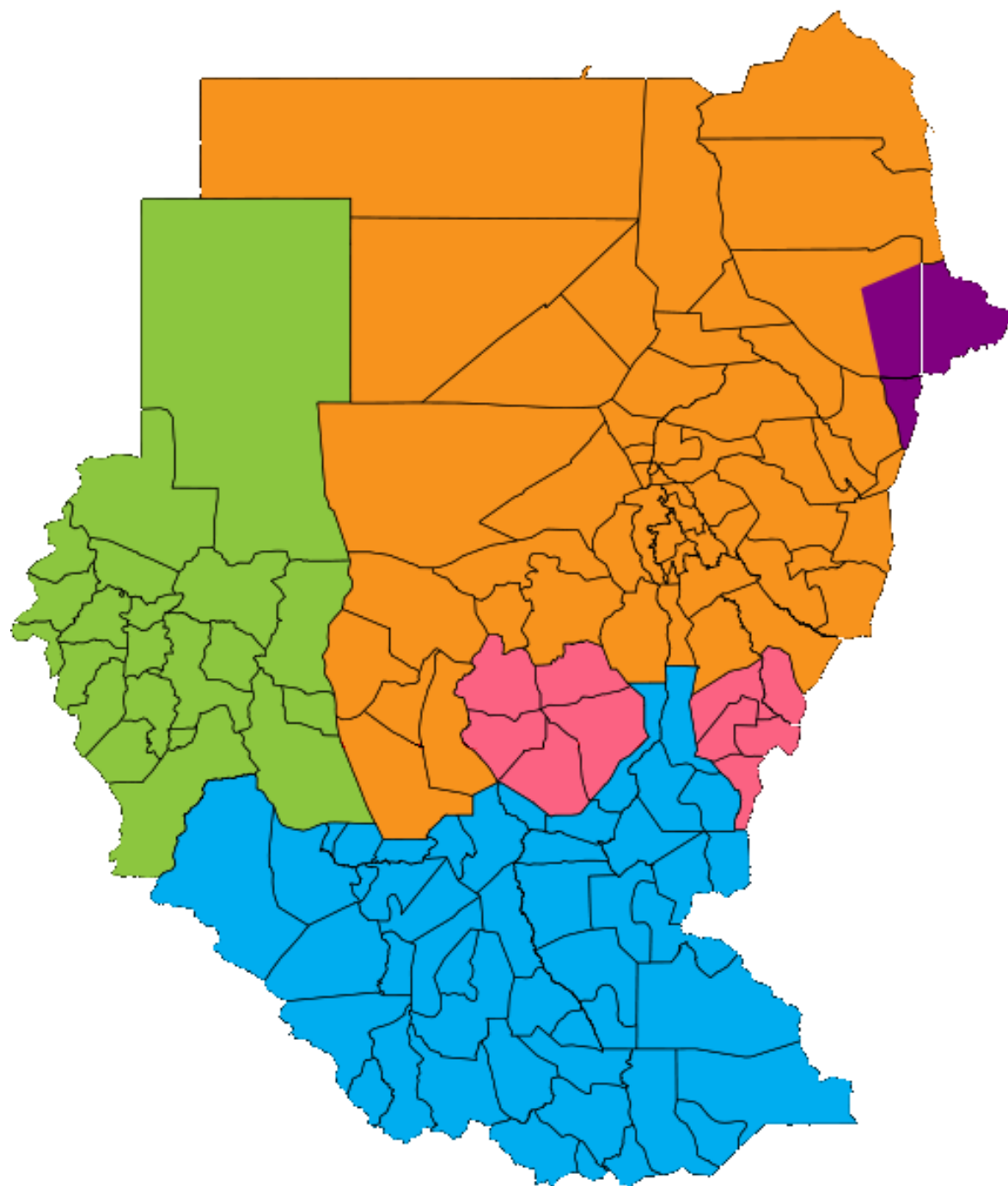


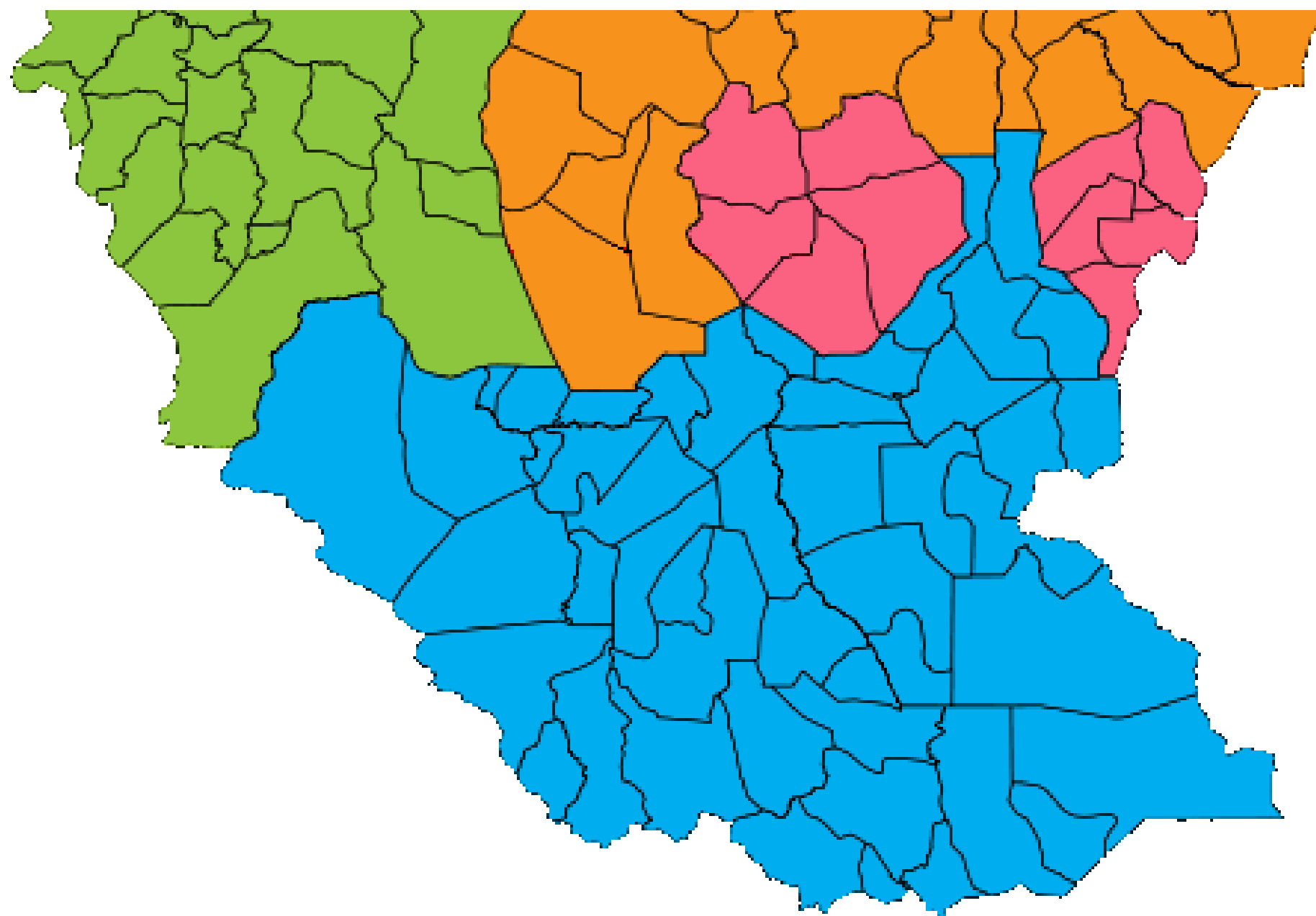
Sustainable Energy Options and Planning for South Sudan



