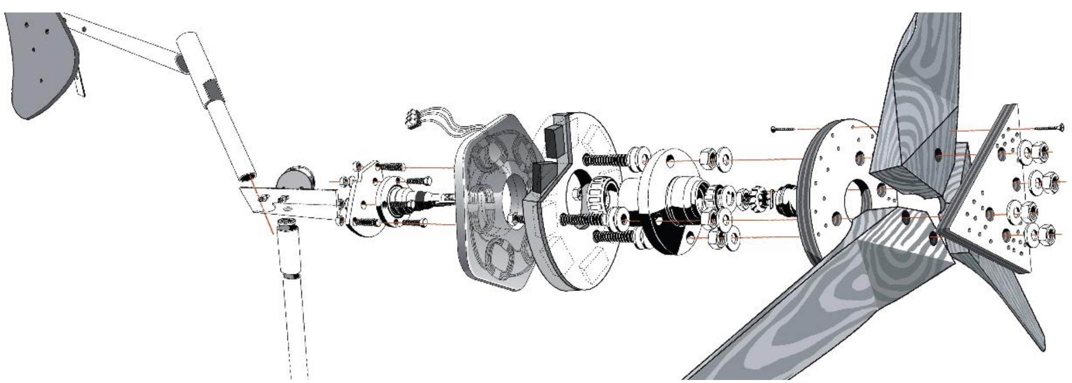
SWT Basics & Market Assessment for SWTs

Jon Sumanik-Leary

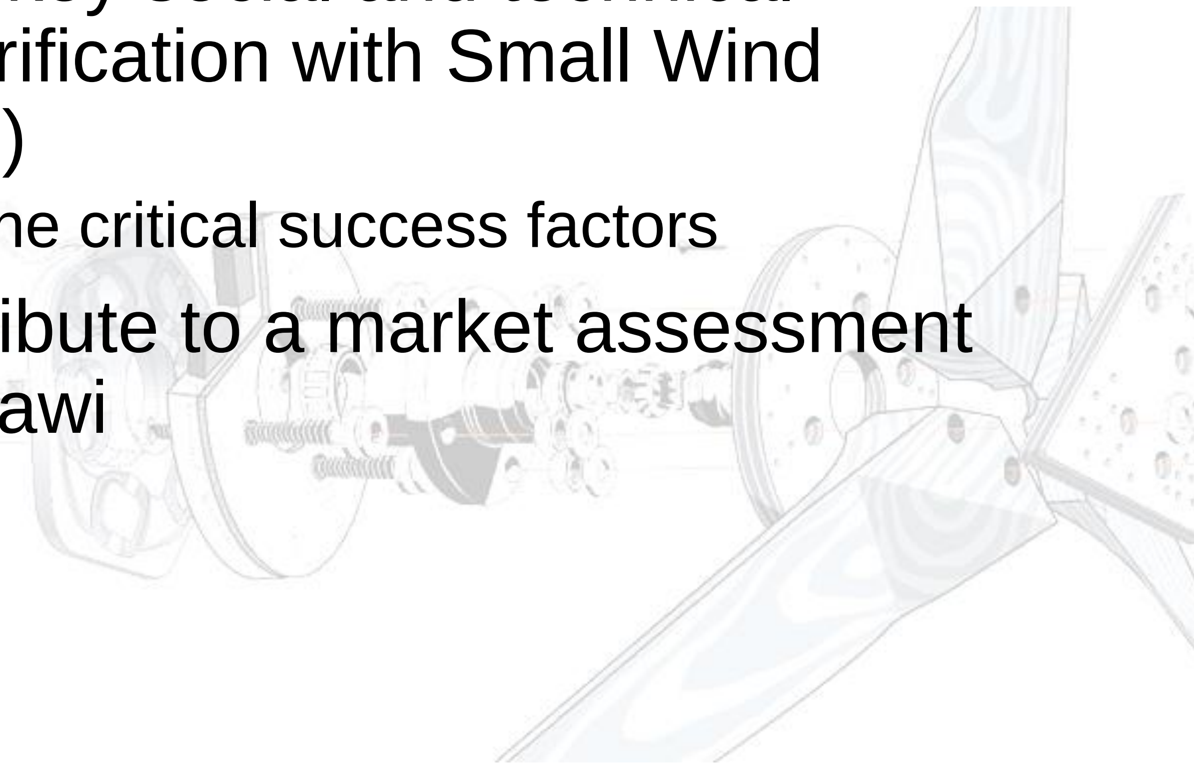
jon.sumanikleary@gmail.com

Wind Empowerment Coordinator



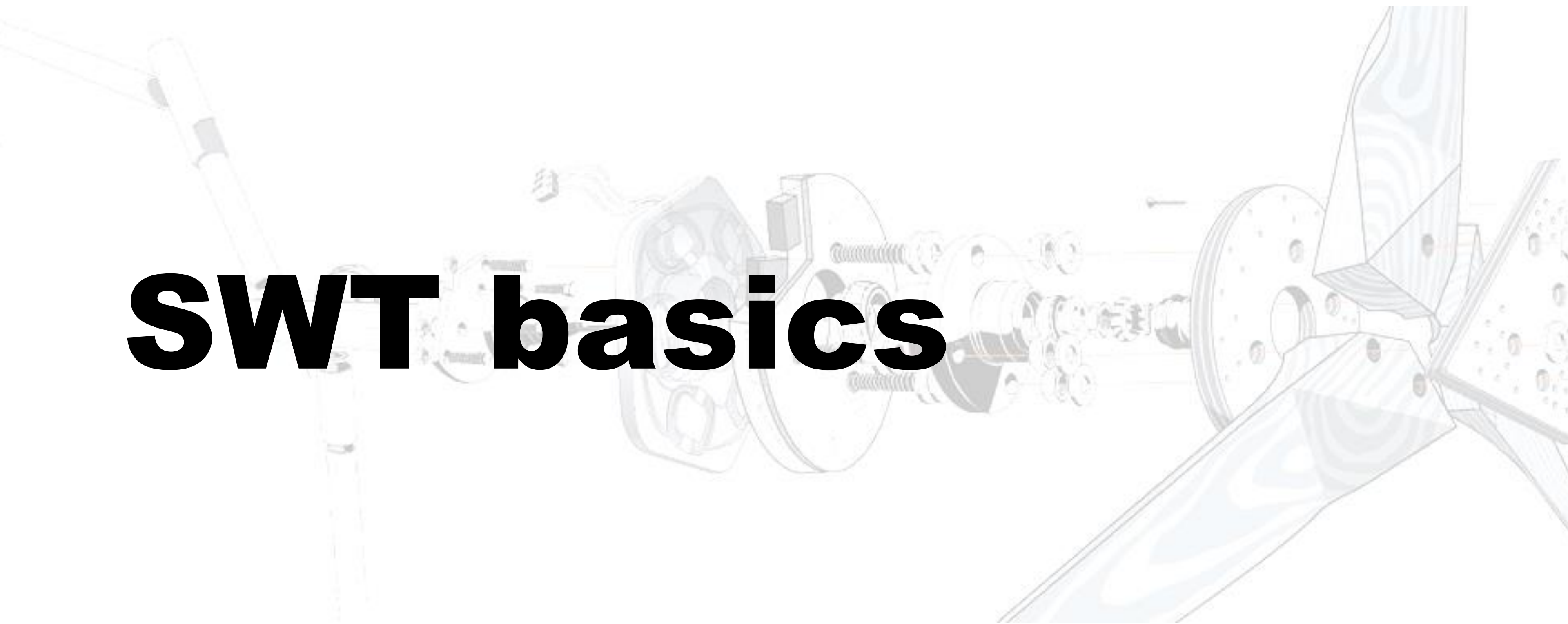
Key learning objectives

- Understand the key social and technical aspects of electrification with Small Wind Turbines (SWTs)
  - Be able to list the critical success factors
- Be able to contribute to a market assessment for SWTs in Malawi



Outline

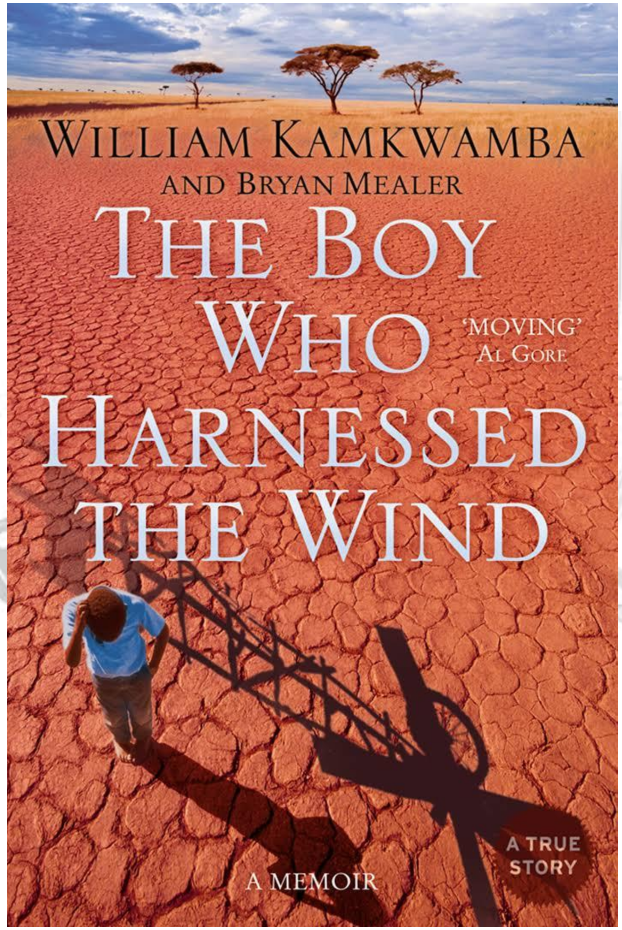
- SWT Basics
- Market Assessment for SWTS
  - Comparison of methodologies from Nicaragua and Ethiopia
  - Presentation & discussion on preliminary results from Malawi



SWT basics

Introduction

- SWTs are a third option for renewable rural electrification
  - PV simpler & more scalable
  - Hydro generally cheaper per unit of electricity



Advantages

- Potentially **lower life cycle costs** ($/kWh) than solar PV on a good wind site (>5m/s).
- **Hybrid systems** can reduce dependence on battery storage and lower life cycle costs when resources are complementary.
- **Life cycle costs spread more evenly** over lifetime than solar PV.
- Can be **manufactured locally**.
- Easy for end-users to observe and spot problems before failures occur.

