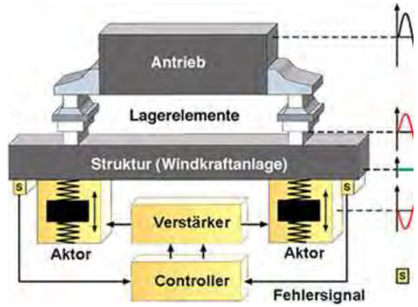
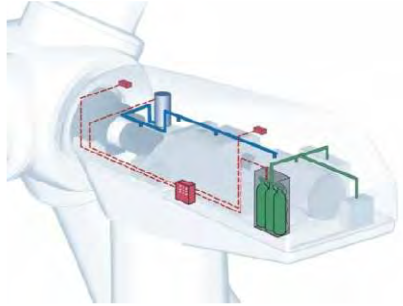




engineering capacity building program

ecbp

Ethiopian Metal Sector development through establishment of a Wind Turbine Industry

Summary Presentation June 2009

The ecbp assignment was to prepare Ethiopian decision makers towards the establishment of an Ethiopian-based wind turbine industry – for promotion of the metal and energy sector

Assignment in October 2008:

- what is the strategic need for having an Ethiopian wind turbine industry?
- what will be the cost of an Ethiopian produced wind turbine?
- what will be the benefits of Ethiopian made wind turbines?
- which wind turbine technology is suitable for Ethiopia?
- where could it be produced in Ethiopia?
- to which markets could wind turbines be exported?
- what is the impact on the Ethiopian industrial structure?
- what is the socio-economic impact of enhanced electrification?
- what are optimal structures for financing wind parks?
- who would be interested to provide finance?
- who would be interested to provide technology?
- what contribution can and should Ethiopian universities make?
- which overall energy technology strategy might Ethiopia adopt?

Source: Dr Peer Ederer

Main outcome: negotiations are initiated to establish an Ethiopian wind turbine industry

Ministry of Mines and Energy: In principle decision to explore Aysha as site for Ethiopian made wind turbines

Ministry of Trade and Industry: In principle decision to privatize Akaki Spare Parts Factory to make it available as facility for manufacturing renewable energy generation equipment

EEPCO: In principle decision to accept up to 300 MW wind generated energy from Ethiopian made wind turbines at Aysha at prices that are comparable to hydro generated electricity

Danotek, Ryle and Enervest: in principle decision to transfer critical technologies to Ethiopia

Source: Dr Peer Ederer

The ecbp intervention has led to a significant paradigm shift

Status October 08:

- 0% local value added
- 3 m$ per 1 MW rated power
- wind power considered a luxury to be funded externally, donor driven

ecbp inter-vention

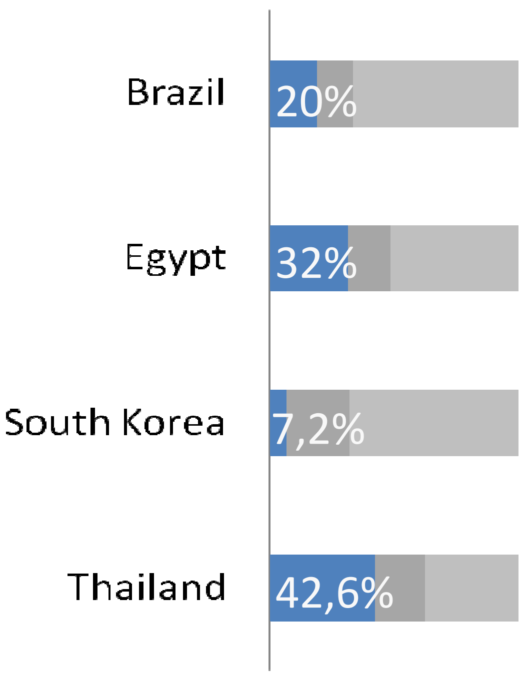
Status May 09:

- 60% local value added
- 1.6 m$ per 1 MW rated power
- wind power considered a strategic opportunity for an export-led energy sector

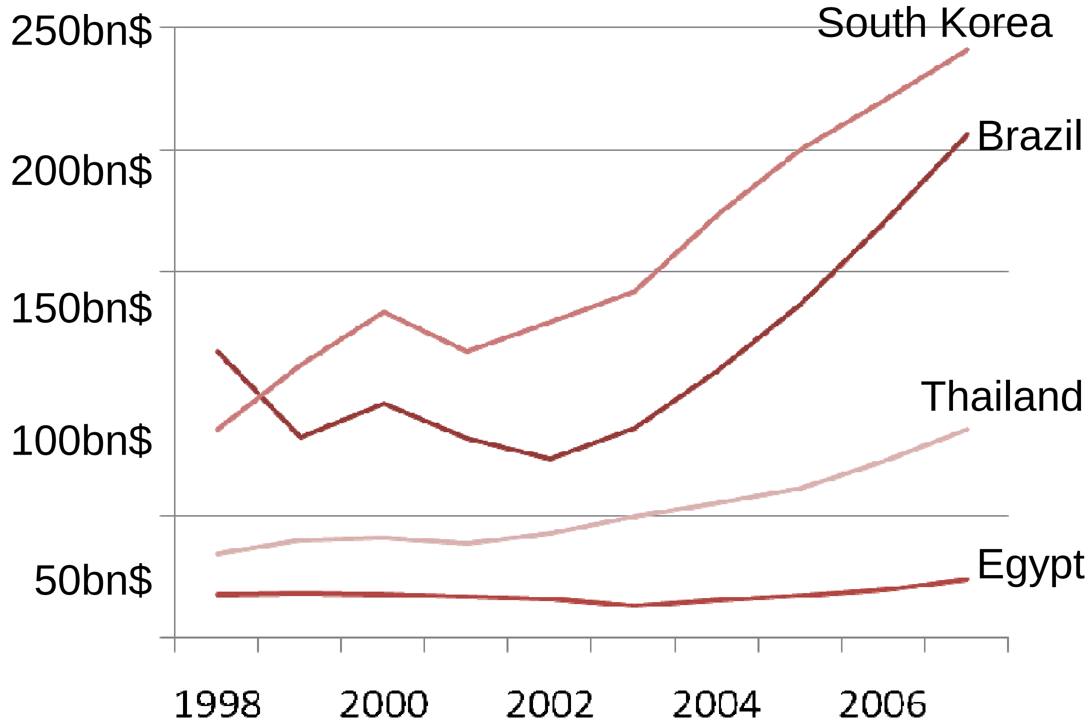
Source: Dr Peer Ederer

Brazil, Egypt, Korea and Thailand are benchmarks for Ethiopia

Share of labor force
in agricultural sector (2007)