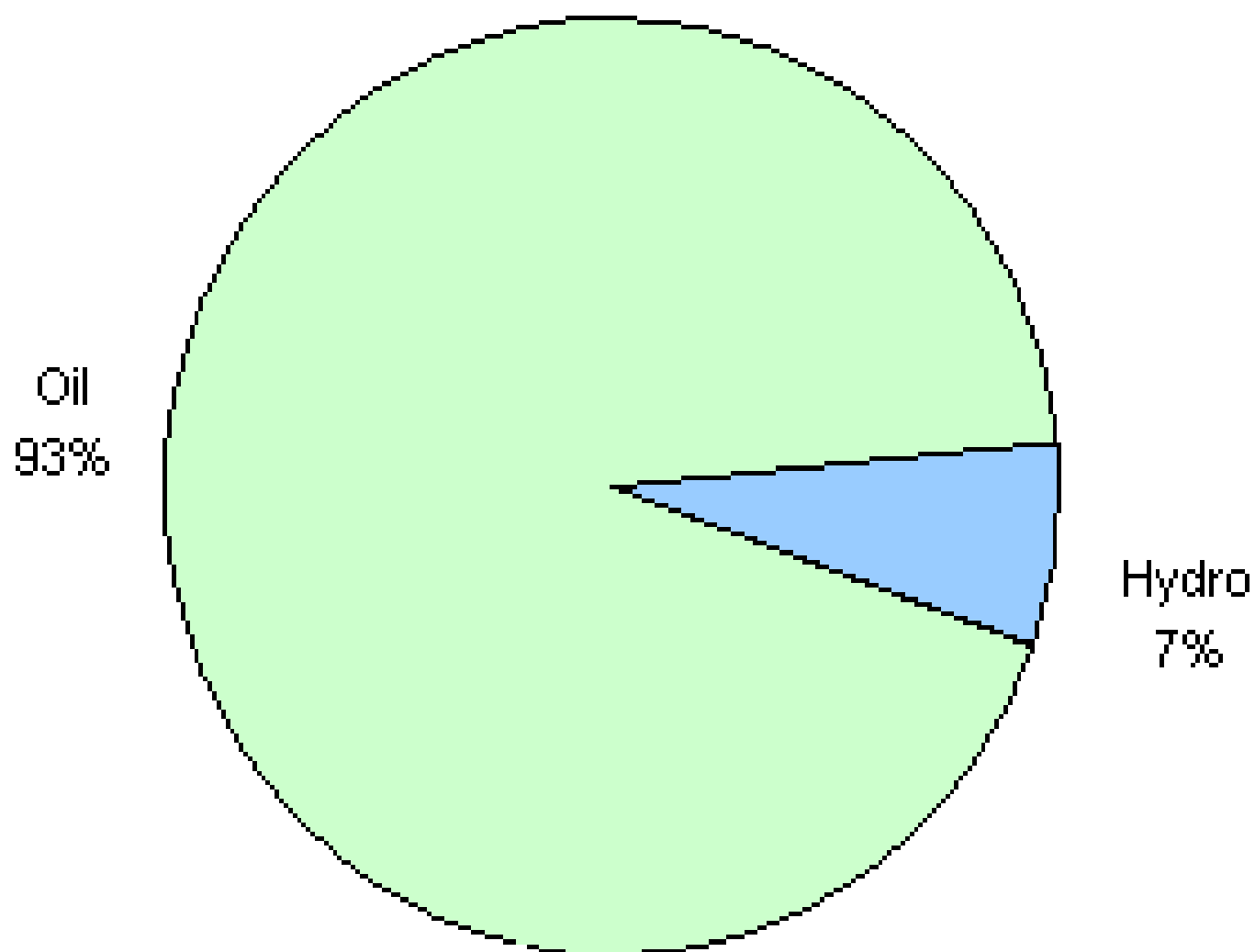
**James Leidel
Oakland University
November 2008**