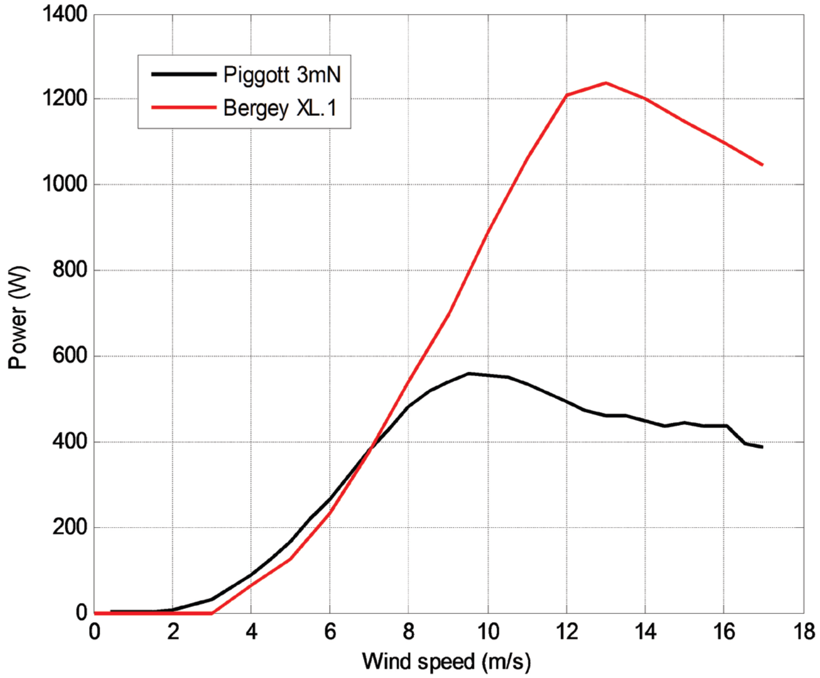
Disadvantages

- **Highly unpredictable resource**.
  - **Larger battery bank** than solar PV generally required if using SWTs alone.
  - **Difficult to assess**
  - **High spatial variation**
  - Significant power reductions with **altitude**
- Statistically rare extreme wind speeds can **destroy the turbine** and/or tower, **so long-term wind data collection** is needed for safe design.
- **Poor reliability**
  - Access to spare parts, tools & technical knowledge essential.
  - Remote sites can increase maintenance costs significantly.
- Difficult to transport
- Difficult to install
- Higher life cycle costs ($/kWh) than hydro
- Highly vulnerable to **environmental hazards** (e.g. lightning strikes, humidity, heat, salinity, dust, sand)

Key terminology

- Power curve
- Rated power
- Cut-in speed
- Annual Energy Yield (AEY/AEO/AEP)
- RAEY
- Efficiency
  - many definitions, e.g.

$$\text{Efficiency} = \frac{P_{DC}}{P_{wind}} = \frac{IV}{\frac{1}{2}\rho A V^3}$$



P_{DC} = DC electrical power delivered to the batteries (W)
P_{wind} = power available in the wind (W)
I = current (A)
V = voltage (V)
ρ = density of air (kg/m³)
A = swept area of wind turbine (m²)
V = wind velocity (m/s)

Typical applications

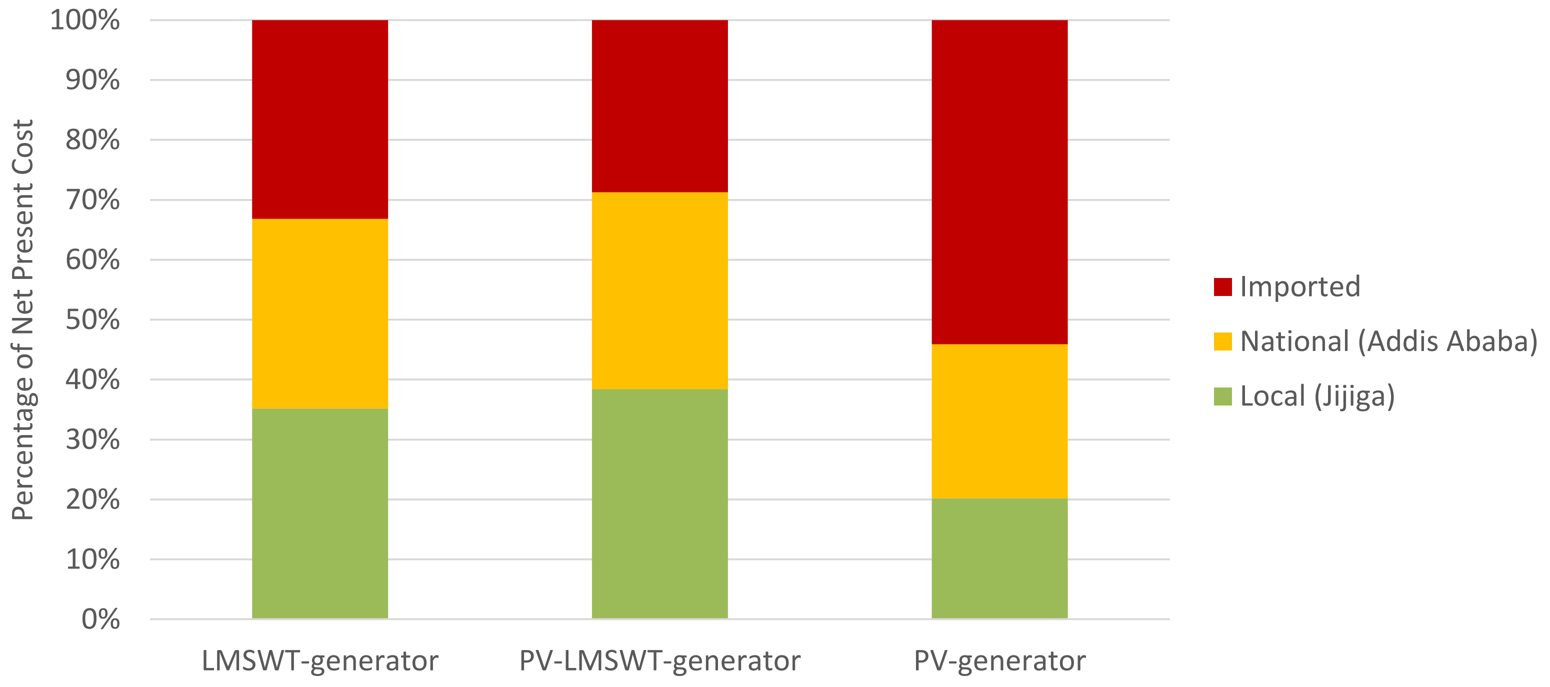
- Wind/solar (+diesel) **hybrids** for **battery charging**
  - **Household** systems
    - 100W scale possible, but high unit costs as **not as modular** as PV
    - **More complex** than SHS
    - **Fewer good wind sites** than good solar sites
  - **Productive** applications
    - **Agriculture** (irrigation, agricultural processing equipment)
    - **Small businesses** (power tools, fridges/freezers),
  - **Community mini-grids**
    - Multiple households
    - Community services (lighting and computers for schools, health centres etc.)
    - Productive applications

Local manufacture vs importation

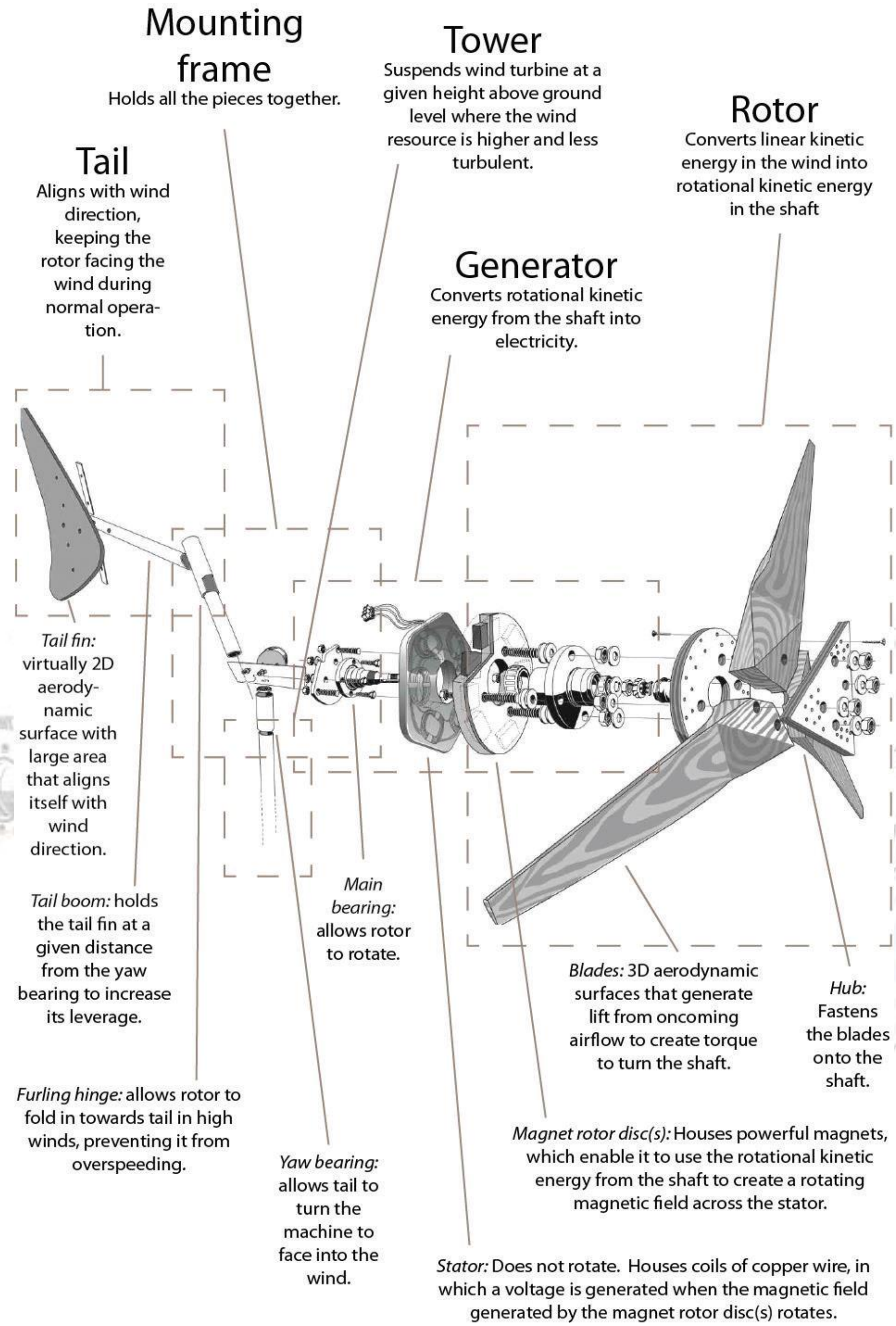
- Local manufacture
  - **Local jobs**
  - **Stronger supply chain**
  - Reinvesting money in **local economies**
  - Lower upfront cost
  - **Participatory manufacture**
- Importation
  - **Reliability**
  - International **shipping & import taxes**