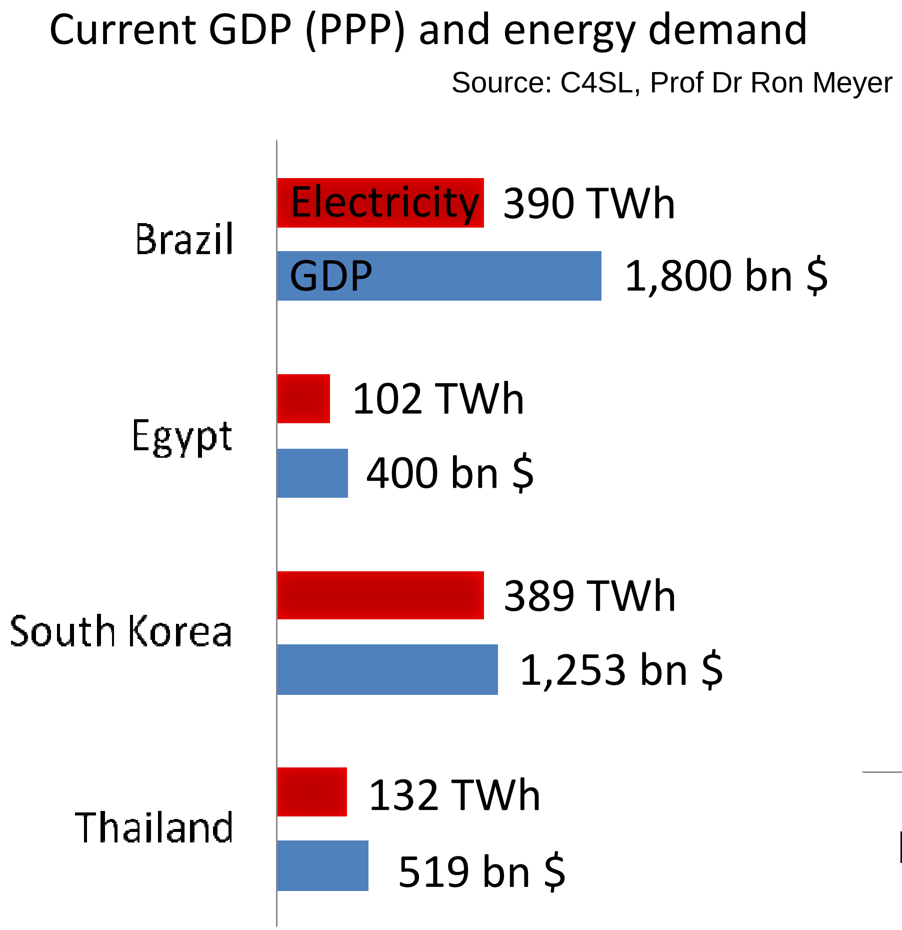
Industrial production value-added
(1998-2007)

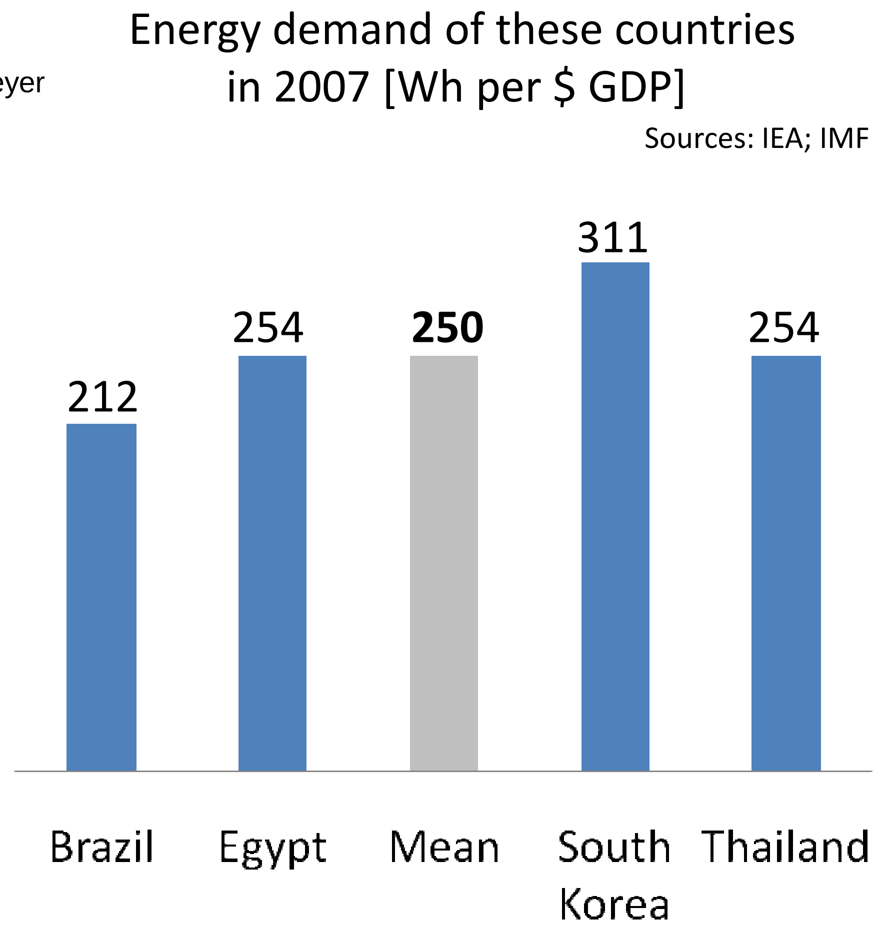


Sources: CIA; Undata

Source: C4SL, Prof Dr Ron Meyer

Every $ GDP requires 250 Wh electricity supply



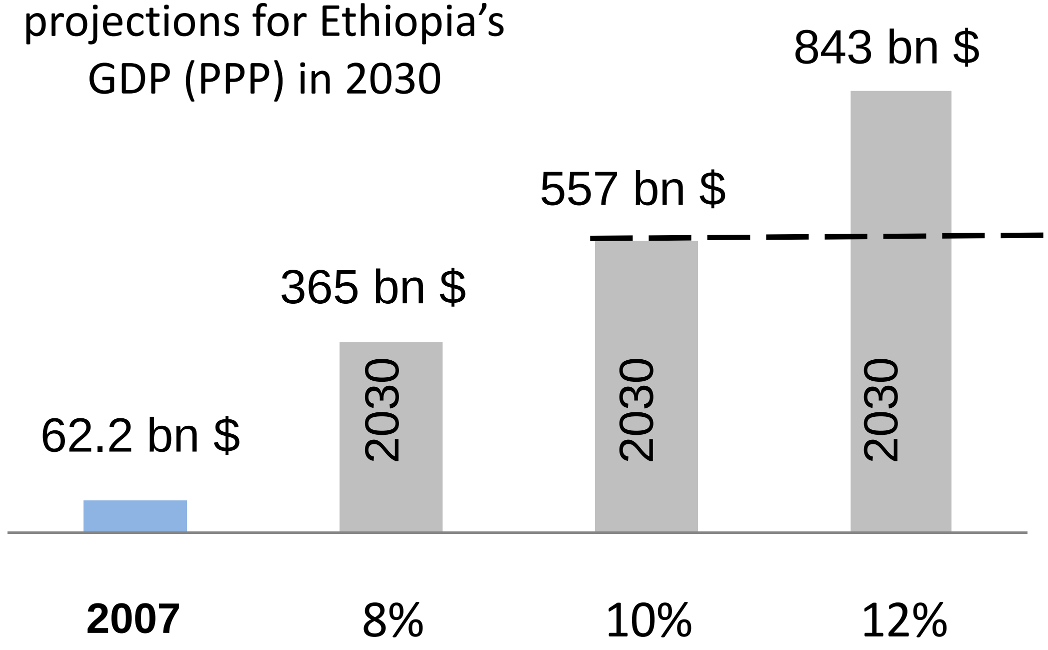


The current energy demands of Brazil, Egypt, South Korea and Thailand can serve as benchmarks for 2030 energy demands of Ethiopia's potential export countries.