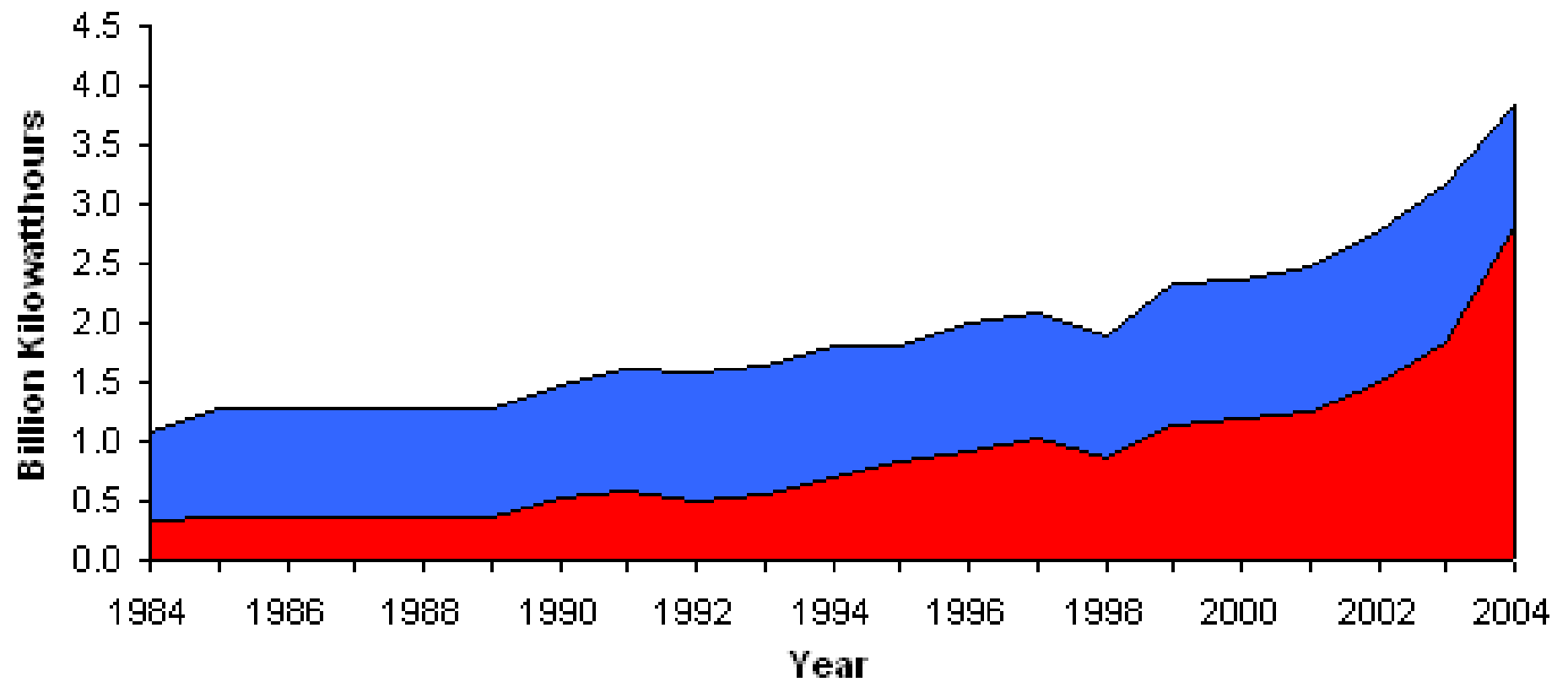
Total Energy Consumption in Sudan, by Type (2004)



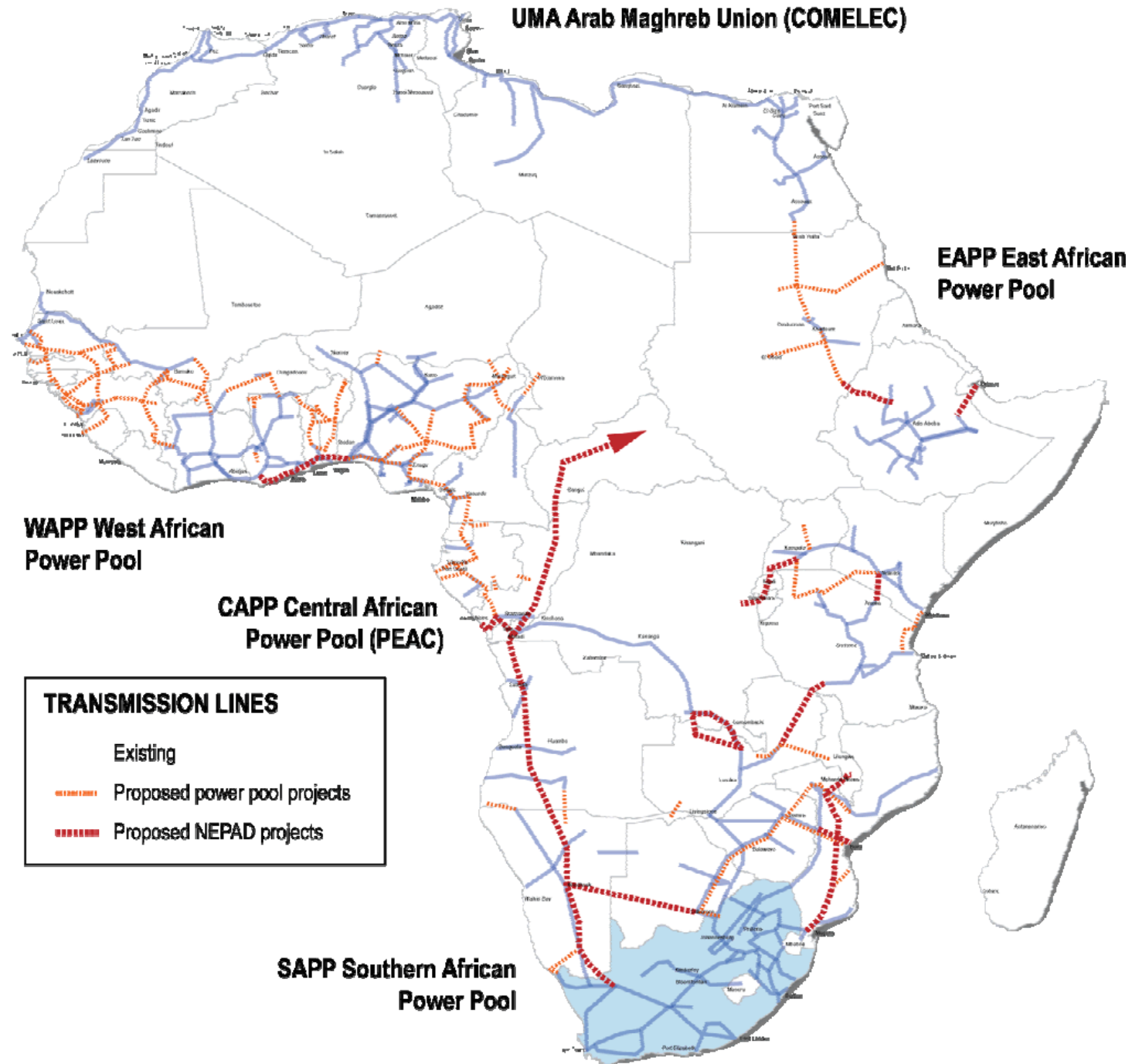
Source: International Energy Annual, 2004