Value chain analysis

- **Where** is the money spent?
  - In Ethiopia:

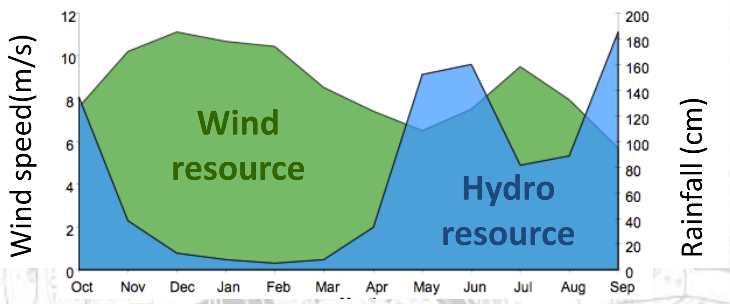


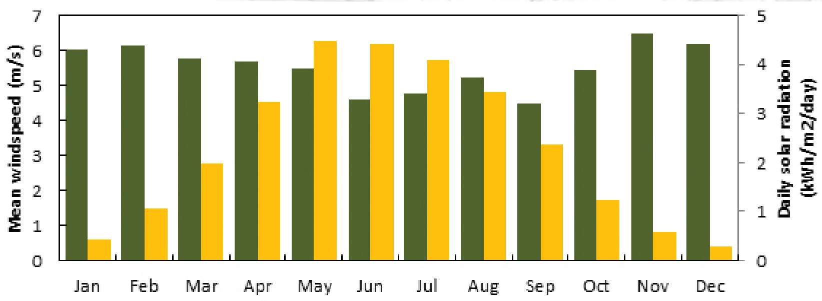
Key components

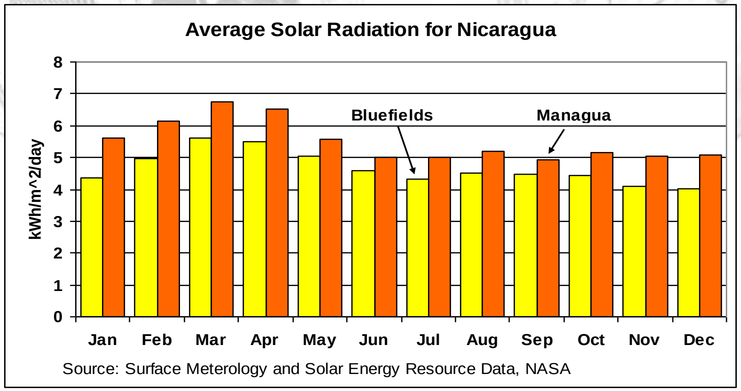


Wind/solar hybrids

- **Compatibility** of resources **different** in each place
  - Nicaragua
  - Scotland

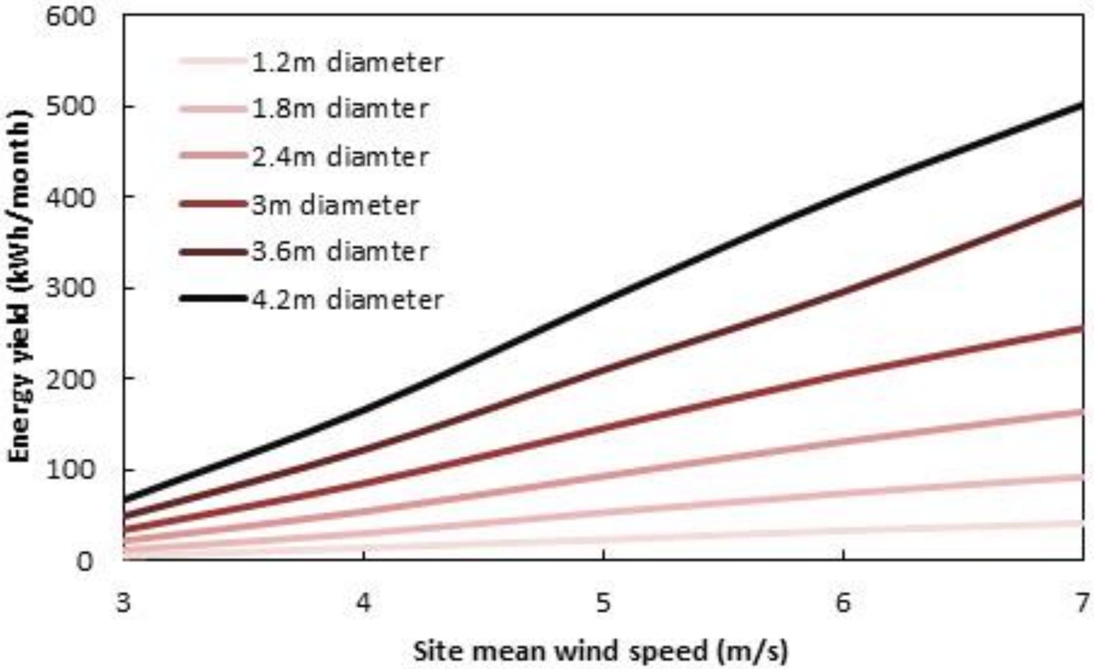






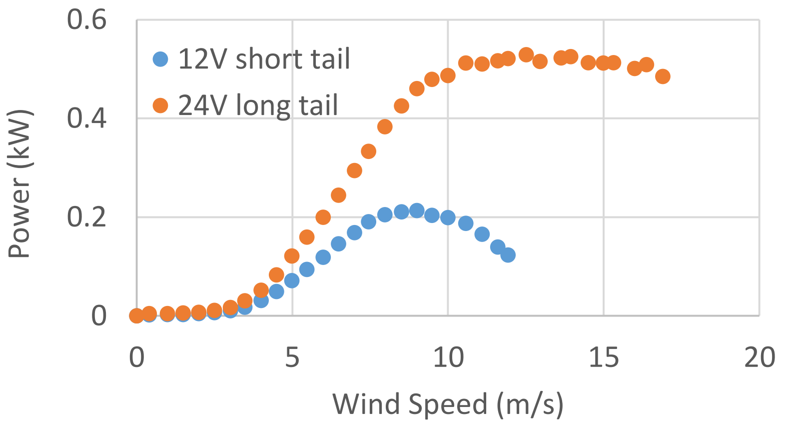
Energy yield & power performance (Matt)

- PαV3
  - Doubling the wind speed generates **EIGHT** times more power



Energy yield & power performance (Matt)

- Actual energy yield **very** difficult to predict
  - **Every SWT different**, especially if locally manufactured
    Furling system
    - Accuracy of blade geometry
    - Cable length & diameter
    - Tower height
    - Voltage
    - Furling system
    - …



- Khennas, Dunnett et al. (2008): *"the best approach may be to make an **informed guess** and then **refine this in light of practical experience**."*

Energy yield & power performance (Matt)

- Actual energy yield **very** difficult to predict
  - **Every site different**
    - Obstructions (turbulence & shelter)
    - Seasonal & inter-annual variation in wind resource
    - Air density changes due to altitude
    - Local topography
    - …
- Khennas, Dunnett et al. (2008): *"the best approach may be to make an **informed guess** and then **refine this in light of practical experience**."*

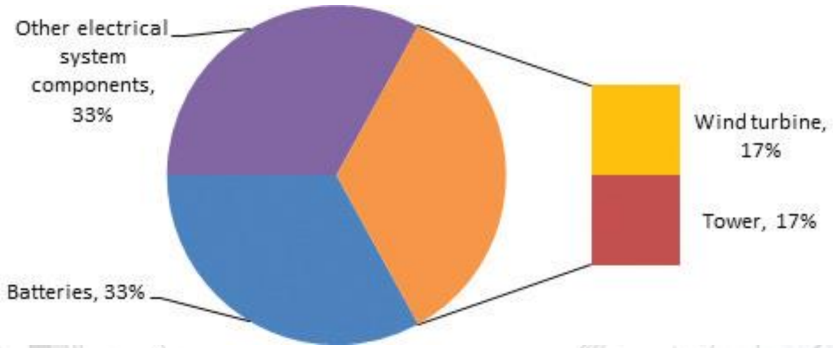
Towers

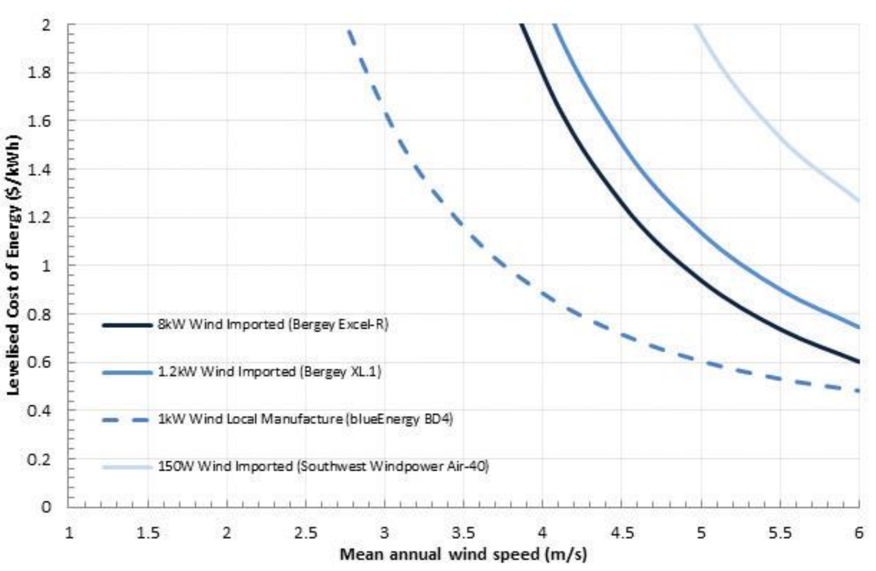
- **Taller** = better wind resource, lower turbulence
- **Shorter** = cheaper, easier to install/maintain
- Typically **6m** (open areas w. good wind resource) **to 30m** (many trees/buildings & poor wind resource)



Economics

- Key factors:
  - Rotor **diameter.**
  - **Wind resource**.
  - Where & how it is **manufactured/assembled/installed**.
  - How it is **maintained**
    - End-user training
    - Distance to service centre
    - Environmental hazards