ecbp engineering capacity building program

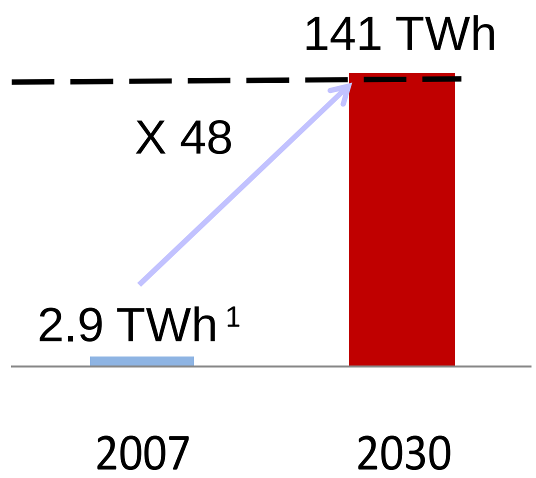
Ethiopia: 48-fold electricity supply increase needed to ensure growth

Economic growth projections for Ethiopia's GDP (PPP) in 2030



(Based on annual growth rates 2002 – 2007)

Energy needed to ensure growth projection (Assumption 250 Wh / $ GDP)



Projection: 10% growth

EEPCO demand forecast (2003): 8 TWh/year in 2025; See under additional information

Source: C4SL, Prof Dr Ron Meyer

[1] EEPCO (2008): 3.3 TWh

Sources: IEA; IMF; UNdata; UNDP

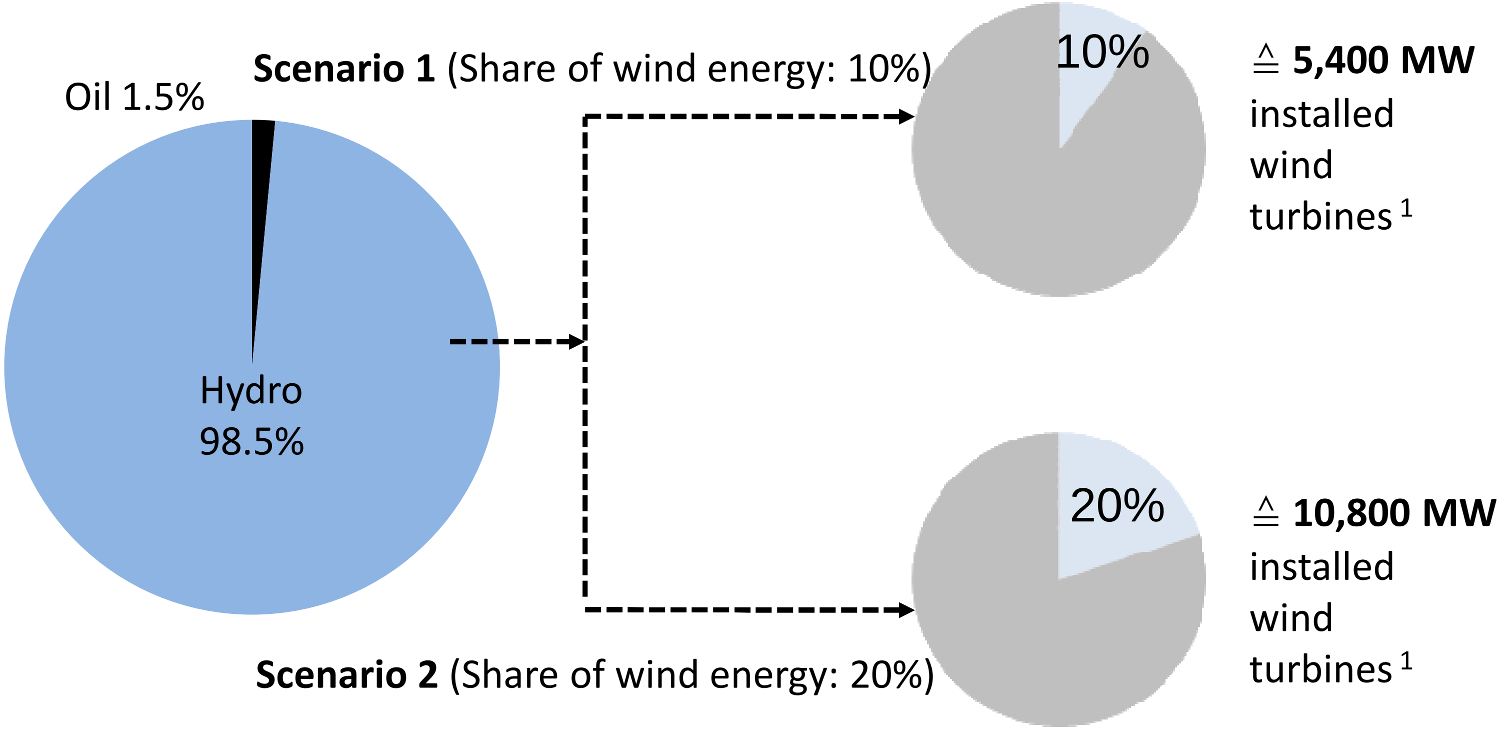
Ethiopia: Possible output of wind turbines is 5,400 MW to 10,800 MW until 2030

Actual electricity production in Ethiopia: 2.9 TWh

Prospective electricity production in Ethiopia in 2030: 141 TWh

2007

2030



Source: C4SL, Prof Dr Ron Meyer

[1] (Assumption: Capacity Factor = 30%)

Sources: IEA

For each of the 8 investigated countries a substantial wind energy demand could be identified

Kenya will increase its electriciy need 15-fold to 79 TWh until 2030 at an annual growth rate of 7,5%. At 10% share of wind energy of the total energy production and at 30% capacity factor the country will have a need for **3000 MW** installed capacity of wind turbines.

Ghana will increase its electricity need 8-fold to 55 TWh until 2030 at an annual growth rate of 8,8%. At 10% share of wind energy of the total energy production and at 30% capacity factor the country will have a need of **2100 MW** installed capacity of wind turbines.

Tanzania will increase its electricity need 45-fold to 102 TWh until 2030 at an annual growth rate of 9,6%. At 10% share of wind energy of the total energy production and at 30% capacity factor the country will have a need of **3900 MW** installed capacity of wind turbines.

Mozambique will increase its electricity need 4-fold to 37 TWh until 2030 at an annual growth rate of 9,7%. However, these numbers for Mozambique are misleading, because most of its current electricity generation is from the Cabora Bassa hydro station, whose electricity output is contractually sold to South Africa. Nonetheless, at 10% share of wind energy of the total energy production and at 30% capacity factor the country will have a need of **1400 MW** installed capacity of wind turbines.

Madagascar will increase its electricity need 37-fold to 33 TWh until 2030 at an annual growth rate of 9%. At 10% share of wind energy of the total energy production and at 30% capacity factor the country will have a need of **1300 MW** installed capacity of wind turbines.

Yemen will increase its electricity need 10-fold to 42 TWh until 2030 at an annual growth rate of 5%. At 10% share of wind energy of the total energy production and at 30% capacity factor the country will have a need of **1600 MW** installed capacity.