Sudan's Electricity Generation, by Source, 1984-2004

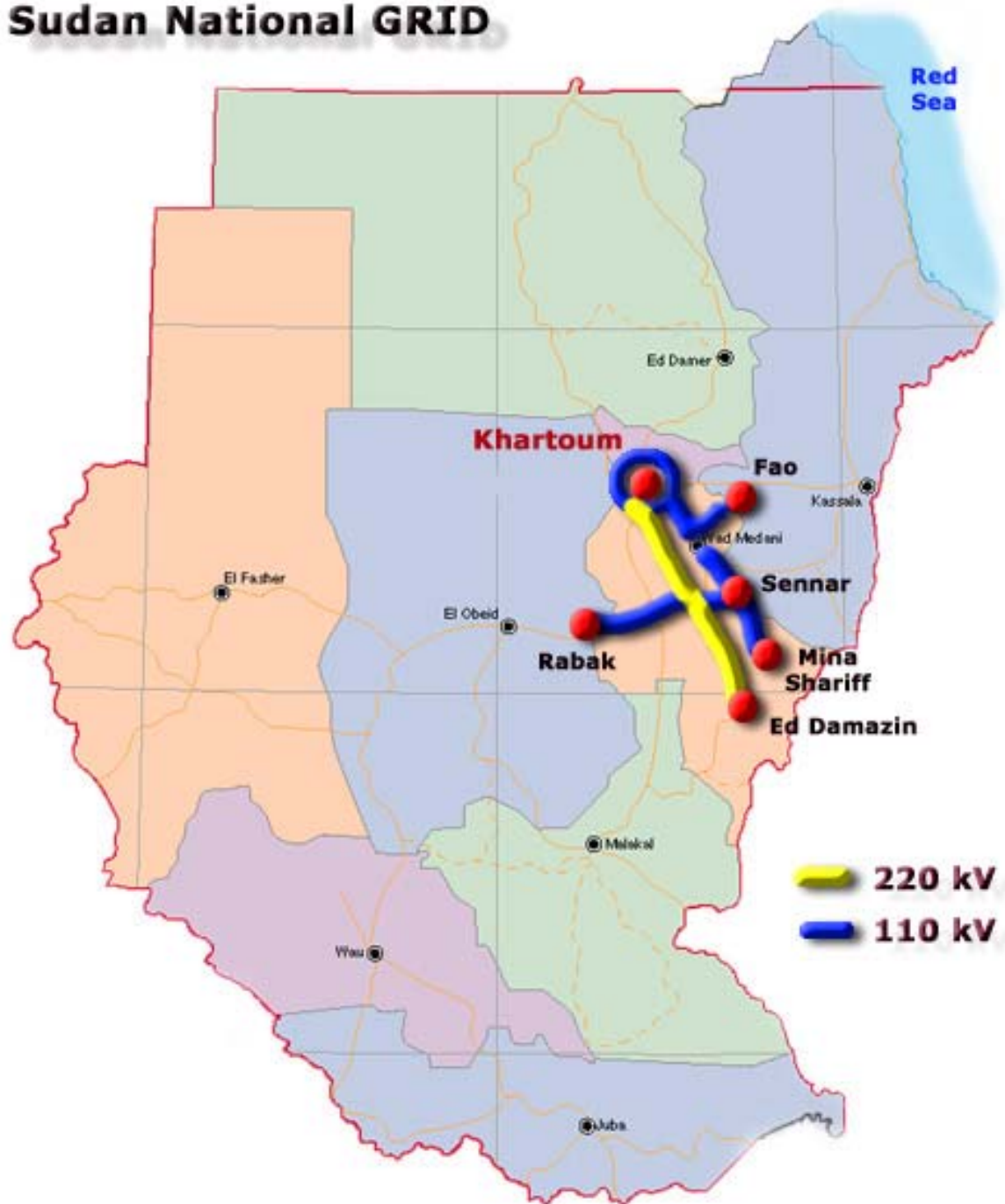
■ Conventional Thermal ■ Hydroelectricity



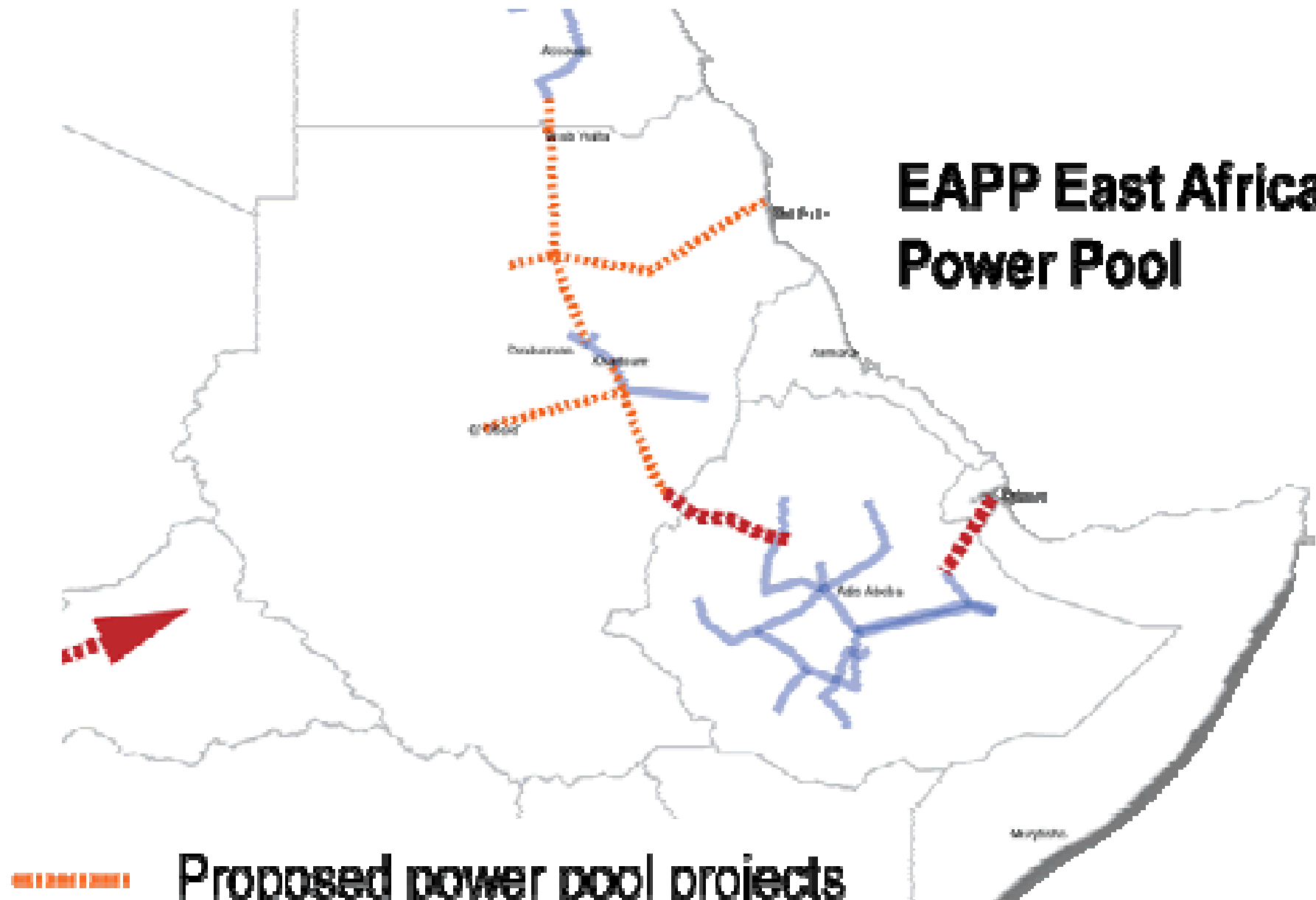
Source: International Energy Annual, 2004