VAWTs, roof mounting & shrouded turbines

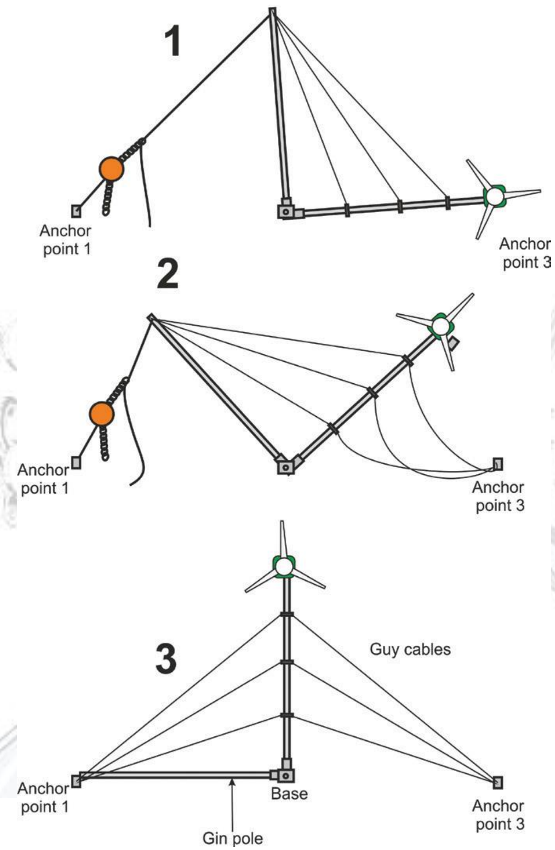


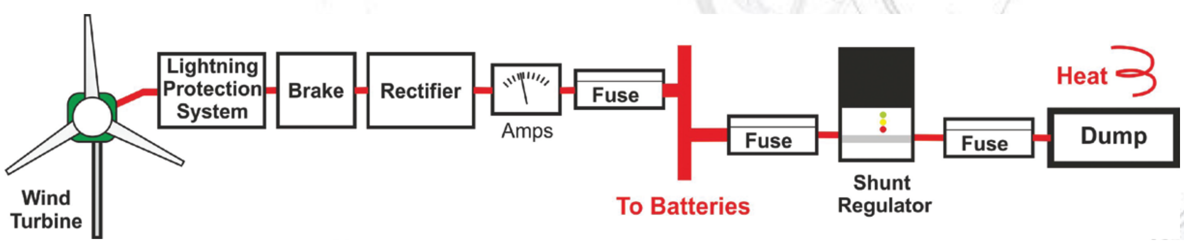





Site selection and installation

- Site selection (MATT)
- Transportation
- Foundations
- Electrical installation
- Assembly



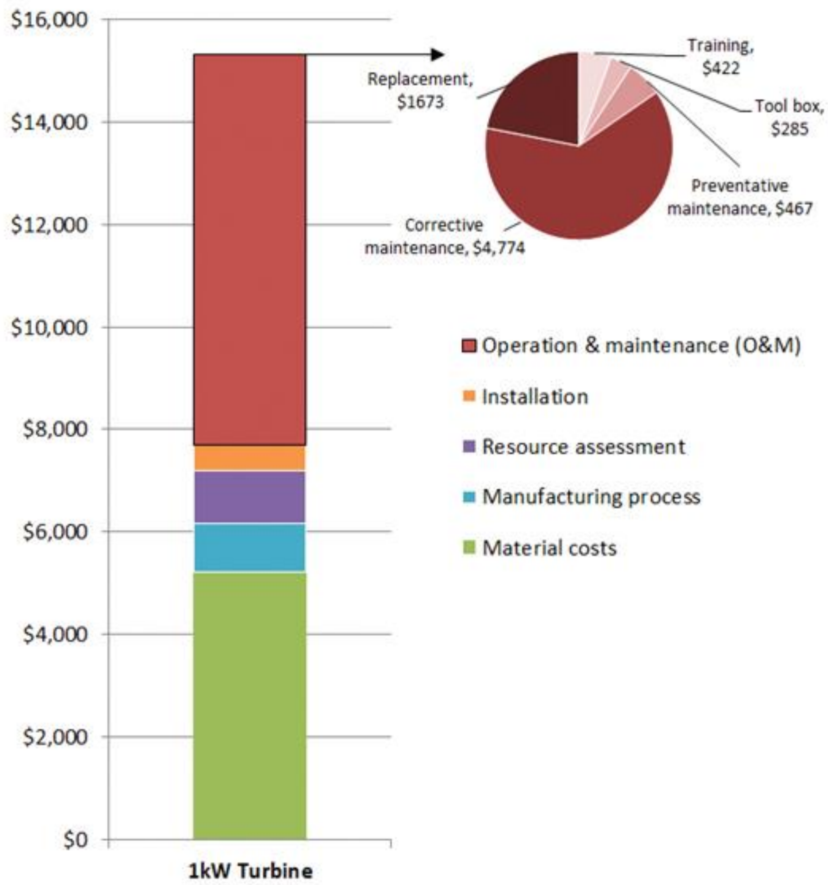


Operation & maintenance

- **Failures are inevitable!**
  - **Frequency** of failures
    - Manufacturing **quality**
    - **Environmental hazards**
    - **Preventative** maintenance
  - **Downtime**
    - -> Access to **maintenance services** essential
      - **Service networks**
      - **Community technicians**
        - Capable **AND** motivated

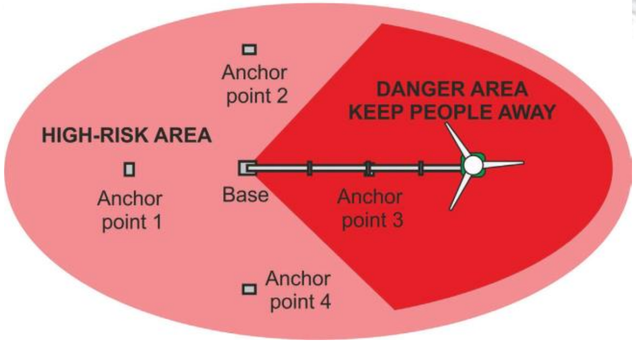
Operation & maintenance

- Maintenance costs **highly variable**
- Opportunity to **create jobs** in **rural areas**
- Spreads cost of system out over lifetime
  - Users **MUST** be aware of **maintenance requirements** from the beginning



Safety

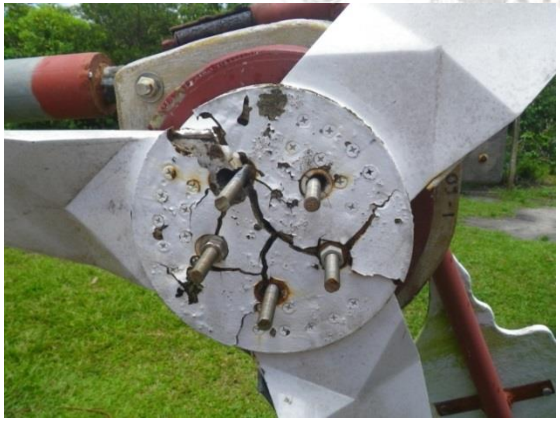
- Magnets
- Lightning
- Carrying heavy components
- Raising/lowering tower
  - Do not climb (without a harness)
  - Electrical brake
  - ‘Drop zone’



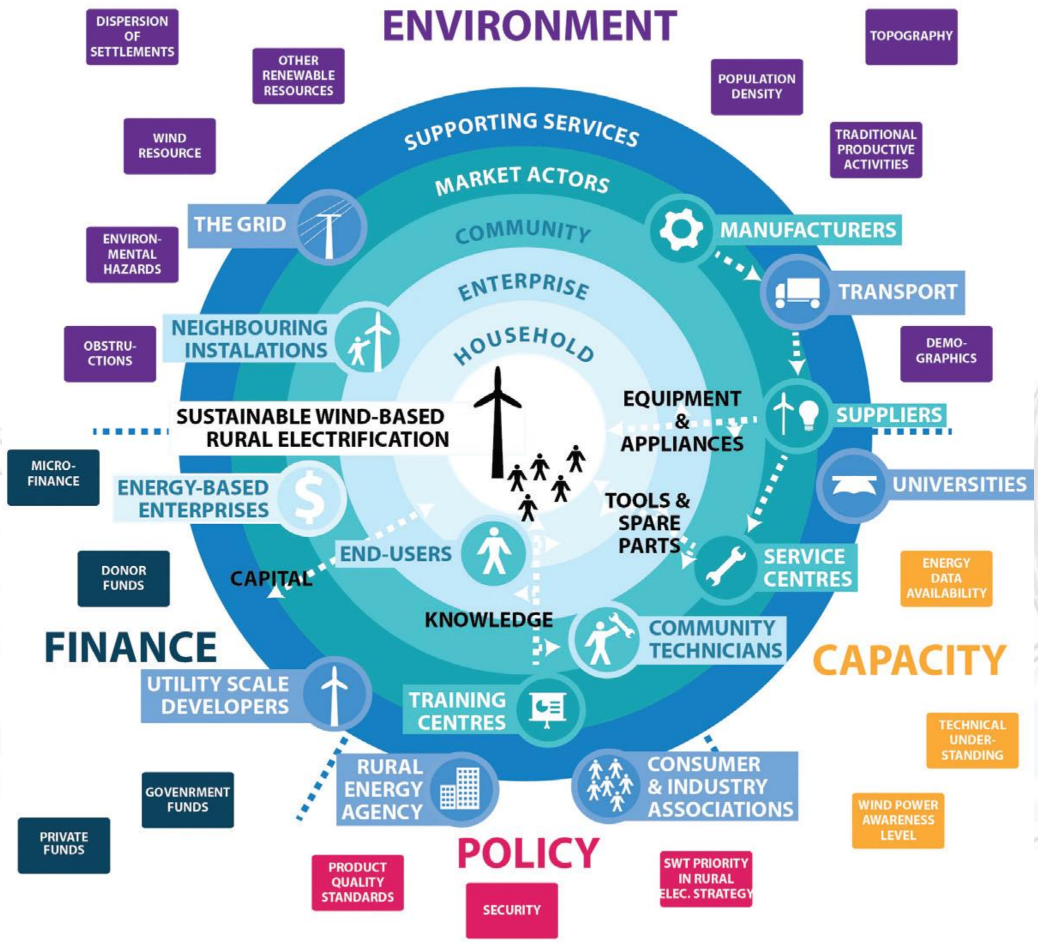
Market Assessment for SWTs

What happens if you don't do a market assessment?