Pakistan will increase its electricity need 6,6-fold to 493 TWh until 2030 at an annual growth rate of 7%. At 10% share of wind energy of the total energy production and at 30% capacity factor the country will have a need of **19000 MW** installed capacity.

Afghanistan will increase its electricity need 46-fold to 37 TWh until 2030 at an annual growth rate of 9%. At 10% share of wind energy of the total energy production and at 30% capacity factor the country will have a need of **1400 MW** installed capacity.

Source: C4SL, Prof Dr Ron Meyer

What is the cost of an Ethiopian turbine?

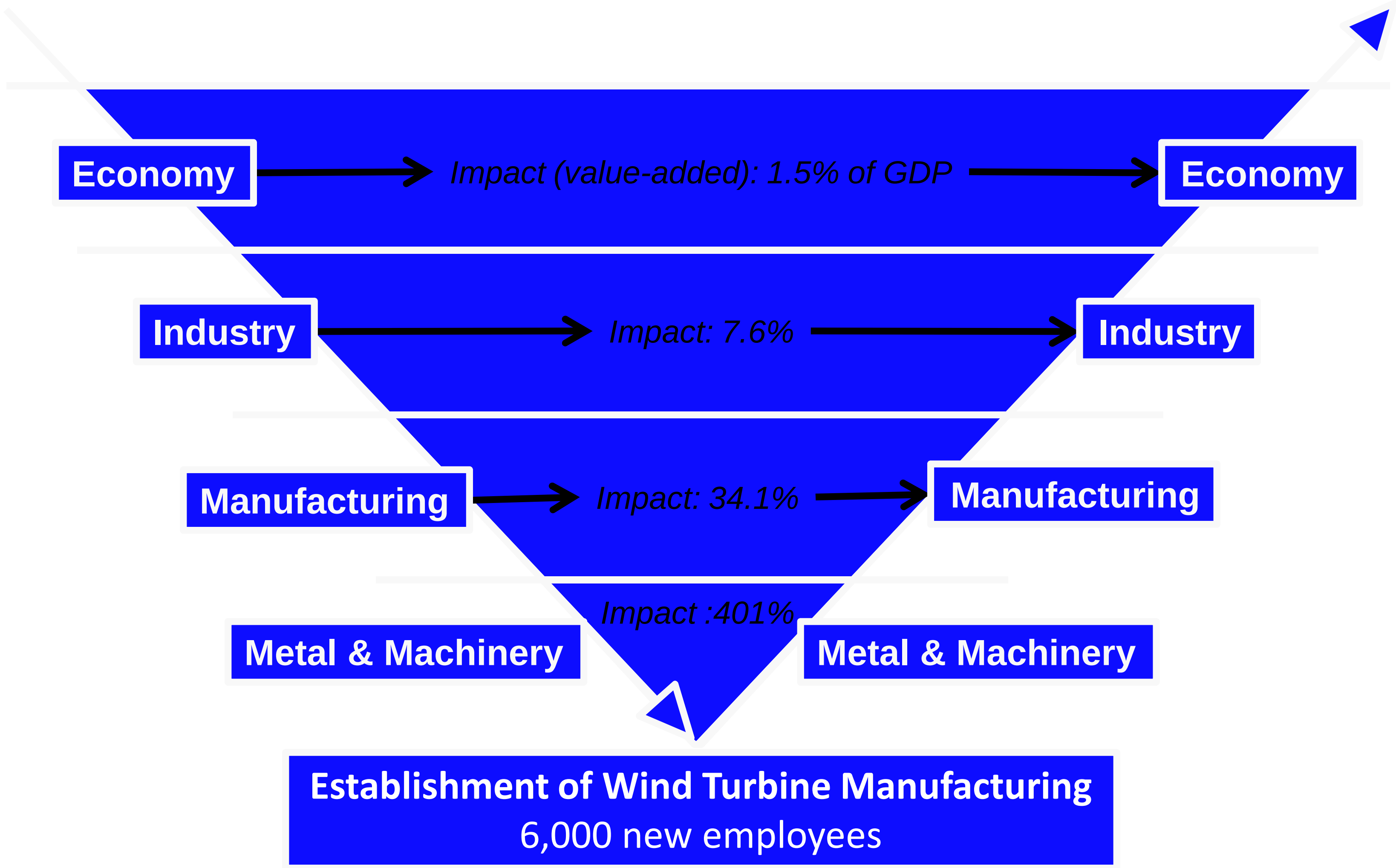
The cost of an Ethiopian turbine will be ~1,3 mio / MW (plus installation and power plant costs for final costs)

Results of financial business planning scenarios

Scenario 1 - Base				
size of turbines	1000	kW	Gross value of production 2017:	259,800
production volume	200	MW pa	Import value of production 2017:	115,140
technology transfer	in 5 years	completed	Local value added of production 2017:	144,660
			Export value of production 2017:	129,900
			Balance of payments of production 2017:	14,760
			Cost of naked wind turbine	**1,299,000**
Scenario 2 - Smaller turbines				
size of turbines	800	kW	Gross value of production 2017:	244,275
production volume	200	MW pa	Import value of production 2017:	107,750
technology transfer	in 5 years	completed	Local value added of production 2017:	136,525
			Export value of production 2017:	122,138
			Balance of payments of production 2017:	14,388
			Cost of naked wind turbine	**1,221,375**
Scenario 3 - Larger turbines				
size of turbines	1500	kW	Gross value of production 2017:	303,200
production volume	200	MW pa	Import value of production 2017:	132,027
technology transfer	in 5 years	completed	Local value added of production 2017:	171,173
			Export value of production 2017:	151,600
			Balance of payments of production 2017:	19,573
			Cost of naked wind turbine	**1,516,000**

Source: Dr Philipp Schuller

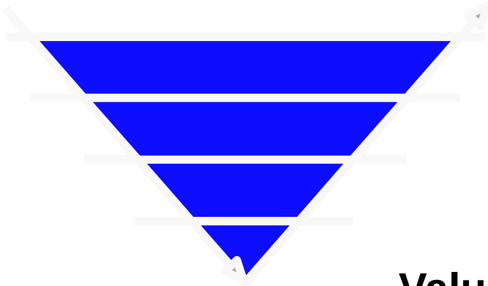
What is the industrial impact?



