Hybrid PV/Wind Minigrids for Rural Community Energy Projects: Case Studies in Ethiopia and Nepal

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Local Manufacturing of Small Wind Turbines for Hybrid Microgrids of up to 10kW

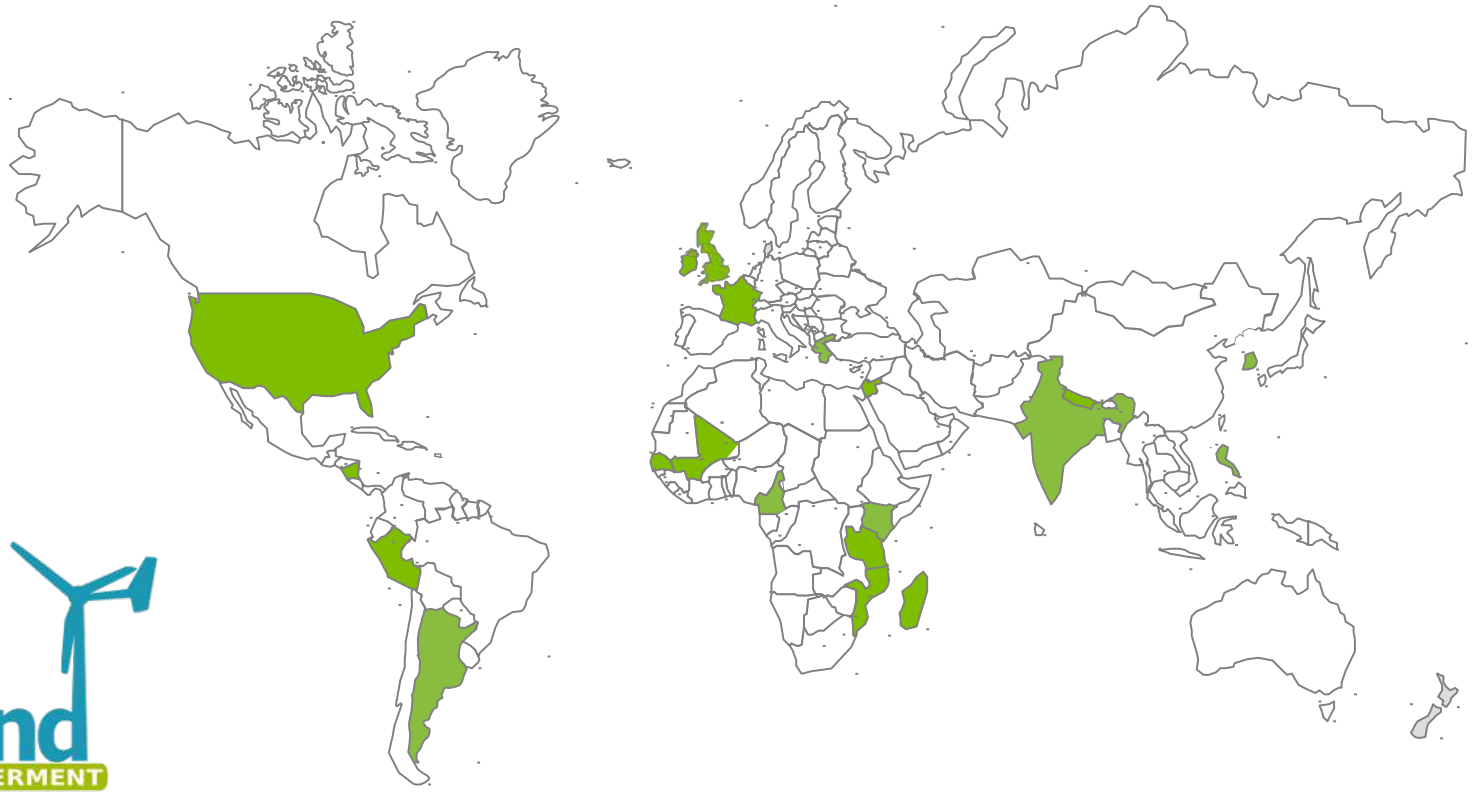






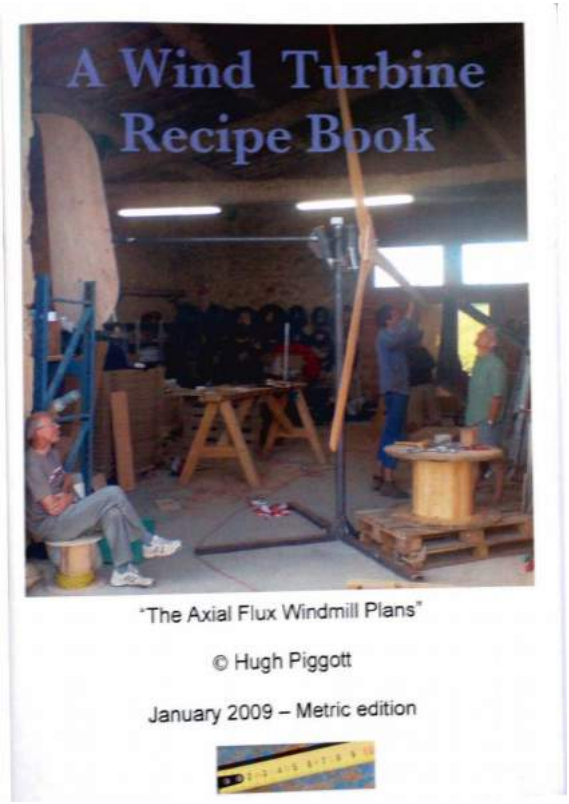
Rotor Diameter: 1.2m to 6m - Power: 200W to 5kW @ 10m/s - Horizontal axis three blade wooden rotor - Constant pitch angle - Variable speed machine - Coreless axial flux permanent magnet (AFPM) generator - Double rotor single stator configuration - Passive gravity furling tail system