- Sustainability of SWT initiatives **much more dependent on context than solar PV**
  - => MA much more important, as it **matches products/services** (RETs) with **people** who might **need them**, taking into account a range of **contextual factors**



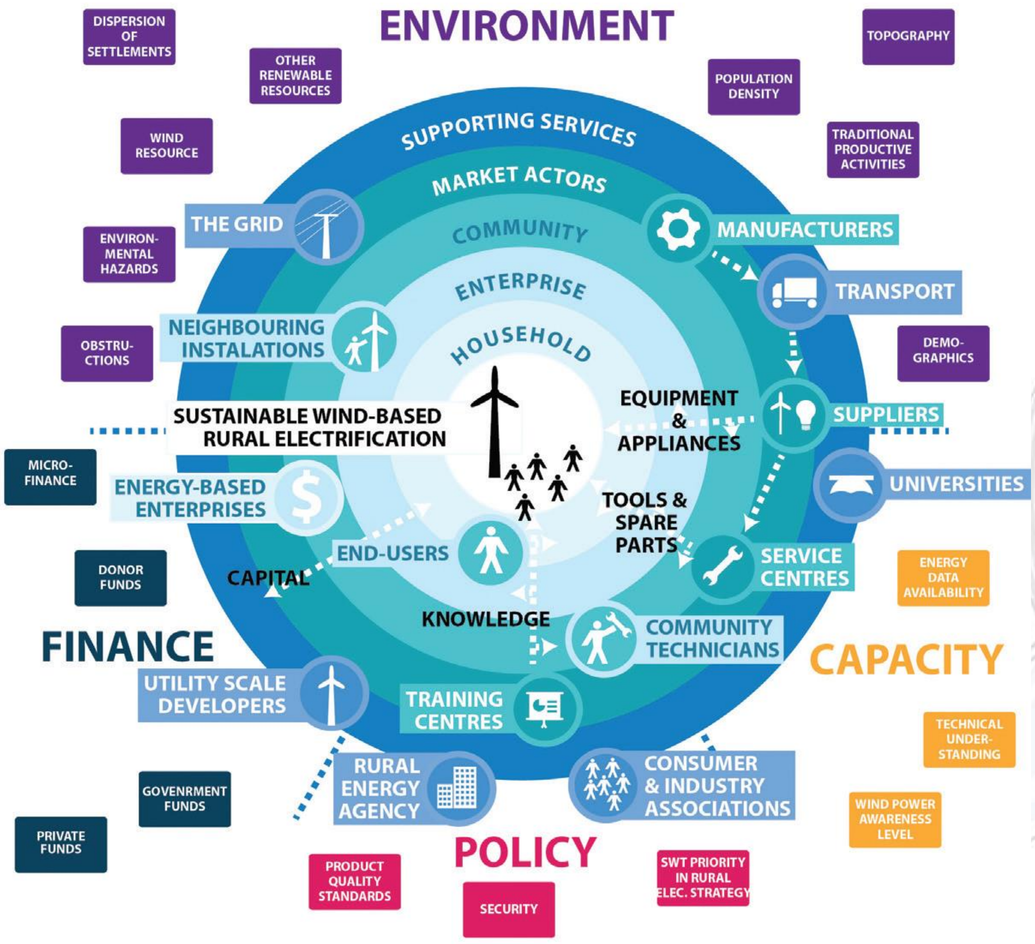
Ideal context



Ideal context

- **Enabling environment**
  - Environment
    - **High wind resource (>4m/s monthly average throughout the year) in the regions where most people lack access to electricity.**
    - **Lack of environmental hazards (low frequency of dangerously high winds and lightning strikes and cool, inert environment to prevent corrosion, overheating or contamination with dust/sand).**
    - **Solar or hydro resources that peak in the opposite season to the wind resource and cannot provide sufficient power generation throughout the year.**
    - **Flat plains with no trees or other obstructions (to cause turbulence, reduce wind speeds and necessitate individual site assessment).**
    - Wind resource that peaks in the same season as traditional productive activities, e.g. dry season for farmers in need of irrigation.
    - High air density (cold, low altitude) for maximum power extraction and cooling of the generator.

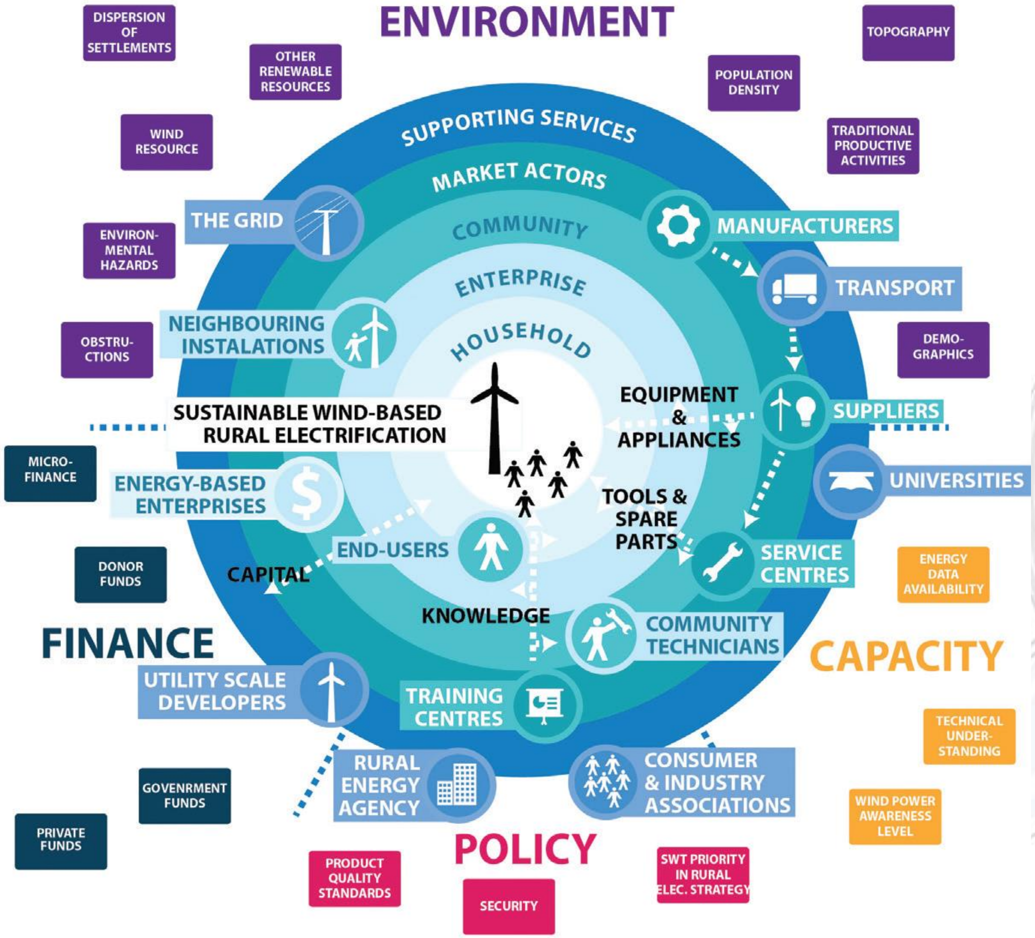
Ideal context



Ideal context

- **Enabling environment**
  - Finance
    - **If insufficient access to capital, the potential for establishing energy based enterprises should be high and/or innovative financing models such as pay-as-you-go energy metering should be available.**
    - **Targeted subsidies for providing maintenance services or wind resource assessment can be effective.**

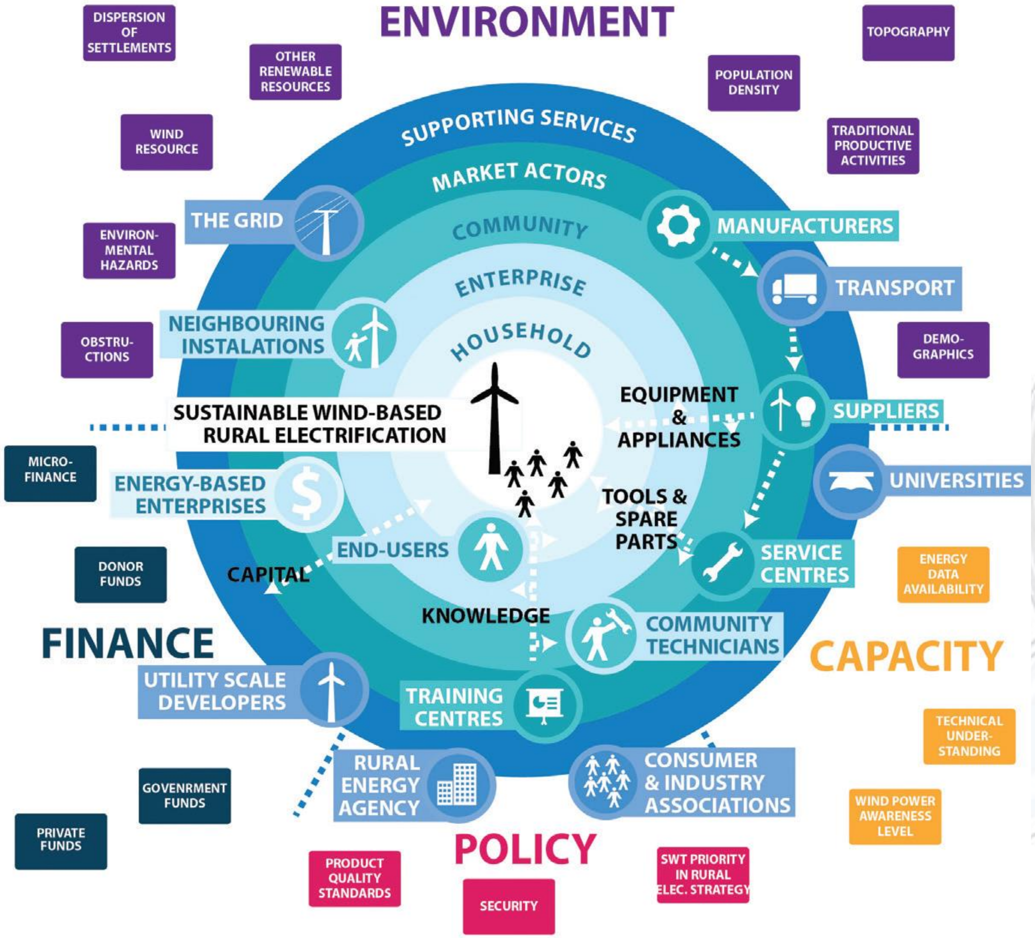
Ideal context



Ideal context

- **Enabling environment**
  - Capacity
    - **High level of awareness of SWTs and understanding of the technical advantages and disadvantages.**
    - **Freely available high quality wind maps (validated with anemometry in the areas where SWTs are most viable, of high resolution and relevant to low hub heights).**