Source: University of Manchester, Dr Raimondo Guerra

Expected output of establishing a wind turbine manufacturing in Ethiopia

Establishment of Wind Turbine Manufacturing



Employment:
Creation of 6,000 new jobs

Explanation of the assumptions:

1. 200 MW of turbines produced per year in 2014
2. In Germany and US, one MW of wind turbine production typically generates 10 jobs
3. Manufacturing depth in Ethiopia will be 75% of the level of the German wind turbine industry
4. Productivity of Ethiopian work force is 25% of the German work force
5. 200 MW * 10 workers / 25% Ethiopian productivity * 75% manufacturing depth => 6.000 jobs in the metals and machinery sector
6. These assumptions are independently verified by a per components manufacturing analysis of expected Ethiopian productivity for wind turbine manufacturing

Value Added:
Additional $108M per year

Explanation of the assumptions:

1. 200 MW of turbines produced per year in 2014
2. Production cost of turbines to be USD 1.3 Mio
3. 55% local value added in Ethiopia on the turbines
4. 75% of the local value added in the metals and machinery sector

=> USD 108 Million

Source: University of Manchester, Dr Raimondo Guerra

Case studies illustrate how electrification yields substantial socioeconomic benefits to the Ethiopian society 1/2

Social Benefits

- Improved education is realized through the increased study time and evening classes for adults that electric lighting allows as well as TV and radio use.
- On average electric lighting adds an extra 77 minutes/day for pupils and 27 minutes/day for adults. This increases the annual study time of pupils by more than 400 hours/year.
- The increased study time also results in a higher number of school leaver qualifications. In Bonga, Ethiopia the rate of qualifications attained went from 10% in 1986 to 80% in 1990 after electrification.
- Increased TV and radio use particularly by women has increased the awareness of healthcare issues, especially the knowledge about methods of contraception. This has led to a statistically significant decrease in the fertility rates.
- Besides the improved healthcare knowledge of women improved healthcare comes in the form of longer opening hours of local clinics, better treatments due to the use of electrical equipment and clean water and the refrigeration of vaccines and other medical supplies.
- Electric lighting means that on average Kenyan local health clinics are now providing services for 15 rather than 11 hour each day and in Ribaue District it even allows a 24 hr emergency attendance increasing the number of treated patients per day.
- The use of electrical equipment and safe drinking water has also leads to improvement of the quality of care provided.
- The cool storage of vaccines and other medical supply make it possible to use them over much longer periods of time and make their application safer.

Source: University of Manchester, Dr Raimondo Guerra

Socioeconomic benefits continued 2/2

Economic Benefits

Case study Bebeka-Kite in Ethiopia

- The overall amount of hectarage of the local coffee plantation has increased from 10 ha in 1980 to more than 6.700 ha in 1990 after electrificiation
- The use of electrical equipment for the washing and dehusking of first class Arabica coffee has caused an increase in productivity of 35 -40%.
- Over the 10 year period from 1980 to 1990 the coffee plantation has generated total net benefits of 4.35 times the total costs for both the equipment and the electricity consumption.
- Based on relatively expensive diesel-generated electricity prices of US$ 0.2 per kWh the total net benefits of using relatively cheaper grid-electricity should have been even greater.

Case study Ribáuè District in Madagaskar

- The extension of the national grid from the provincial capital Nampula had initial investment costs of US$ 4.0 million or US$ 2.100 for each of the existing 1.900 customers in 2005.
- The main economic player is the cotton factory which increased its productive efficiency by 30% between 2000 and 2005. In addition the local maize mills provided a more reliable service and local shops, bars and restaurants opened.
- While the project has created positive benefits from year one and generated net benefits of US$ of 1.698 million over the 5 year period these have only become cash-flow positive in 2004.
- The cotton factory has contributed 39% of total net benefits in the form of commercial energy savings and another 24.4% through productivity gains in the cotton processing while the local shops, bars and restaurants have contributed 8% of total net benefits.
- While the forecast ranges between US$ 20 million to 40 million total net benefits at a discount rate of 5%, the project would still produce US$ 4million to 6 million total net benefits in 2020 at a discount rate of 20%.
- Over this period education evolves as a major contributor to total net benefits.

Source: University of Manchester, Dr Raimondo Guerra

engineering capacity building program

What is the most suitable technology for Ethiopia?

Smaller scale, western technologies are most suitable for an Ethiopian production of wind turbines

Criteria	Vestas V 52 850 kw	Gamesa G 58 850 kw	Fuhrländer 1250 kw	Mitsubishi MWT 1000 kw	DeWind D4 600 kw	SEC SeWind D6 1250 kw	Goldwind S43 600 kw	China Windey 750 kw	Sinovel 600 kw	Suzlon S 52 600 kw	Suzlon S64 1250 kw	Innovative Power-1250 kw	Conergy PW56 900 kw
(1): Track Record; # of sold turbines	5	5	4	5	4	3	5	4	4	5	5	2	2
(2): Track record: # of licensed sold	5	3	5	2	4	1	2	1	1	2	2	1	1
(3): Complexity of design and difficulty for production	3	3	3	2	4	3	5	5	3	5	3	3	3
(4): Reach of the supply chain of components	4	4	4	2	4	4	5	5	4	5	5	3	3
(5): Willingness and experience to work in least developed countries	3	3	4	2	4	2	2	1	2	4	4	4	4
(6): Infrastructure requirements in terms of weight of turbine	4	4	3	3	5	3	3	3	3	5	4	4	4
Score of wind turbine desig	**3.9**	**3.5**	**3.9**	**2.5**	**4.2**	**2.5**	**3.3**	**2.7**	**2.6**	**4.2**	**3.7**	**3.0**	**3.0**

Source: Renewco GmbH, Jörg Kubitza

After a shortlisting process, three companies were assessed to be a potential contributor to manufacturing wind turbines

- Mesfin Engineering (Mesfin) – mostly a fabricator, has the potential to engineer, fabricate, ship to site and install foundations, and towers. Outside the scope of this note, but through its corporate ownership, Mesfin management expressed it might be able to provide finance and invest in additional manufacturing skills like a foundry or a machining center. Having Mesfin undertake the work package for foundations and towers would be technically medium to low risk. There is sufficient factory space on the premises in the city of Mekele to also undertake assembly (although the hub would have to be done elsewhere in a precision environment) .
- Akaki Spare Parts Factory (Akaki) - a vertically integrated metal processing job shop, could undertake casting of the hub (technically medium to high risk), small part machining (low risk), nacelle assembly (low risk) and hub machining and assembly (medium to high risk). The site has considerable potential but will require significant investment (of expertise, culture change and money) to enable it to realize this potential .
- Maru Manufacturing (Maru) - a fabricator and assembler, is an impressive small private business, where a shrewd investment in machinery for automation (very bold step in an environment where labour is low cost), demonstrates a clear recognition of the benefits of automation above that of pure cost reduction. Could produce foundations and tower components, and could assemble nacelles. The management of the business itself is a valuable aspect to the business.