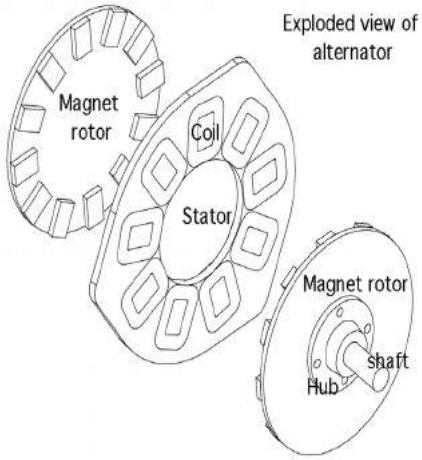
Wind Empowerment: An International Network of Small Wind Turbine Manufacturers

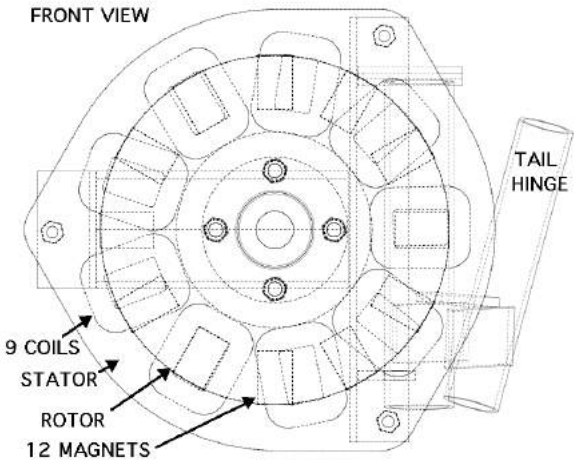


Seven years since its initiation in Dakar in 2011, the Wind Empowerment association has grown to include **56 organizations from 31 countries**, operating now on most continents, and using a '**Design Global Manufacture Local**' production model.

The Standardized Manufacturing Process of the 'Wind Turbine Recipe Book'