Sudan National GRID



EAPP East African Power Pool

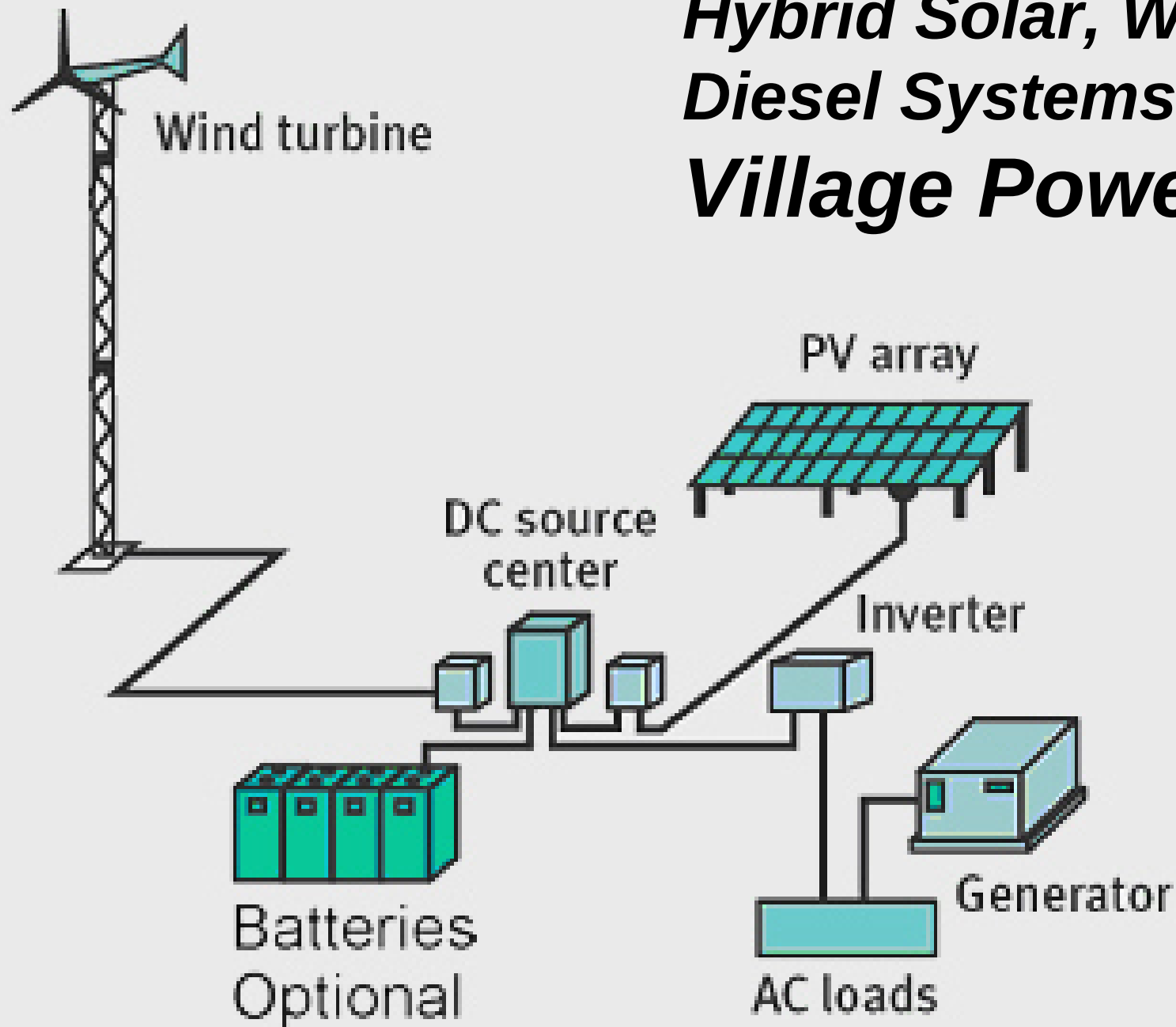


 Proposed power pool projects

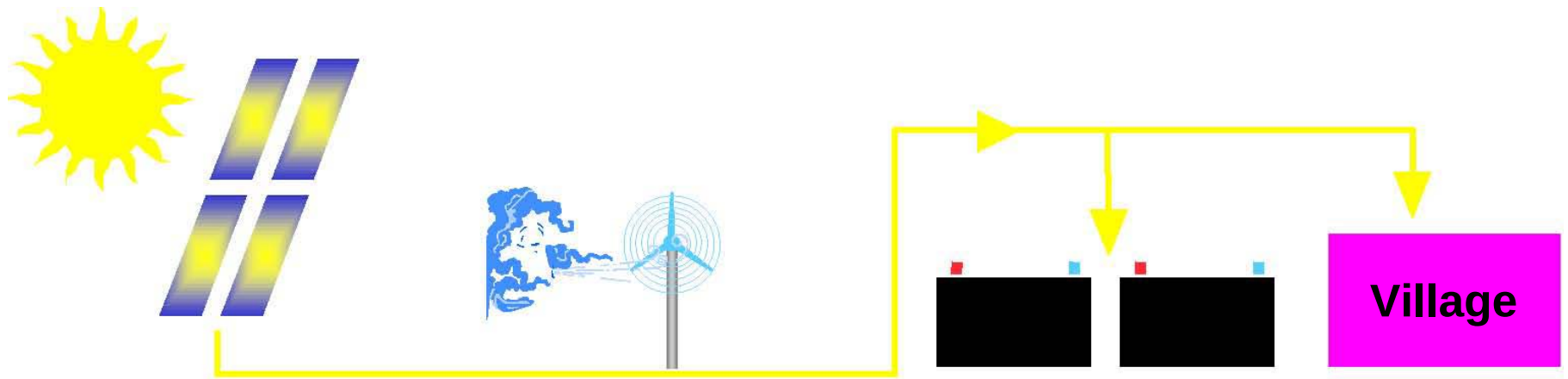
 Proposed NEPAD projects

Application	Grid	Energy Source	Equipment	Size
Portable lighting	off grid	solar	LED lantern	5-10 W
Rural home	off grid	solar	lighting and communications	50-100 W
Rural home Cook stove	off grid	biomass briquette, bottled gas, solar	Cook stove	
Solar street lighting	off grid	solar	LED lighting	50-100 W
School, church, or small building	off grid	solar, wind, diesel	lighting, communications, computers	1-5 kW
Office or other larger building	off grid	solar, wind, diesel	lighting, communications, computers	5-25 kW
Rural village	off grid	solar, wind, hydro, diesel, biomass	lighting, communications, computers, refrigeration	25-250 kW