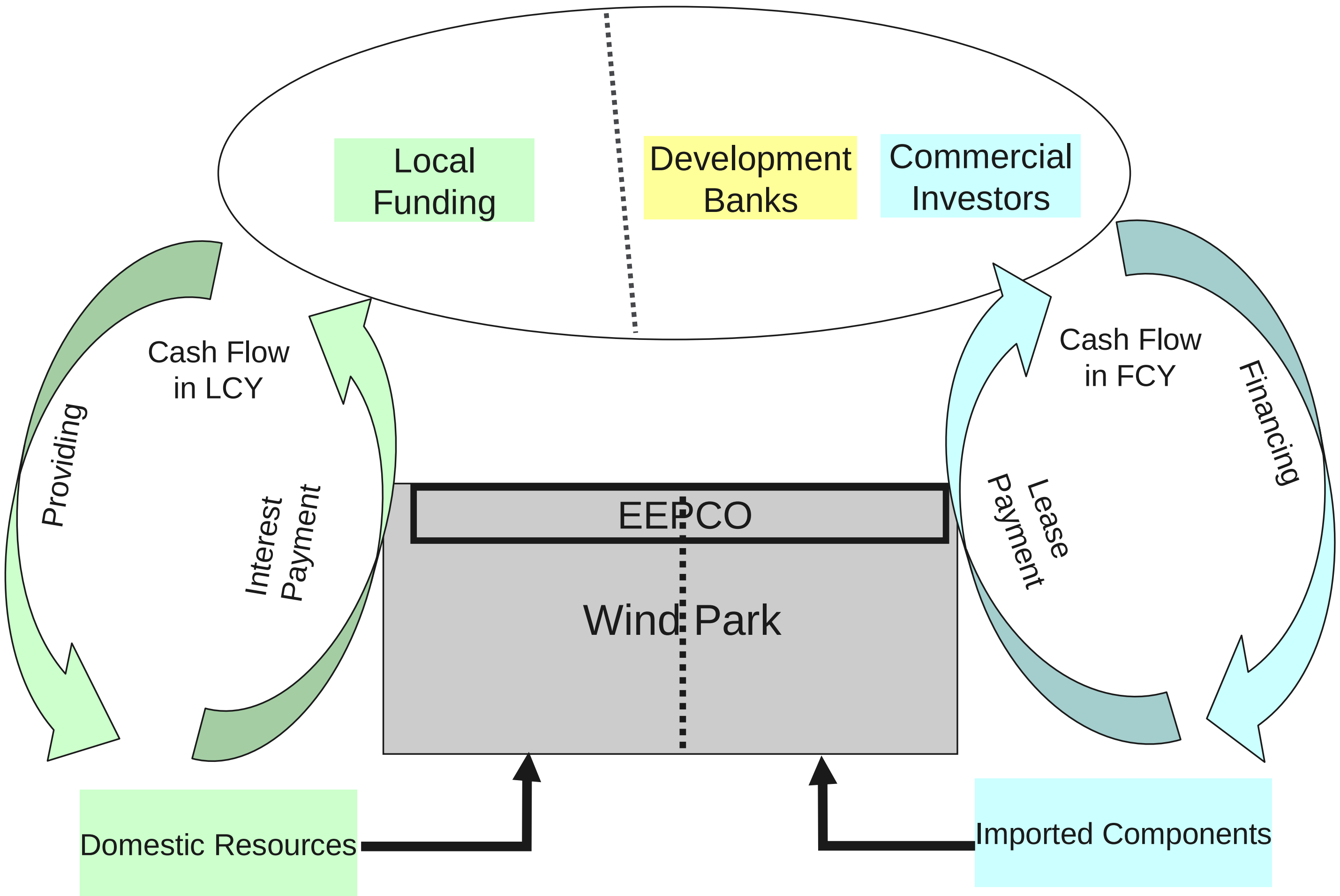
Source: Renewco GmbH, Dr Andrew Sharratt

ecbp engineering capacity building program

View of ASPF Manufacturing building today

View of a wind turbine assembly operation which was designed and built by the manufacturing engineer who evaluated ASPF

As a financing vehicle a ppp-structured fund is recommended



Source: Frankfurt School of Finance and Management, Prof Dr Sebastian Fritz

Next steps ecbp: facilitate university support and deepen the Ethiopian supply chain structure in the metal sector

Status October 08:
- 0% local value added
- 3 m$ per 1 MW rated power
- wind power considered a luxury to be funded externally, donor driven

ecbp inter-vention

Status May 09:
- 60% local value added
- 1.6 m$ per 1 MW rated power
- wind power considered a strategic opportunity for an export-led energy sector

Further ecbp support:
- to entice/support universities to build a research and training agenda with muscle
- to capacitate suppliers so that a renewables cluster can develop and entrench

Source: Dr. Peer Ederer; Stephan Willms

How can universities support the process?

An Ethiopian Renewable Energy Institute (EREI) would bundle research, focus attention and leverage knowledge

- University staff
- PhD students
- Students and Ethiopian population
- Foreign experts, institutes and universities
- Private sector

EREI

- Publications + studies
- Professional training
- Community involvement
- Global exchange of ideas
- Research with private sector
- Promotion of Ethiopian energy development

Source: Stephan Willms

How can universities support the process?

Examples for global institutes

Jülich Research Centre
Fuel cells; plasma physics; material science; photovoltaics; safety research; technology Evaluation; offshore wind (…)

PhD courses in a multitude of topics

Helmholtz Association
To solve the grand challenges that face society in energy and other areas

Wind, solar, geothermics, biomass

Institute for wind energy and energy System technology (IWES)
Fraunhofer: expand Germany's leadership in wind energy;Energy system technology

ForWind
Wind research; scientific cooperation in industry oriented projects; further education

Measurement, modelling, aerodynamics, Loads, fatigue assessment

Research Group Wind Energy
Initiate innovative research; networks for education; financing support

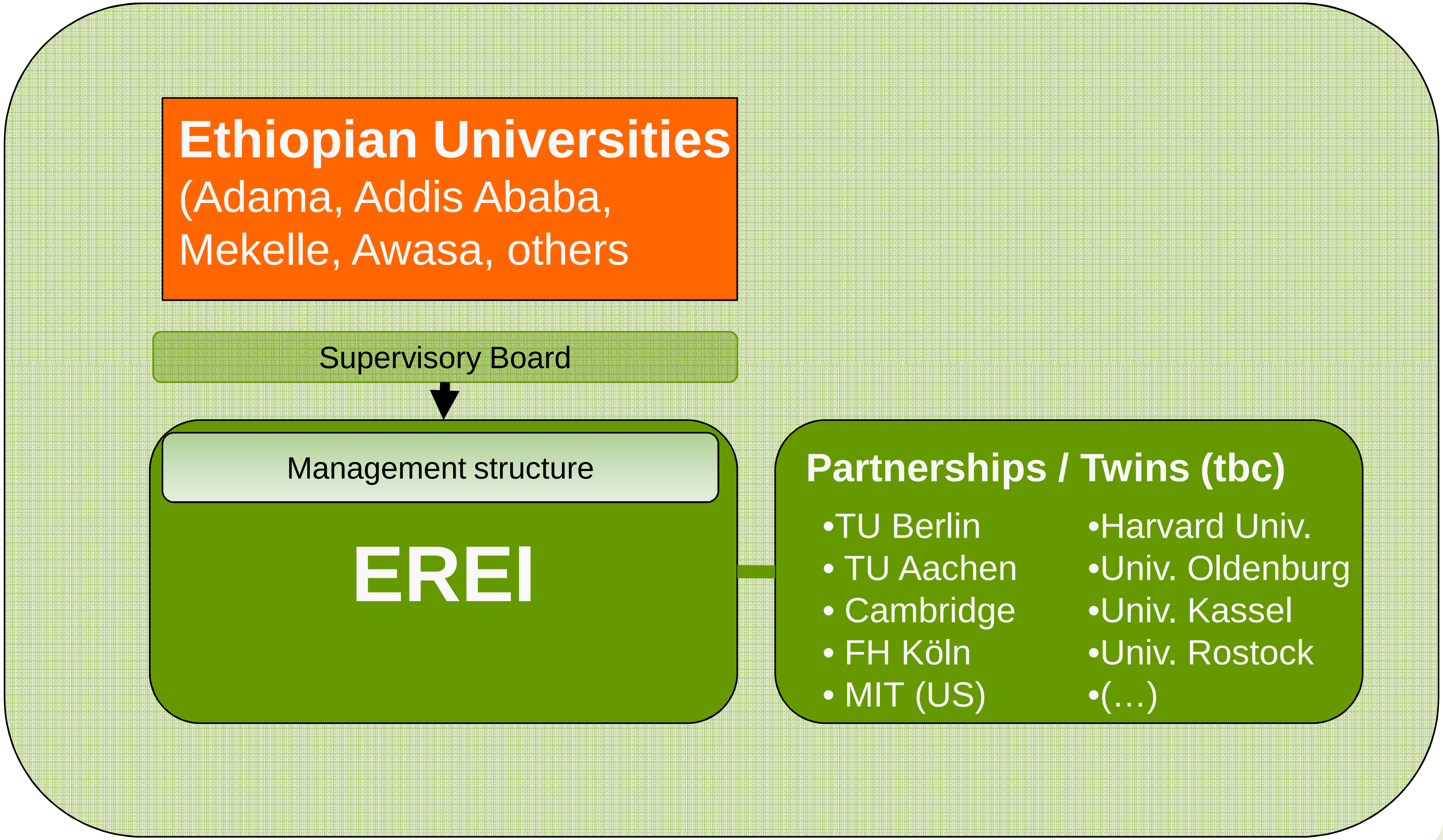
Aerodynamic rotor; permanent magnet Generator; gearless transmission