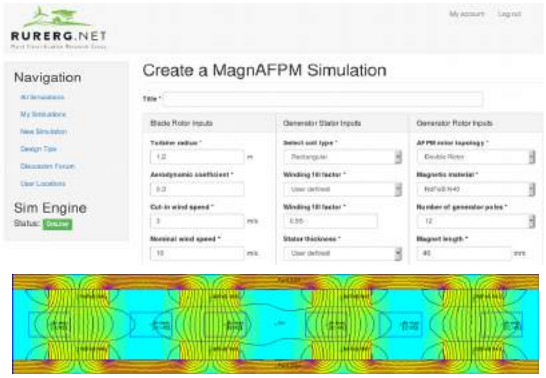


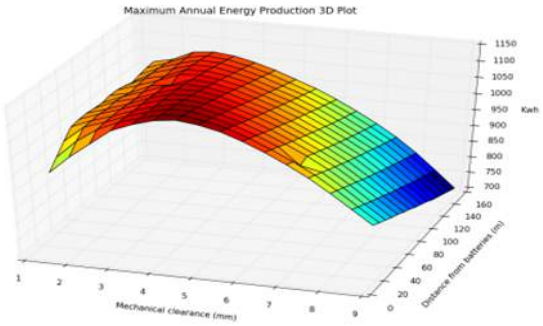


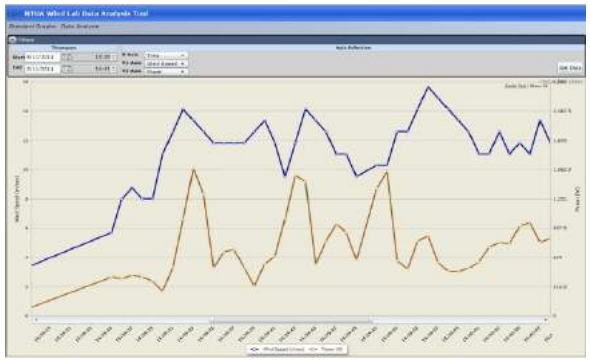
Estimated monthly energy production at different mean windspeeds						
Turbine diameter mm	1200	1800	2400	3000	3600	4200
Power rating	200 W	350 W	700 W	800 W	1000 W	1000 W
Mean 3 m/s	5 kWh	12 kWh	22 kWh	34 kWh	49 kWh	67 kWh
Mean 4 m/s	14 kWh	30 kWh	54 kWh	85 kWh	122 kWh	166 kWh
Mean 5 m/s	23 kWh	53 kWh	93 kWh	146 kWh	210 kWh	286 kWh
Mean 6 m/s	33 kWh	74 kWh	131 kWh	205 kWh	296 kWh	402 kWh
Mean 7 m/s	41 kWh	92 kWh	164 kWh	256 kWh	369 kWh	502 kWh
Estimate cost of materials	£250	£350	£500	£600	£800	£1000

The 'Wind Turbine Recipe Book' by Hugh Piggott is a technical manual describing a '**standardized**' manufacturing process for a set of six windmills. Based on the 'Recipe Book' designs local manufactures have collectively built, installed and tested more than **1000 wind turbines**, creating a vast pool of common knowledge.

Open Design Tools Developed to Meet Practitioners' Needs on the Field







- **OpenAFPM design tools:** The *MagnAFPM* tool is used for designing a generator for a specific set of rotor blades and a specific set of permanent magnet dimensions. The *UserAFPM* tool is used to validate the performance of a specific generator geometry by performing a 2D finite element analysis using FEMM. The *OptiAFPM* tool uses the particle swarm optimization (PSO) to optimize the dimensions of the permanent magnets while optimizing the generator's efficiency, cost and/or mass.

- **WindSYS design tool:** A modeling tool for wind electric systems with direct battery coupling, which configures the system for maximum annual energy production by optimizing the power transmission cable's cross-sectional area as well as the AFPM generator's air gap, while minimizing system cost.

- **WindLabDAT data analysis tool:** Calculates the performance characteristics of a small wind turbine based on electrical and meteorological measurements, according to IEC 61400-12-1: Power performance measurements of electricity producing wind turbines

Electrification of Rural Community Shops in the Somali and Afar Regions of Ethiopia

During 2015, members of Wind Empowerment joined Mercy Corps Ethiopia, in order to provide productive uses of energy from off-grid renewable energy systems using 3m and 3.6m locally manufactured small wind turbines in 1.3kW and 1.8kW installed capacity PV/Wind hybrid minigrids, as part of Mercy Corps' program PRIME (Pastoralists' Areas Resilience Improvement through Market Expansion).

Wind EMPOWERMENT

MercyCorps

Productive uses of electricity: Mobile phone charging, refrigeration of agricultural produce and soft drinks, charging of mobile lanterns for lighting, television projection, radio.