Larger city	ON GRID	solar, wind, hydro, diesel, biomass	lighting, communications, computers, refrigeration, air conditioning, industry	multiple MW
Transportation fuel	ON GRID	Jatropha or sugar cane	Biodiesel or ethanol plant	millions of gallons per year

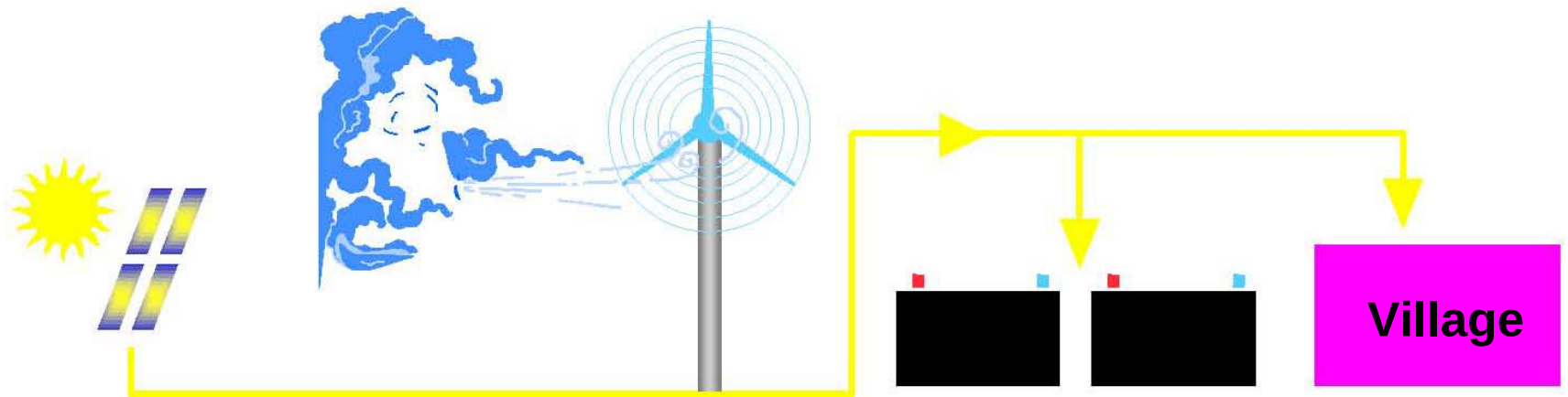
Hybrid Solar, Wind, Diesel Systems for Village Power



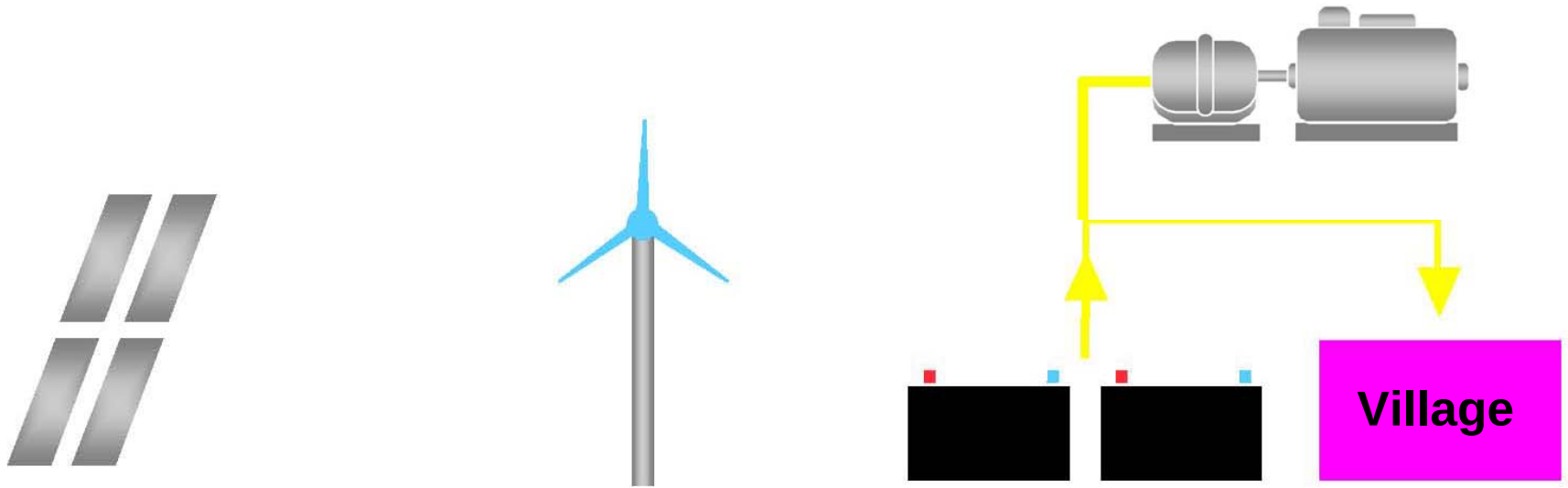
Sunny days produce energy from the solar arrays



Windy days produce energy predominantly from the wind turbines



**On still, cloudy days the batteries or diesel backup
will serve the village power load.**







Isolated Community

Private Utility

- 2 MW Wind, 4.6 MW Hydro,
16.9 MW Diesel

Remote installation



Wales Alaska

Wind Turbines
(Induction, Stall-Regulated)
 $2 \times 65 \text{ kW} = 130 \text{ kW}$

