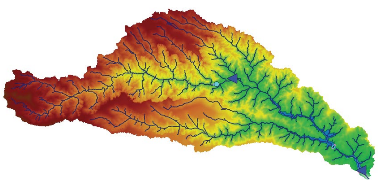
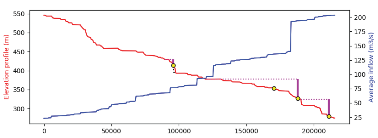
OVERVIEW

Hydropower and Environmental Resource Assessment (HERA) is a software to support the development of hydropower and pumped hydro storage (PHS) projects. The objective is to maximize the economic benefit and minimize socio-environmental impacts. An integrated investment-operation model is used in the selection process. More generally, the selection of hydropower and PHS projects by HERA can also consider other benefits to the electric grid, such as the support of the integration of variable renewable energy sources (wind power and solar PV).

Due to its multidisciplinary characteristics, HERA's development team has specialists in water resources, civil, and environmental engineering, computer science, GIS and mathematics. By integrating engineering calculations with geoprocessing techniques, cloud computing and optimization methods, HERA allows millions of alternatives to be intrinsically considered as part of the solution method. This flexibility greatly supports an objective discussion of tradeoffs by the stakeholders. As seen in the next figure, HERA has three main modules, described in the sequence.





Geoprocessing

- Extraction of drainage areas
- Candidate site selection
- Head x Area x Storage curves
- Inflow regionalization
- Project interferences

Engineering

- Layout selection
- Project design
- Budget estimate

Optimization

- Selection of projects that maximize the economic benefit of hydropower
- Non-linear, integer, multistage, stochastic mathematical problem

GEOPROCESSING

This module includes geoprocessing functions related to the basic information required: Digital Terrain Model (DTM), characterization of geological information and hydrology. These activities can be computed in the cloud to speed up computational time. Free publicly available Digital Elevation Model (DEM) such as NASA's SRTM may be used, as well as specific surveys, if available.

For PHS the DTM is processed to find sites with a sufficiently large head difference between the upper and lower reservoirs. Many more filters can be used, such as the maximum distance between the reservoirs.

Land cover
to estimate the costs of vegetation removal and impacts.

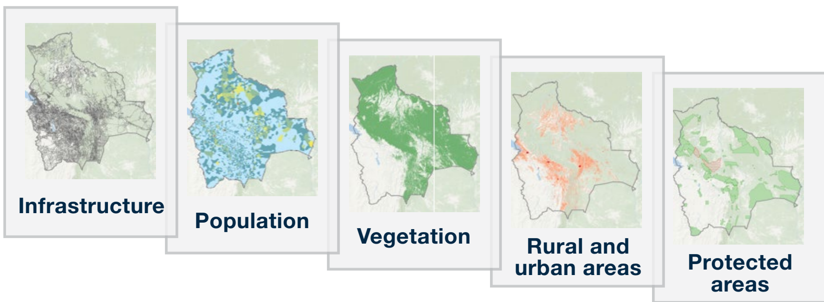
Population density
to estimate the number of families to be relocated and costs.

Environmental protected areas and Indigenous or Traditional Communities Lands
to verify interferences of reservoirs with those areas.

Urban and rural areas
to estimate the cost of land acquisition.

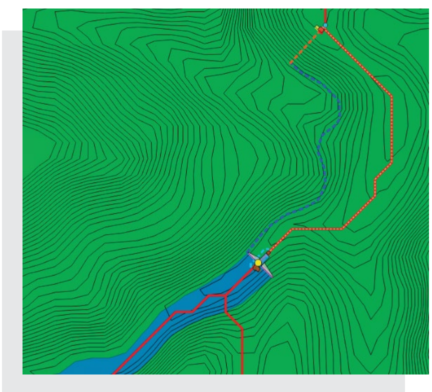
Pipelines, channels and others
to estimate the cost of relocating such structures.

HERA computes the intersections between reservoir flooded area and layers of user provided information (i.e. shapefiles) to determine costs related to environmental aspects and constraints. For each site, different options can be studied by varying the head and engineering layouts. A plant scheme of each project with estimated costs and installed capacity can be visualized.



