6.1. Overall Conclusions

A sustainable and long term solution is proposed for energy requirements of irrigation sector of Indian agriculture systems. A new approach for sizing the ratings of grid connected AC and SPV powered DC irrigation pumps is presented. Energy and cost savings are assessed and CO$_2$ emission mitigation potential is evaluated. Proposed methodology is employed in agriculture lands of Malaprabha Riverbed at Kittali village, Badami Tq, Bagalkot Dst, Karnataka, India.

Identification of suitable method for assessment of crop water requirements in the agriculture lands at Malaprabha Riverbed is presented. Five different methods are employed for assessment of evapotranspiration. Results are compared with standard reference Penman-Monteith estimated values. The comparison revealed that, Turc and Thornthwaite methods yield excessive values of evapotranspiration and Blaney-Criddle, Hargreaves and Christiansen methods give optimum results. It is concluded that, Blaney-Criddle method is most suitable method for the selected site. Further, actual crop water requirement of various crops are assessed.

Energy conservation opportunity in irrigation systems and solution is presented. Methodology for optimally sizing the pumps based on water need and local hydraulic conditions is proposed. Survey is conducted for 51 agriculture lands at Malaprabha riverbed and optimal sizing of pumps is carried for each case and suitable standard pump sizes are suggested. For 51 cases of the survey, optimal sizing of pumps indicated excess installations of 30%, 596 kWh of energy is conserved per day, saving Rs.1132 and reducing the CO$_2$ emissions by 541 kg/day. Results proved that, significant energy can be
conserved by optimally sizing the pumpsets. It is concluded that, implementation of the proposed scheme in large scale, will be a boon for the energy conservation and reduces the burden on national grid.

A new method to size SPV powered DC irrigation pump is presented. New concept of selecting water flow rate based on the operating hours of SPV pump is presented. Water requirement, head offered and corresponding efficiency of motor-pump are considered for assessing the HP rating. Proposed methodology is validated by conducting performance tests on a 1 HP SPV powered DC pump. The proposed methodology is used assess HP ratings for water requirement of 50000 to 300000 liters of water per day and for heads varying from 1m to 12m. The results revealed that, proposed methodology is much suitable for small scale farmers, where water requirement can be assessed much nearer to the actual. Further, the proposed method is employed to assess optimum sizes of DC pumps for the selected agriculture farms in Malaprabha Riverbed. Methodology for sizing SPV panels based on local solar potential is presented. Cost analysis of the irrigation systems proposed for small scale agriculture lands is carried out. The cost comparison of selected 14 cases indicates that, for same agricultural lands optimal sizing of SPV pumps can save Rs.11,86,479.00, i.e 27% of the total investments. Results revealed that, optimally sized SPV based irrigation pumps proves to be cost economic with payback period of average 8 years. It is shown that optimized selection of irrigation pumps can be effective in cost reduction as well as in water management.

Feasibility of Wind-Solar hybrid systems and standalone SPV systems is verified for AC and DC irrigation loads. Optimal cost analysis of both AC and DC systems is presented. HOMER software is used for optimizing the system components. Simulations are carried based AC and DC load profiles and available renewable energy potentials. Cost and electricity generations are compared for both cases. It is concluded that, for riverbed DC irrigation pumps SPV standalone systems are the feasible and economic option.

6.2. Future Scope

In India, electrical energy consumption in agriculture was recorded highest in 2014-15 among all other countries. This indicates the need for research in energy systems for
irrigation. The energy availability and distribution decides the nation’s growth very significantly. In this regard, the present work has proposed an analytical solution to be implemented for large scale. Further in continuation, following works can be taken up in said domain:

- Irrigation can be made cooperative with reference to a selected segment of water resource for grid connected AC pumps. Further, the same can be extended for the government owned SPV systems.
- Feasibility study can be taken up for small sized AC water pumps operating with varying DC input voltage.
- Net metering provision can be proposed for SPV based irrigation systems, which will pump back power to grid during the off hours of irrigation.
- Vertical axis WTG systems can be incorporated in small sized DC irrigation systems, which work even during the night hours and with lower wind velocities.