Battery Bank

240 VDC, 130 Ah
~30 kWh

Rotary Converter
156 kVA

Secondary Load
Controllers

School Heating
System

Resistance
Heaters

Diesel
Plant
Hydronic
Loop

Diesel #1
142 kW

Diesel #2
75 kW

Diesel #3
148 kW

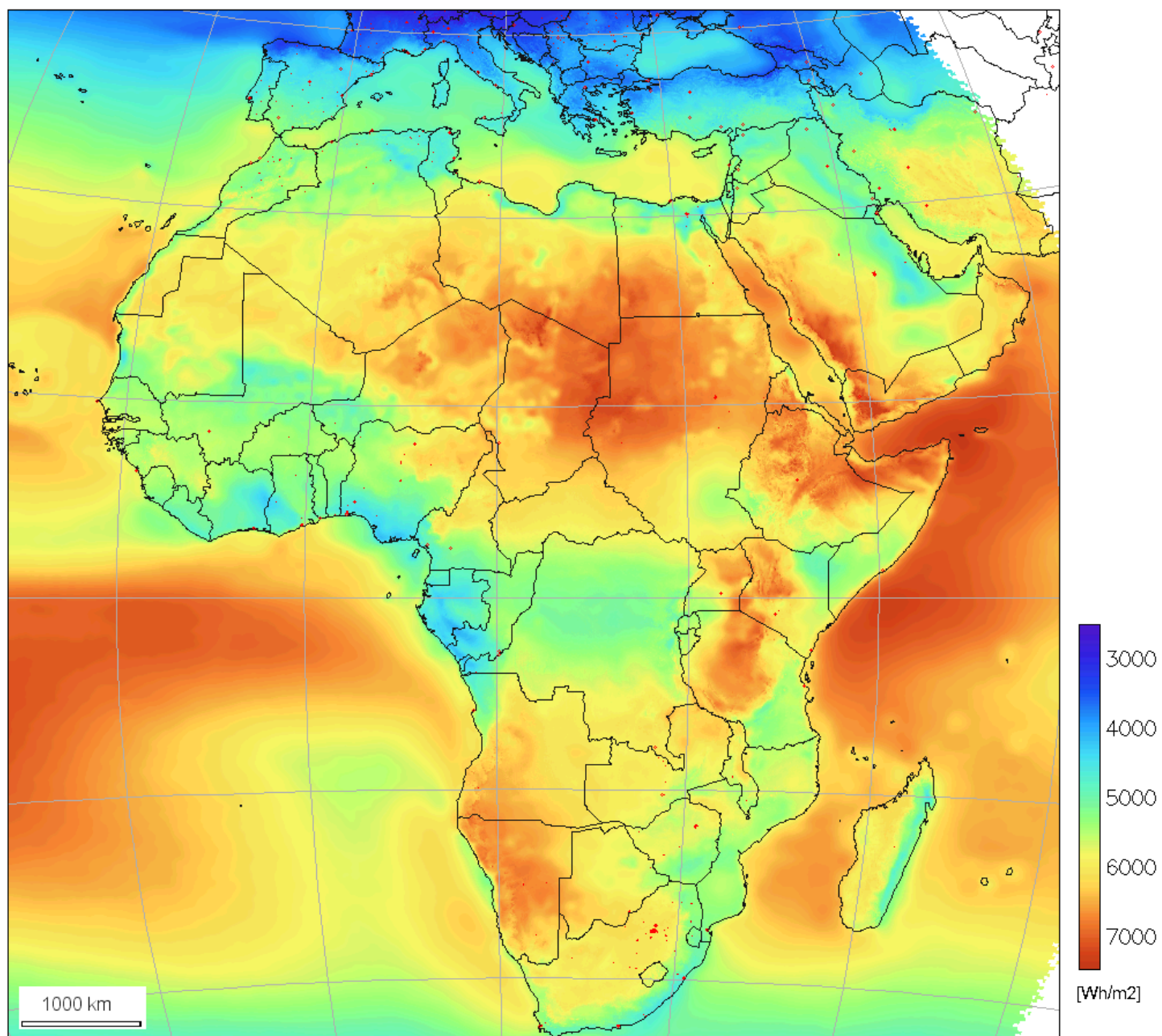
Primary Village Load
40-120 kW