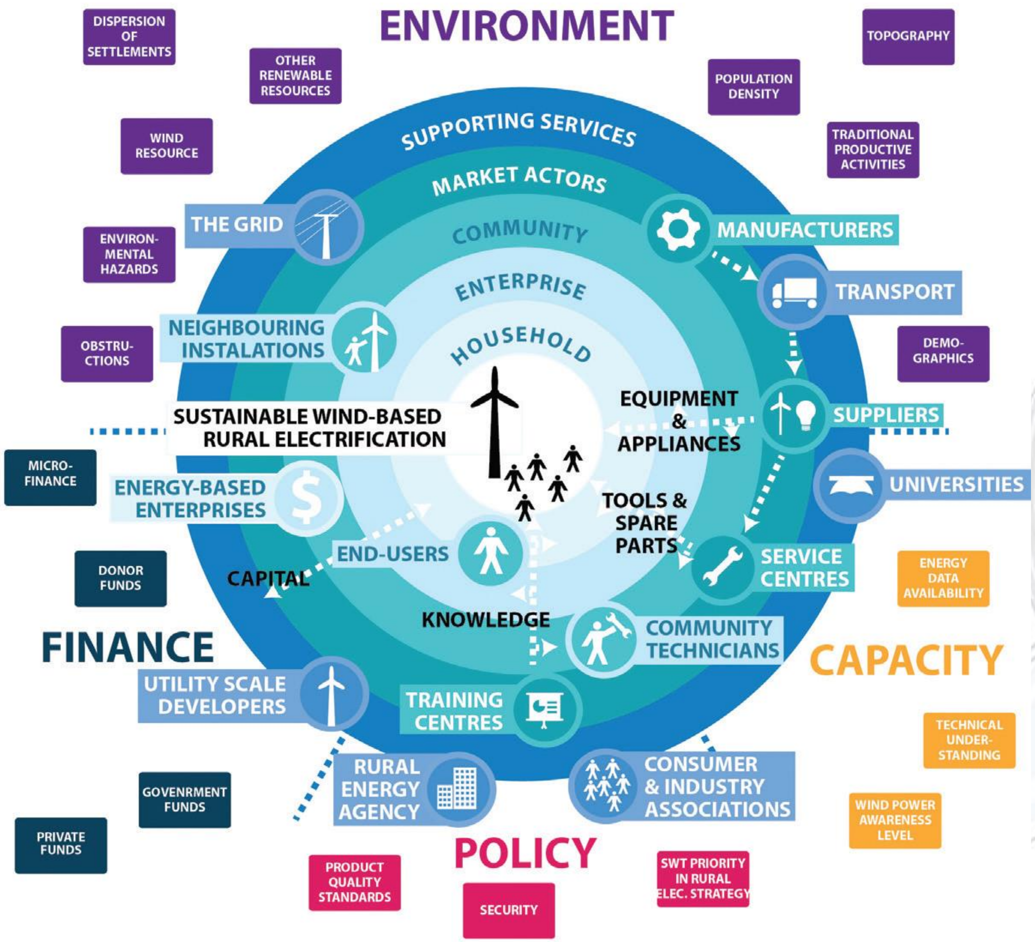
Ideal context



Ideal context

- **Enabling environment**
  - Policy
    - * **A realistic evaluation of the national potential for SWTs and a plan for how to achieve this potential, which forms part of national rural electrification strategy.**
    - * **In complex terrain, individual wind studies should be supported for each new location.**
    - * **Strong and consistent institutional support to foster the development of a strong SWT ecosystem, in particular the social infrastructure required for maintenance.**
    - Product quality standards that ensure consumer confidence, but don't unnecessarily hinder manufacturers.
    - Government endorsement to build trust in SWTs.
    - Tax exemptions for imported SWTs, wind pumps, power electronics and batteries.
    - Favourable feed-in tariff to encourage grid-tied SWTs.

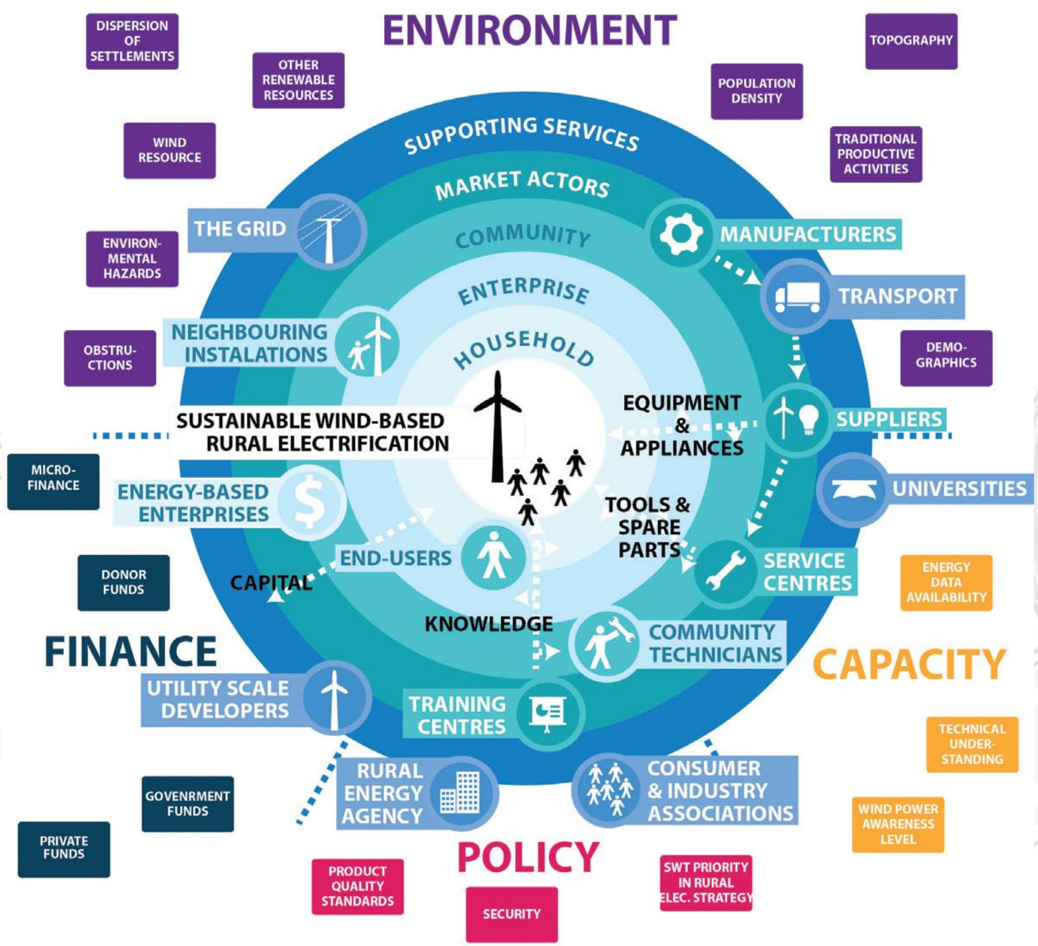
Ideal context



Ideal context

- **Supporting services**
  - **Good transportation infrastructure that facilitates easy access to installation sites.**
  - **Consumer and industry associations that share knowledge between SWT market actors and give them a voice in the policy arena.**
  - Universities that are willing to collaborate with SWT market actors in specific research projects, as well as offering wind power related training.
  - Utility-scale wind farm developers willing to support SWT market actors with funds and experience.
  - Grid electricity available in a nearby town/city (if manufacturing centrally).

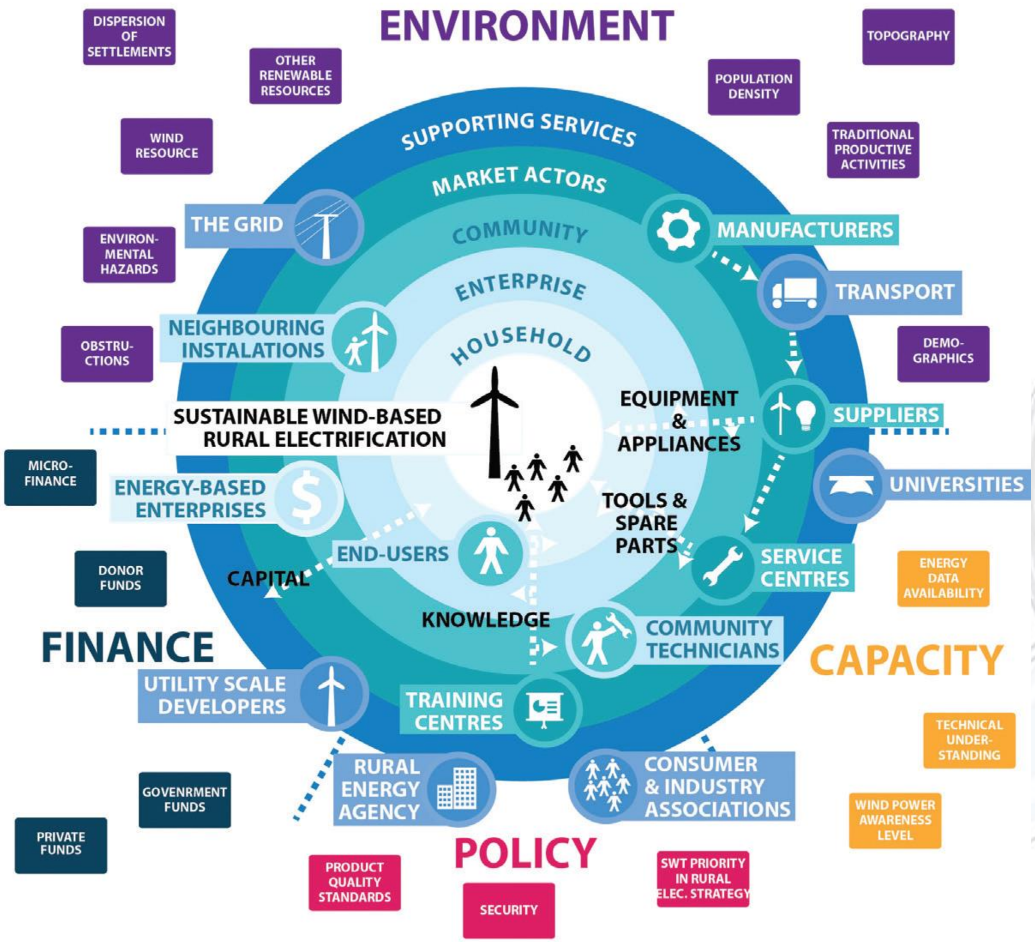
Ideal context



Ideal context

- **Market actors**
  - **A variety of training and demonstration centres that can raise awareness of SWTs and empower community technicians/end-users.**
  - **A network of service centres capable of bridging the gap between the supplier/manufacturer and the community by offering technical support for SWTs at a local level.**
  - A variety of construction material suppliers offering products relevant to SWTs (if manufacturing locally).
  - A variety of SWT manufacturers offering a range of products that are well matched to local needs.
  - A variety of SWT suppliers with regional branches in all areas where SWTs are viable, offering support for site selection and system design, as well as installation.