Risoe Institut
Result oriented research focussed on Danish Society; large projects, training, business orientation
12MW turbines, blade manufacturing, Vanadium batteries, materials, (…)

Source: Stephan Willms

Exemplary structure of an Ethiopian REI

Ethiopia would need to develop its own solution



Source: Stephan Willms

Possible scenarios for EREI

Scenario 1: Connecting existing activities

Within a build up phase of 3 years Ethiopian universities have joined forces and put together their existing activities into an EREI. Twinning arrangements with partner universities have been established. Even though activities are still happening at their original universities, the EREI managed to make Professors join forces e.g. when it comes to obtaining funds. Through communication campaigns on renewable energy the EREI has become well known in Ethiopia and in neighboring countries. It focuses mainly on teaching.
Budget: 80.000€ annually

Scenario 2: Real research but small

Just as in Scenario one but with a stronger focus on proprietary research and a more international exposure. Twin partnerships with European institutes and universities have been set up and several project groups are working on the development of new and better energy applications for the Ethiopian and African context. Several PhDs can travel to foreign countries on a regular basis. Likewise there are 2-3 foreign PhDs working in Ethiopia. **Budget: 155.000€ annually**

Scenario 3: Creating an internationally renowned institute

After a build up phase of 5-7 years the EREI is the best reputed institute in Africa with strong links to twin partner institutions in Europe, US and Asia. It has a regular exchange of 10 PhD students with foreign students working in the institute on one year contracts. The EREI manages to attract top researchers and teachers to come to Ethiopia for seminars, summer schools and for medium to long term research. The institute has along the lines of different renewable energies: hydro, wind, geothermal, bagasse and solar and works in a matrix organization with faculties of several local universities.
Budget: 525.000€ annually

Within 3-5 years EREI could have itself established

Founding Phase
- Acquisition of twinning partners
- Planning and structuring
- 1st call for papers
- 1st Summer Academy

ecbp support:
- Start up funding
- Twinning support
- Changing curricula

ecbp support:
- Assistance in communication
- Access to schools

ecbp support:
- To be defined

Build up phase
- Deep development of research themes
- Staff development
- Ountry-wide communication
- Participation in international conferences

Sustainability phase
- First successes in publications
- Sufficient external funding gathered
- First doctoral theses finished
- Twin partners intensify cooperation

Source: Dr. Peer Ederer; Stephan Willms

ecbp engineering capacity building program

Potential role of ecbp

	Component I (University)	Component II (TVET)	Component III (Qual.Infra.)	Component IV (Private Sector)
Macro			Institute for national technical certification?	Feed-in Tariffs
Meso	EREI Curriculum Adaptation Management Training	TVET to include skill sets for a RE industry	Introduction of global standards	
Micro			Certify the industry companies	BPR in metal companies 5xCIM experts for Akaki transformation

Source: Dr. Peer Ederer; Stephan Willms

Ecbp can play a major role in further assisting the process of establishing a renewables industry in the country

1. Development of the EREI in cooperation with Adama and Mekelle Universities

- Financial and technical assistance of the EREI
- Development of internship opportunities for EREI students
- Further curricula development at universities to include the area of renewable energy
- Development of university twinning partners globally

2. Support of the upcoming renewable energy industry in the transformation process:

- Technical support through 5 experts in the areas of foundry, welding, forging, manufacturing and supply chain management
- Support in management skill upgrading,
- Support in certification procedures

3. Establishment of an Ethiopian manufacturing incubation centre (EIC)

- CIM expert as Manager of the centre
- Support of micro companies to access finance + technical capacity development (CEE?)

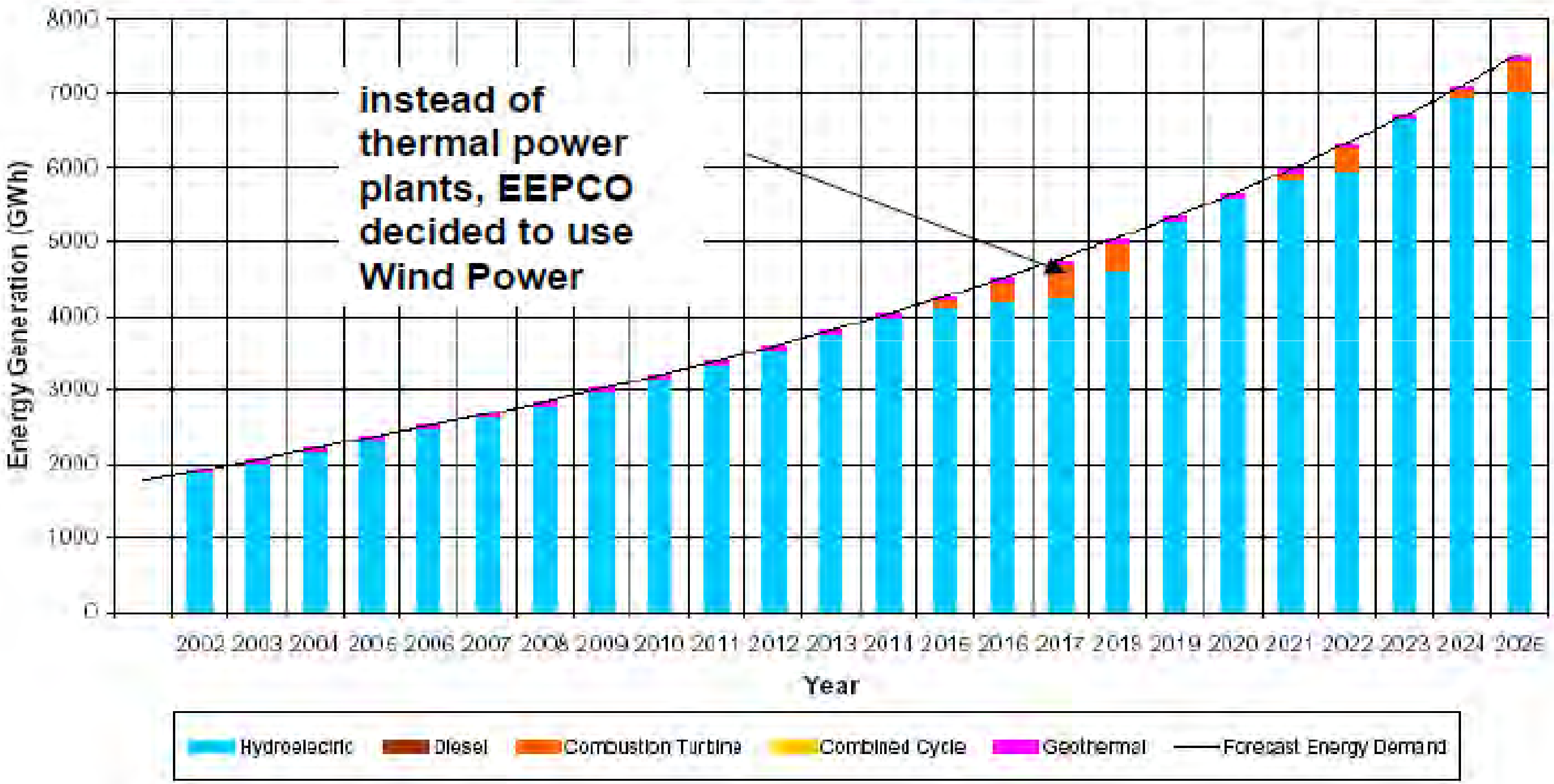
4. Financial support for further studies potentially needed in the future