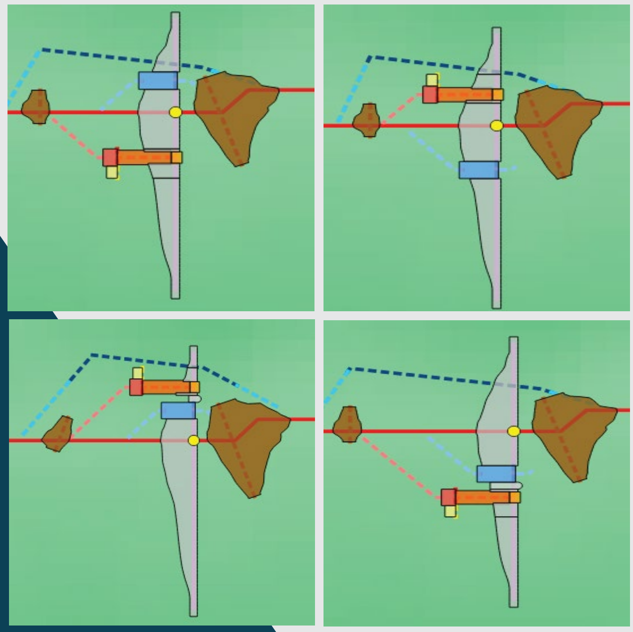
LAYERS OF INFORMATION USED IN ASSESSING PROJECT IMPACTS

ENGINEERING



In this module, an algorithm designs the angle of the dam axis to minimize the distance between the abutments based on the available terrain model. Then, it creates the reservoir by combining the dam geometry with the topography, generating many water elevation alternatives. Finally, it determines the dimensions of the engineering structures and a corresponding estimate for the budget of each project considering civil works, electromechanical components, socioenvironmental impacts and compensations. HERA offers flexibility and transparency, as it provides the edition of parameters and gives easy access to the engineering calculation.

Candidate projects are generated in each location for different water heads and engineering solutions (templates with many types of structures and layouts of how they are disposed along the dam axis, as shown right). For turbines the options are: Bulb, concrete and steel Kaplan, vertical and horizontal Francis, and Pelton. Water conveyance systems include compact structures for low heads; penstock, tunnel and headrace channel for medium or large waterheads. For the river diversion schemes: two-phases on the riverbed, with or without sluiceway, through a tunnel or galleries. For spillway: both controlled and uncontrolled alternatives, including a chute spillway option, considering energy dissipation structures such as stilling basin and ski jump. Finally, dams can be made of concrete, earthfill and rockfill with clay core. Sketches of engineering solutions are shown in the interface.



OPTIMIZATION

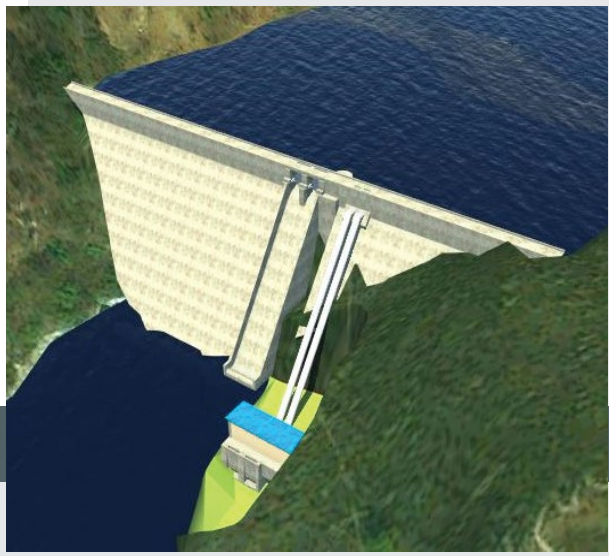
Formulation and the solution of an integer mathematical problem for the selection of the projects considering technical, economic and socio-environmental aspects. Hydropower plants can be selected based on exogenous values for services such as energy, capacity and reserves. Alternatively HERA can be used to support the integration of variable renewable energy sources (VRE) or other technologies. This approach explores synergies of the different project technologies and locations in the optimization model. Several options are possible in the model formulation, such as river fragmentation constraints, min/max ecological water flows, constraints related to the allowed change of natural flows, cumulative impacts of the projects.
As a general procedure, the user:

1- Inputs layers of relevant information (shapefiles);

2- Creates metrics for these layers;

3- Defines constraints for these metrics, applicable to the entire solution space of the projects.

HERA's optimization model is nonlinear because the energy production depends on the product of the head height and powered flow. It is integer because the investment decisions are binary variables. It is stochastic, because river inflows are uncertain (HERA works with scenarios of historical observations). The resulting complex modeling problem requires specialized solution methods.



An automatic 3D model of the projects of shortlisted alternatives is possible through an integration with Autodesk software REVIT and Infraworks. Export to Google Earth is also possible.

VISUALIZATION

The optimization model usually provides feasible solutions that are similar in terms of objective function value, though with different attributes. A visualization tool compares these attributes, to facilitate stakeholder discussion of tradeoffs when discussing development pathways. Additional HERA runs can be made in this process to incorporate a range of user constraints.

APPLICATIONS

HERA has been used in several hydropower planning studies as a tool to aid stakeholders in participatory inventory studies promoted by electricity regulatory environmental agencies.

The Nature Conservancy has been using it as a component of the Hydro by Design methodology in river basins of countries such as Colombia (Magdalena), Nepal (Koshi), Mexico (Coatzacoalcos / Ometepec), and Gabon (Komo, Mbé / Abanga).

Each application brings new knowledge and contributes to the development of HERA. Recent examples include: river basin diversion projects and modeling of minimum flow constraints (Gabon), social issues related to Ejidos and Chimalapas (Mexico), the effect of rare forest coverage and incorporation of project delay and cost overruns associated to socio-environmental risks (Colombia) or engineering solutions including an extension of Eletrobras' engineering guidelines (Brazil) to screen and design PHS projects.

IN 2015 PSR RECEIVED THE ENGIE INNOVATION AWARD FOR THE OPERATING AND TECHNICAL PERFORMANCE CATEGORY FOR THE DEVELOPMENT OF HERA.