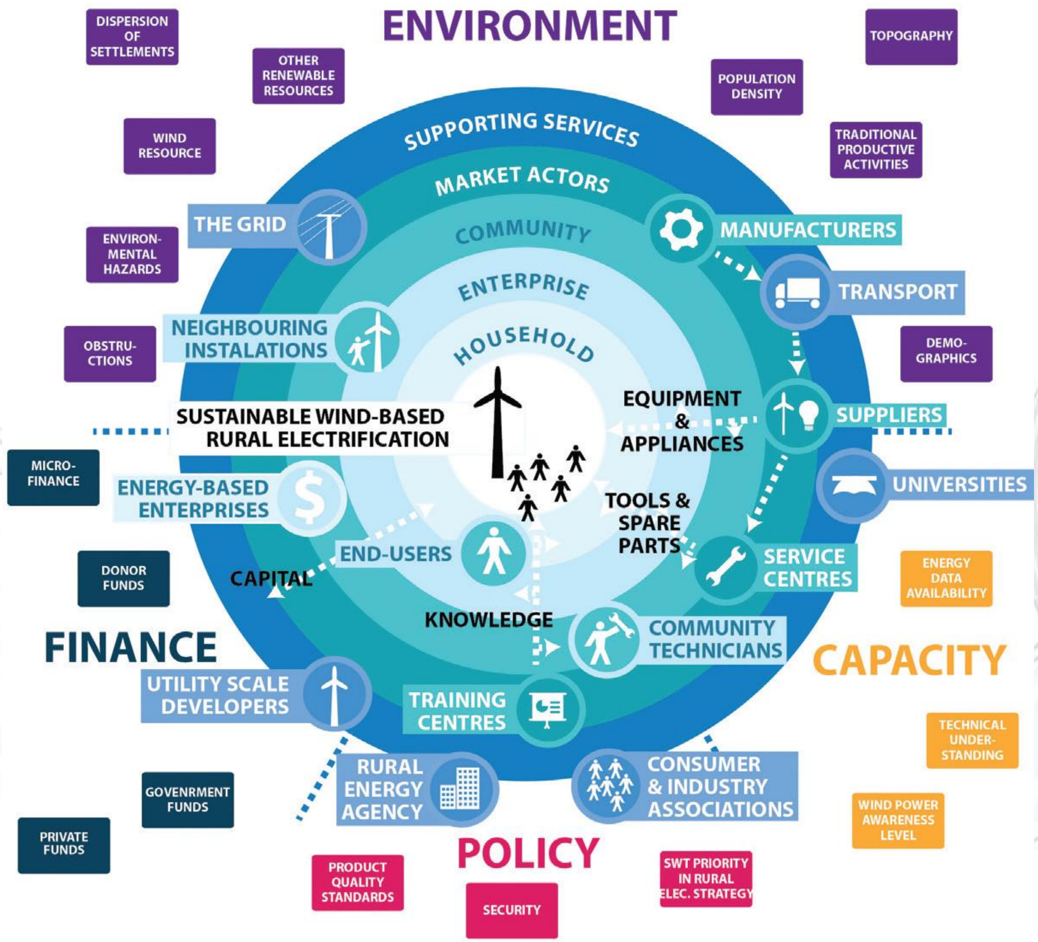
Ideal context



Ideal context

- **Community**
  - ∗ High level of technical knowledge available at a local level.
  - ∗ Highly motivated individuals to take on the role of community technician.
  - ∗ End-users with sufficient capital to pay for O&M costs or a willingness to use the electricity to generate sufficient revenue.
  - End-users that are willing to adapt their behaviour around the availability of the wind resource.

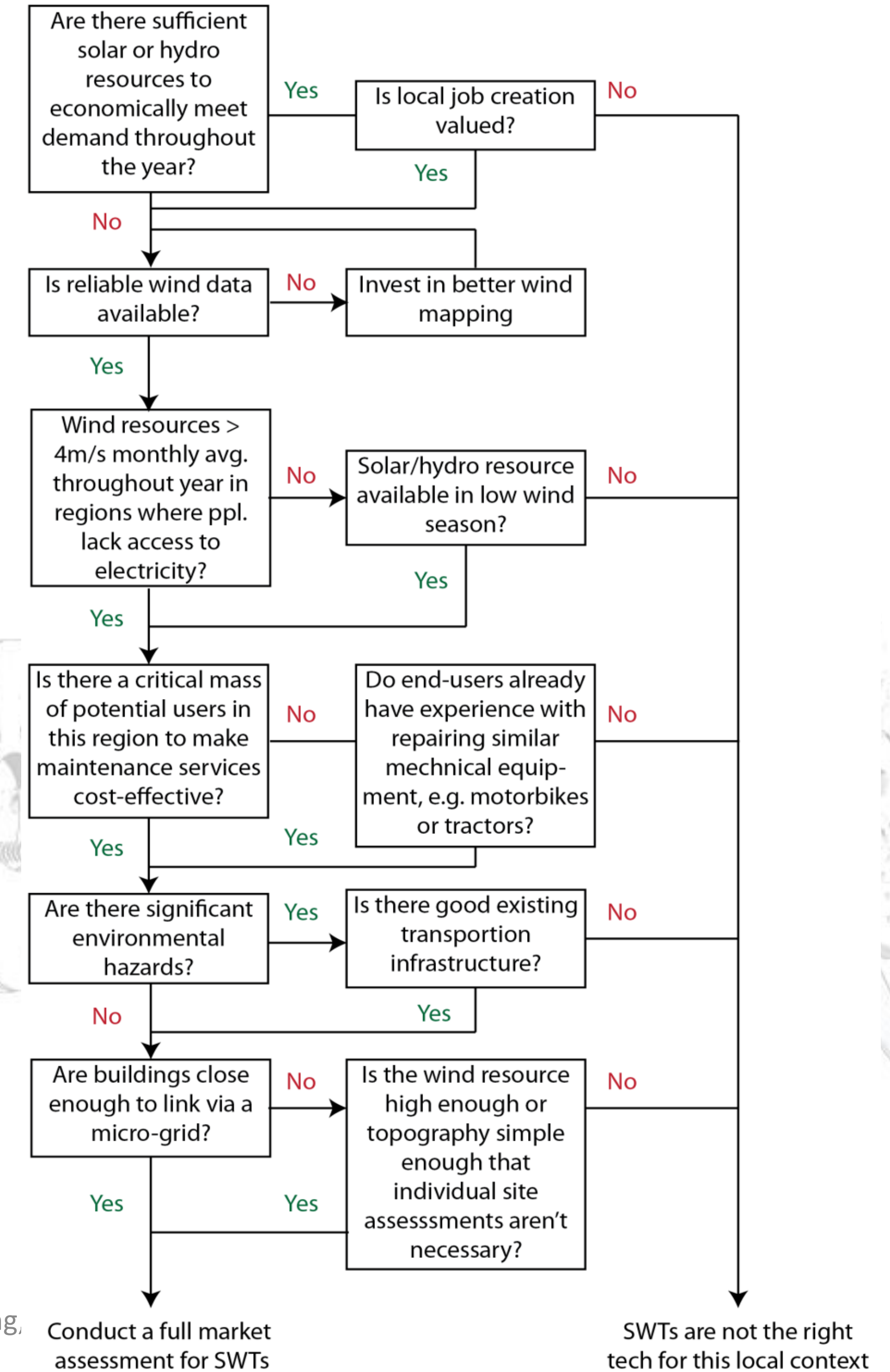
Ideal context



Methodology

Decision support tree

- Preliminary analysis for high level decision makers



Key stages

- STAGE I: Learning from existing initiatives
- STAGE II: Quantifying the market potential
- STAGE III: Mapping the local energy access ecosystem and identifying the key barriers

STAGE I

- Learning from existing initiatives
  - Nicaragua
    - blueEnergy on the Caribbean coast (Neves et al, 2015)
    - Pilot project – Cuajinicuil
    - PV suppliers experience with SWTs
  - Ethiopia
    - MercyCorps PV projects
  - Malawi
    - CEM PV projects
    - GoM SWT projects
    - Students for Malawi SWT projects

STAGE II

- Quantifying the market potential
  - Nicaragua
    - Delivery model: community micro-grid
    - Output:
      - Location of most viable regions
      - Quantification of potential market
  - Ethiopia
    - Delivery model: small commercial centre
    - Output:
      - Location of most viable regions
  - Malawi
    - Delivery model: ?
    - Output:
      - Location of most viable regions
      - Quantification of potential market

STAGE II
Data collection

	Nicaragua		Ethiopia	
Factor	Data collected	Data sources	Data collected	Data sources
Component costs	• Cost breakdowns for LMSWT materials & manufacturing, energy system components, installation & O&M.	• Actual costs from Cuajinicuil pilot project • Quotes from Nicaraguan & overseas RE suppliers	• Cost breakdowns for LMSWT materials & manufacturing, energy system components, installation & O&M.	• Actual costs from Semera & Jijiga pilot projects • Quotes from Ethiopian RE suppliers
Scale	• Modelling 100W, 1kW and 10kW energy systems	• As above	• N/a	•
Place of manufacture	• Comparison of local manufactured SWTs with imported	• As above	• Only locally manufactured SWTs & imported PV	• As above
Population size	• Population per municipality	• National census (INIDE 2005)	• Population per municipality	• IRENA Global RE Atlas

STAGE II
Data collection

	Nicaragua		Ethiopia	
Factor	**Data collected**	**Data sources**	**Data collected**	**Data sources**
Renewable resources	• Map of existing hydroelectric installations and sites with proven resource • Solar resource map • Wind resource maps • In situ wind resource measurements (secondary data)	• MEM • ENCO • UNEP/SWERA • UNI • UCA • blueEnergy	• Hydro resource map • Solar resource map • Wind resource maps • Land use map (obstructions for wind flow) • Altitude (air density) • In situ wind resource measurements at pilot sites (primary data)	Various datasets from IRENA Global RE Atlas Datalogging in Jijiga & Semera
Existing transportation infrastructure	• Population density per municipality • Actual journey costs for remote/near sites • Locations of existing service centres	• National census (INIDE 2005) • Interviews	• Population density map • Actual journey costs for remote/near sites	• IRENA Global RE Atlas • Interviews

STAGE II
Data collection

	Nicaragua		Ethiopia	
Factor	Data collected	Data source s	Data collected	Data source s
Energy access	• Map of existing national grid and diesel mini-grid infrastructure • % with grid access per municipality	• ENEL • National census (INIDE 2005)	Map of existing national grid infrastructure	IRENA Global RE Atlas
Protected areas	N/a		Protected areas map	IRENA Global RE Atlas
Civil unrest	N/a		Overseas travel advisory	FCO
Ability & willingness to pay	• % living in extreme poverty per municipality • Baseline household expenditures on energy in Cuajinicuil	• National census (INIDE 2005) • Cuajinicuil project reports	Baseline household expenditures on energy at pilot sites	Household surveys in Jijiga & Semera