Source: Stephan Willms

Thank You

Additional Information

Wind Power fills Gap



Source: EEPCO/ACRES 2003, Figure 10.7

Technical University of Denmark – MSc in Wind Energy – I/II

General Competence Courses
Design of Wind Turbine
Wind Turbine Measurement Technique
Wind Turbine Technology and Aerodynamics (mandatory)
Technology, Economics, Management and Organization (TEMO)
Planning and development of wind farms

Technological Specialization Courses
High Power Electronics
Power System Networks
Stability and Control in Electric Power Systems
Connection of Wind Turbines to the Grid
Electric Machines in Wind Turbine Systems
Computational Electric Energy Systems

Mechanical Engineering
Projects in Wind Turbine Aeroelasticity
Computational Fluid Dynamics
FEM Heavy
Experimental Methods in Fluid Mechanics
Wind Resources and Loads on Wind Turbines

Elective courses:
Turbulence Theory
Wind Resources and Loads on Wind Turbines
Theoretical Ship Hydrodynamics
Computational Fluid Dynamics
Projects in Wind Turbine Aeroelasticity
Wind Turbine Ice Prevention Systems Selection and Design
Experimental Fluid Dynamics and Data Interpretation
Advanced Fluid Mechanics
Experimental Methods in Fluid Mechanics

Structural Mechanics:
Risk and Decision Analysis
Dynamics of Structures: Theory and Analysis
Plate and Shell Structures
Strength of Materials
Composite Lightweight Structures
Non-Linear Modelling and Analysis of Structures and Solids
Experimental Mechanics
FEM-Light
CAD/CAM

Wind Turbine Construction and Materials:
Advanced Acoustics
Sound and Vibration
Machine Elements
Dynamics of Machinery
Plasticity and Fracture Mechanics
FEM-Heavy
Advanced Vibration and Stability Analysis
Tribology of Machine Elements
Applied Mechatronics

Source: Stephan Willms

engineering capacity building program

Technical University of Denmark – MSc in Wind Energy – II/II

Offshore Technology and Foundation:
Advanced Soil Mechanics
Numerical Modelling in Geotechnical Engineering
Hydrodynamics II
Marine Structures
Computational Coastal Hydrodynamics
Linear and Nonlinear Wave Dynamics

Electrical Design, Grid Connection and Power System Integration
Power Electronics 1
High Power Electronics
Electric Power Engineering, Fundamentals
Power System Networks
Stability and Control in Electric Power Systems
High Voltage Engineering
Power apparatus design and diagnosis
Power engineering project
Connection of Wind Turbines to the Grid
Electric Machines in wind turbine systems
Basic Electric Circuit Theory

Control and Regulation:
Stochastic Adaptive Control
Linear Control Design 2
Robust and Fault-tolerant Control
Computer Control Systems
Fuzzy, Neural, and Adaptive Control
Intelligent Systems
Fluid power – Hydraulic and Water Hydraulic Control
Design of Motion Control Systems

Wind Energy Prognosis and Optimization:
Time Series Analysis
Advanced Time Series Analysis
Static and Dynamic Optimization

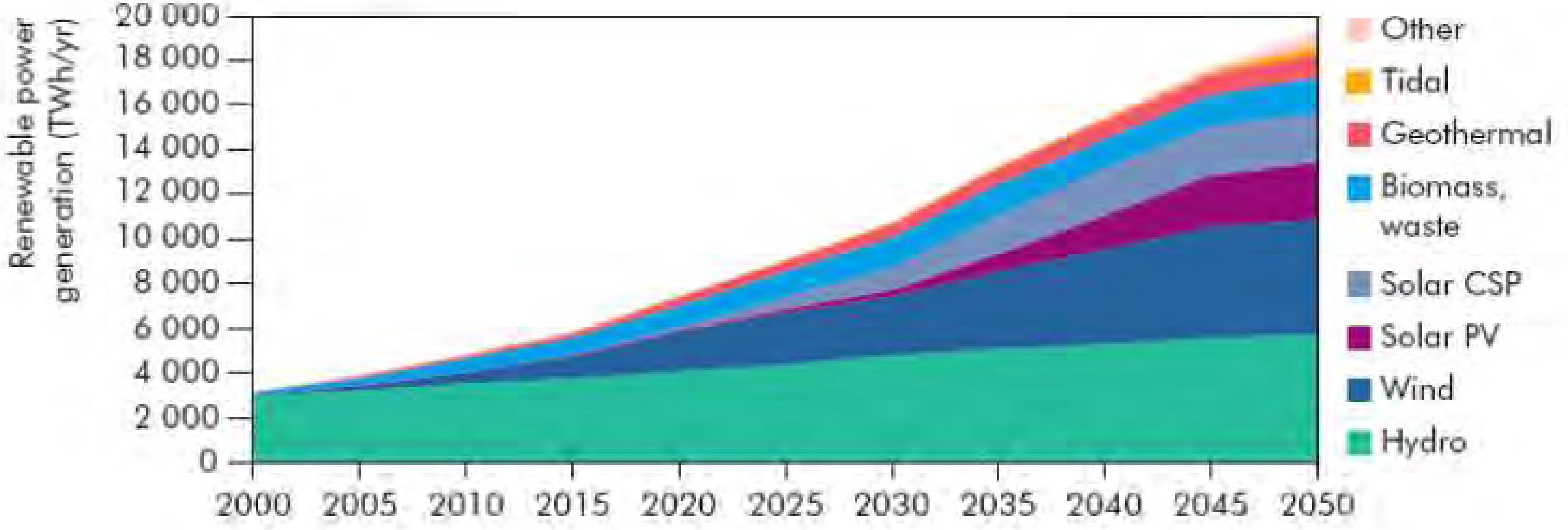
Source: Stephan Willms

View on Akaki from space

Source: Google maps

According to the International Energy Agency and the OECD, wind energy will be the second largest growth sector in renewable power generation

Figure 2.18 ▶ Growth of renewable power generation in the BLUE Map scenario, 2000-2050



Source: Energy Technology Perspectives 2008, IEA and OECD

Aysha