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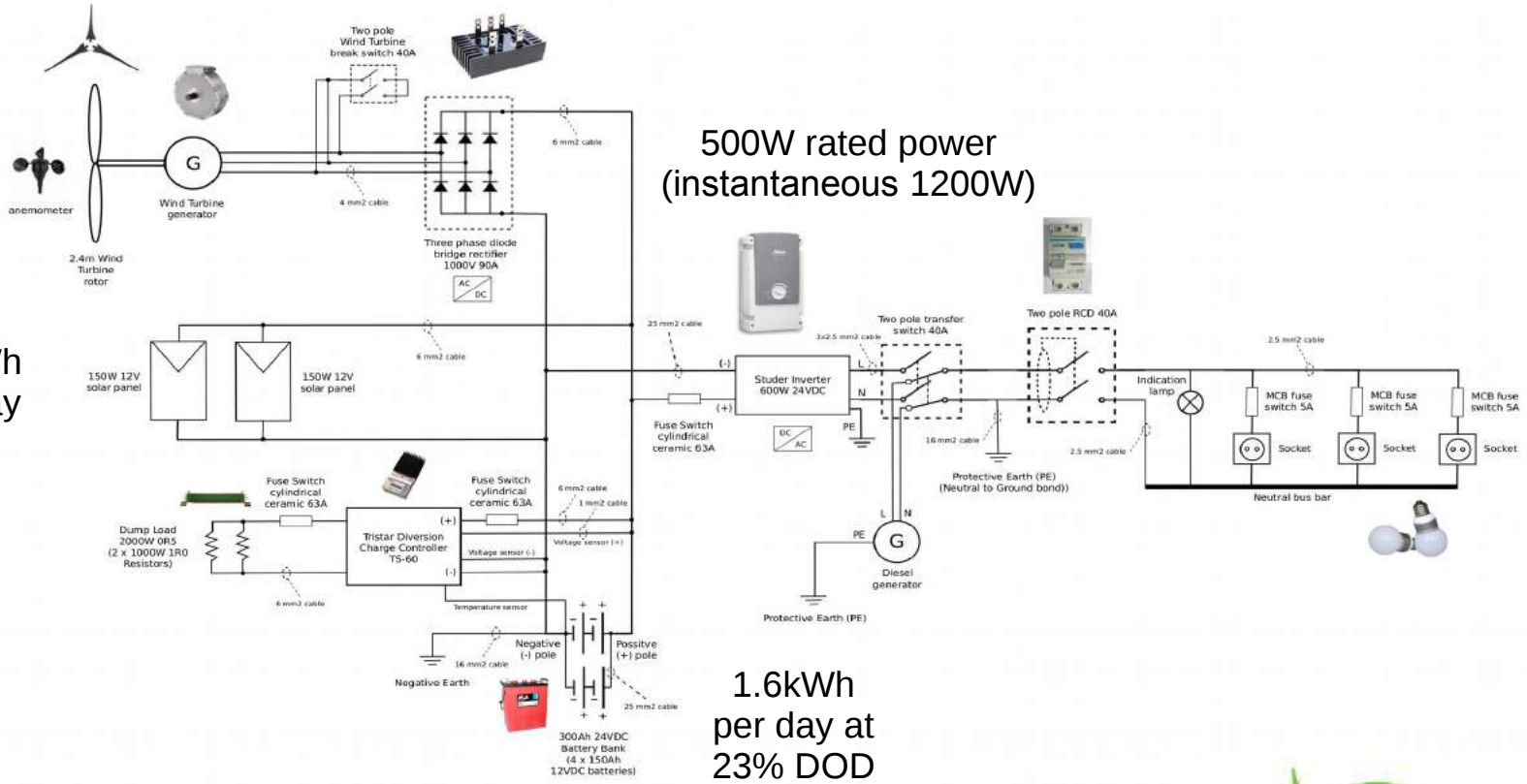
Hybrid PV/Wind Minigrid Topology and System Loads

Load Type	Equipment Rating (W)	Number of Equipment	Running Time(Hrs/day)	Daily Energy (KWh)
Lighting (CFL)	11	3	5	165
Mobile charging station	3	15	17	765
Refrigerator	70	1	8	560
Radio	18	1	8	144
TOTAL				**1.634**

2.3kWh per day at 4m/s

500W rated power (instantaneous 1200W)

1.3kWh per day



1.6kWh per day at 23% DOD

Local Manufacturing of the Wind Turbines in Collaboration with Local Educational Institutions

Metal Working Group

Generator Working Group

Wood Working Group

Jijiga Polytechnic College: 7 day course with 22 participants, of which 18 men and 4 women, all graduates, teachers and students of the college.