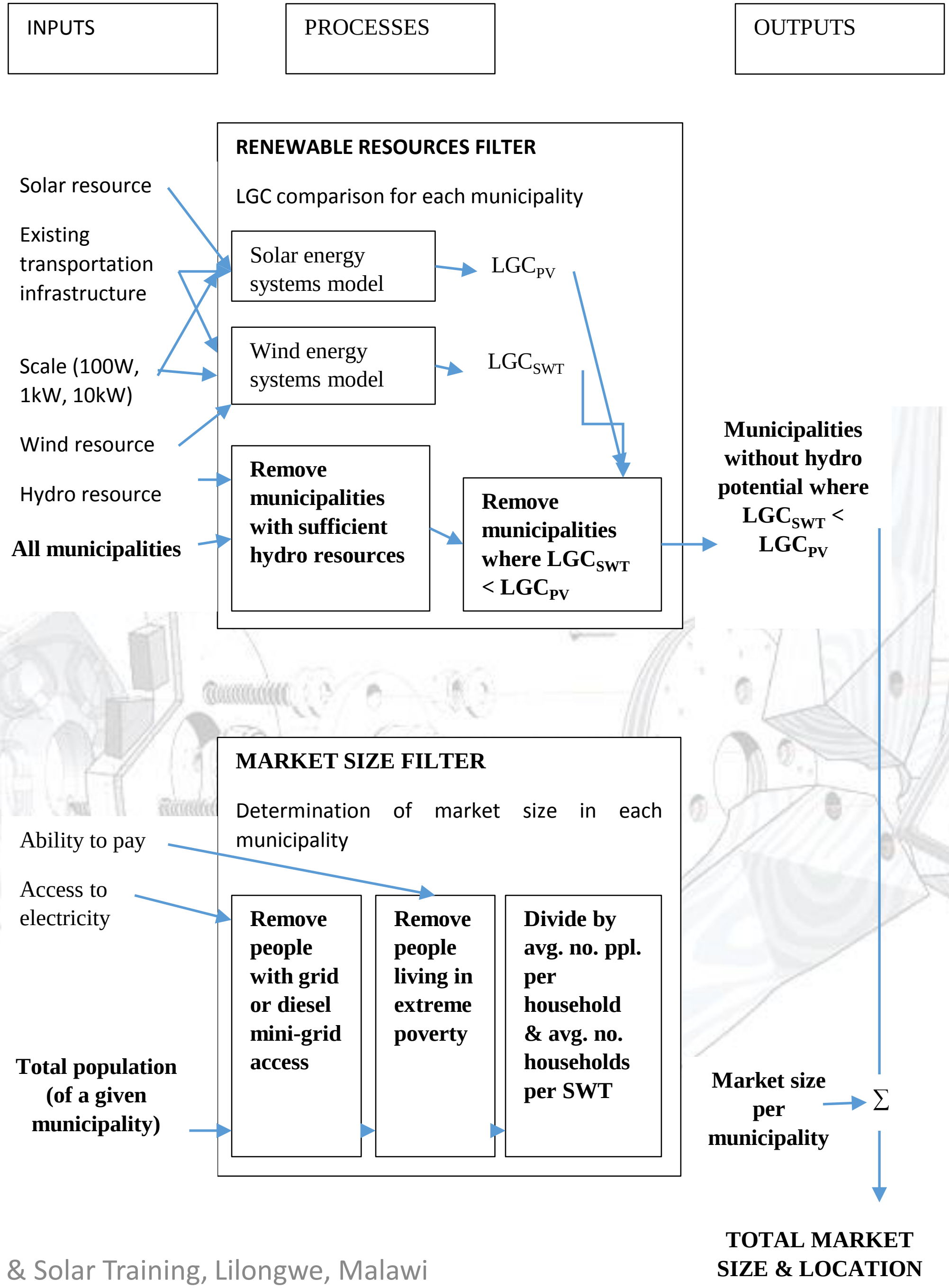
STAGE II Data processing

- Nicaragua

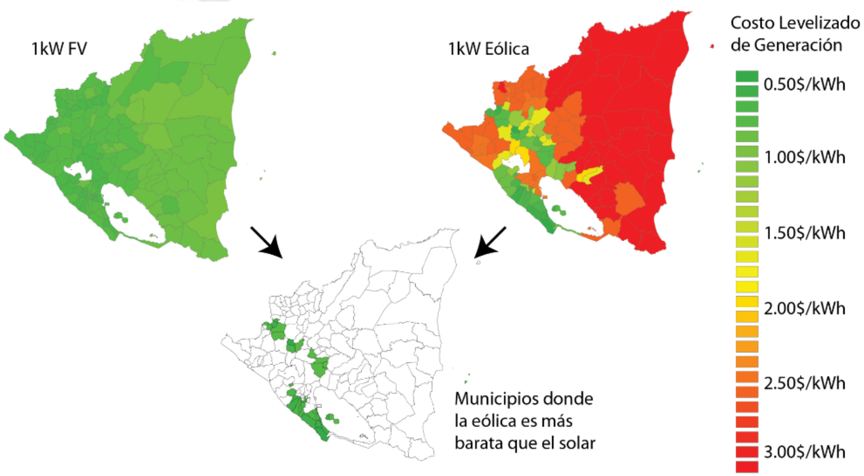
Factor	Data processing techniques	Software	Key output variable
Energy access	Data taken directly from census	• Excel • ArcGIS	% population without access to electricity in each municipality
Scale	Comparable energy systems models constructed for 100W, 1kW & 10kW scales	• Excel • HOMER	LGC for different scales
Place of manufacture	Comparable energy systems models constructed for locally manufactured and imported SWTs	• Excel • HOMER	LGC for locally manufactured & imported SWTs
Existing transportation infrastructure	Categorise each municipality into poor, average or good access based upon population density, then calculate resource assessment, installation & maintenance costs for each category	• Excel • ArcGIS	LGC for different levels of access
Renewable resources	Calculate average resource available in each municipality	• Excel • ArcGIS	Average renewable resource available in each municipality
Ability to pay	Data taken directly from census	• Excel • ArcGIS	% population living in extreme poverty in each municipality
Population size	Data taken directly from census	• Excel • ArcGIS	Population in each municipality

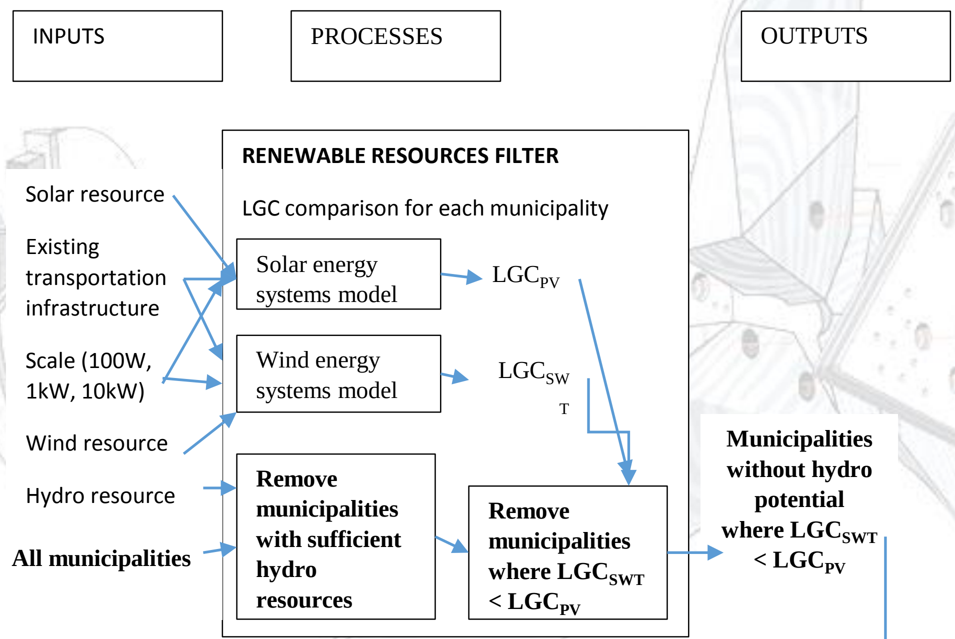
STAGE II Data analysis

- 2 Stage LGC/ GIS Filter

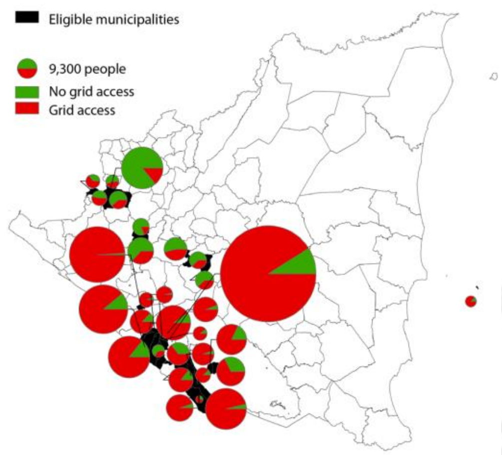


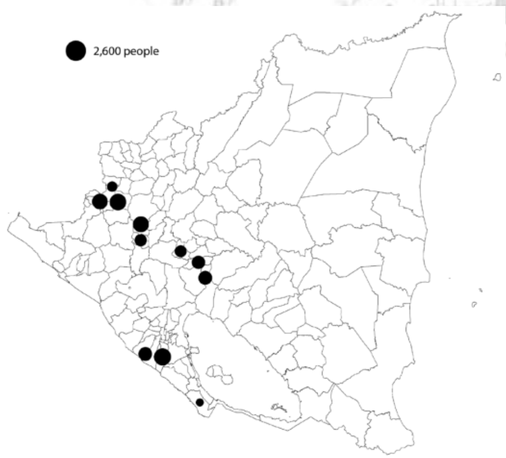
STAGE II
Data analysis





STAGE II
Data analysis





INPUTS

PROCESSES

OUTPUTS

MARKET SIZE FILTER

Determination of market size in each municipality

Ability to pay

Access to electricity

Total population (of a given municipality)

Remove people with grid or diesel mini-grid access

Remove people living in extreme poverty

Divide by avg. no. ppl. per household & avg. no. households per SWT

Market size per municipality → Σ

TOTAL MARKET SIZE & LOCATION

STAGE III

- Mapping the local **energy access ecosystem** and identifying the **key barriers**
  - Nicaragua
    - **Expert interviews**
  - Ethiopia
    - N/a
  - Malawi
    - **Expert interviews**

Results

- Nicaragua
  - **Small market** for SWTs exists, but most viable region already predominantly **grid connected**. **Solar PV scalable** across entire country.
- Ethiopia
  - Market size not quantified, but potential for **wind/solar/diesel hybrids in southeast** of the Somali region. **Solar PV scalable** across entire country.
- Malawi
  - ….

Key messages

- **SWTs more challenging** to implement than PV…
  - …but if well supported, can **create more jobs**, **build more local capacity** & feed more money back into the **local economy than PV**.
- **PV** much more **scalable** (especially in Malawi)
- Market assessment **essential precursor** for **sustainable** implementation of SWTs
- Key factors for decision making:
  - **Wind resource**
    - **Spatial variation**
      - **Critical mass** for service centre
    - **Solar/wind** resource **compatibility**
  - **Value** placed on **local job creation**