Semara University: 9 day course with 24 participants, of which 23 men and 1 woman, all teachers and students of the university.

Theory and Design Sessions

Minigrid Installation and Further Training on System Maintenance and Management

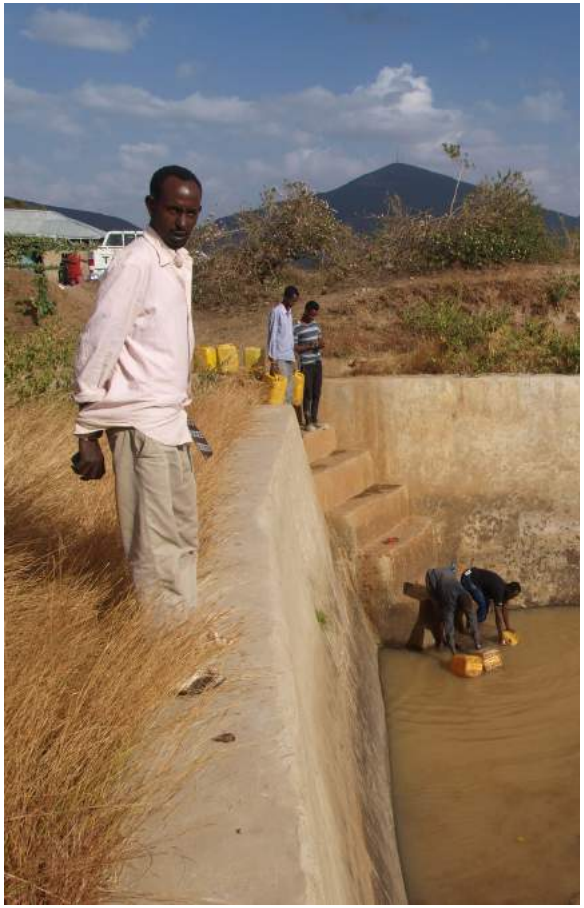
Hybrid System Installation

System Management

SWT Maintenance Procedure

Engagement of the Rural Communities of Handew and Sudan Camp during the Installation of the Minigrid

Civil Works for SWT Tower



Provision of Water for Civil Works

Provision of Food

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Electrification of a Rural Community Clinic in the Palpa Region of Nepal

During 2017, the RurERG joined the Kathmandu Alternative Power and Energy Group (KAPEG) in order to electrify a local health clinic using a 2.4m locally manufactured small wind turbine in a 1.2kW installed capacity hybrid PV/Wind off-grid system. The electrification project was part of a knowledge exchange activity founded by the Wuppertal Institute for Climate, Environment and Energy (WISIONS).

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KAPEG
KATHMANDU ALTERNATIVE POWER & ENERGY GROUP

WISIONS
of sustainability

Community use of electricity: Mobile phone charging, laptops, refrigeration of vaccines, microscope, centrifuge, television projection.

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Local Manufacturing of the Wind Turbine in Collaboration with Local Educational Institution

Metal Working Group

Generator Working Group

Wood Working Group

Kathmandu University: 5 day course with 25 participants, of which 23 men and 2 women, consisting of 15 graduate and undergraduate students from 3 different educational institutions of the country and 10 participants from organizations, such as renewable energy companies and NGOs.

Theory and Design Sessions

Minigrid Installation and Further Training on System Maintenance and Management

Hybrid System Installation

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SWT Maintenance Procedure

Engagement of the Rural Community of Mityal during the Installation of the Minigrid

Civil Works for SWT Tower

Underground Transmission Lines

Provision of Food

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Conclusions

Women's group at the clinic in Mityal, Nepal

Festivities after the installation in Handew, Ethiopia

Local residents at the shop in Handew, Ethiopia

- Minigrids can improve the livelihoods of rural communities.
- PV/Wind hybrid systems can provide a more resilient energy mix.
- The local manufacturing of small wind turbines reduces the initial costs of hybrid minigrids.
- Educational course and trainings create regional maintenance networks and supply chain systems.
- All of the above create an enabling environment for further growth of rural electrification.

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Thank you for your attention!

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