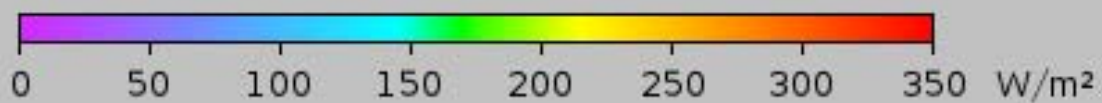
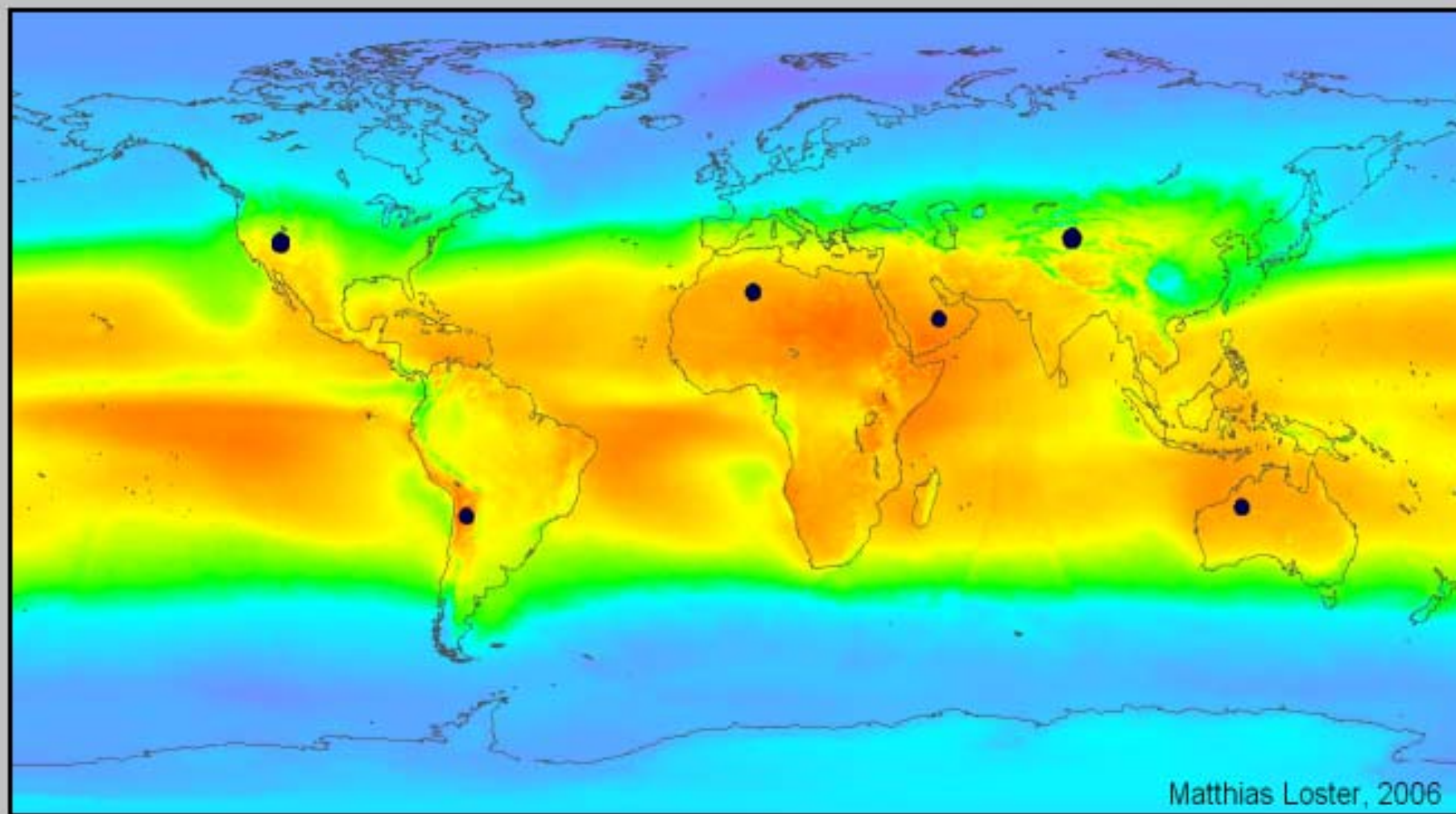




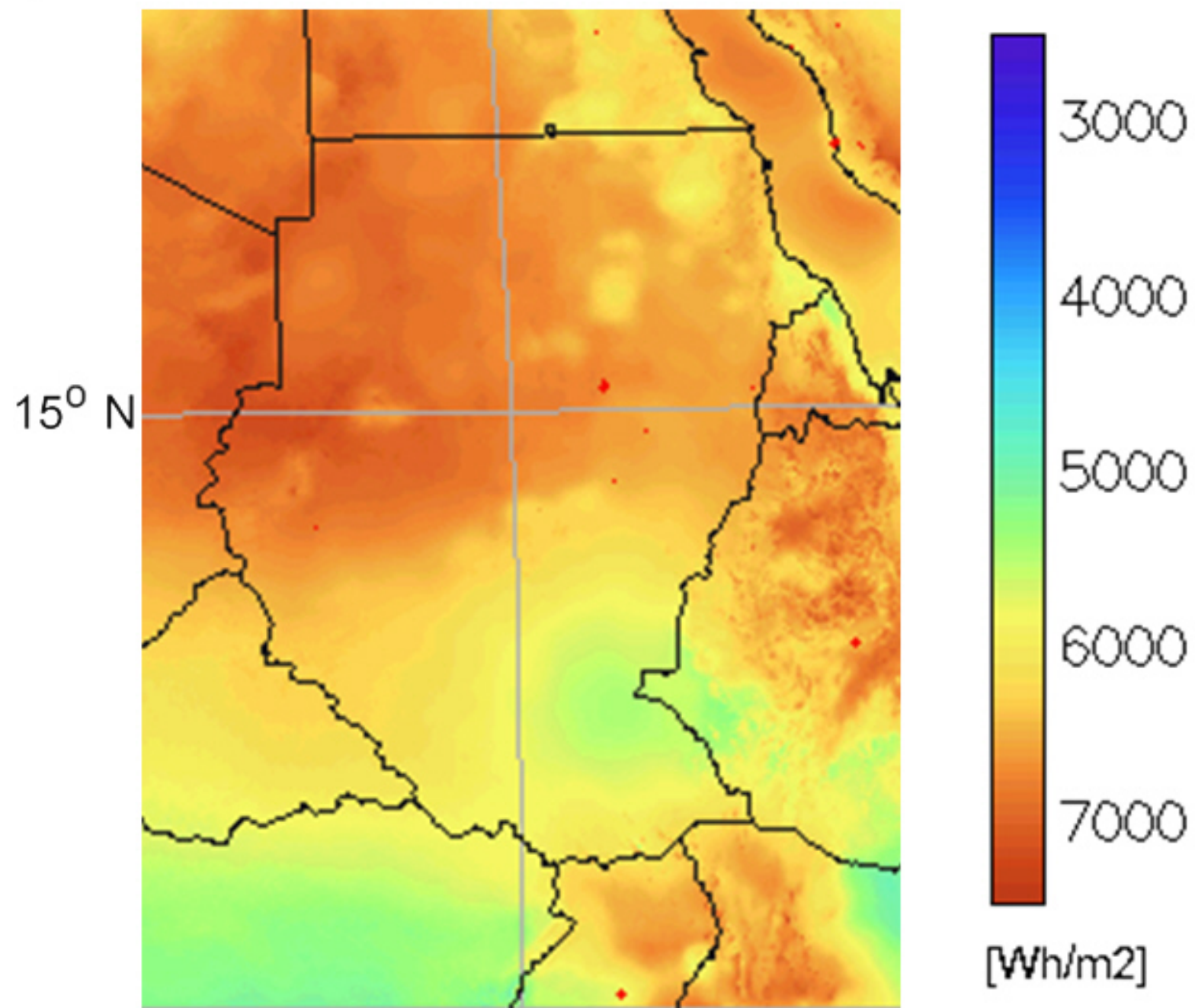
Solar

Global horizontal irradiation (1985-2004)
(annual average of daily sums, Gh)





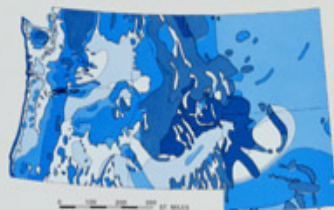
$$\Sigma \bullet = 18 \text{ TWe}$$



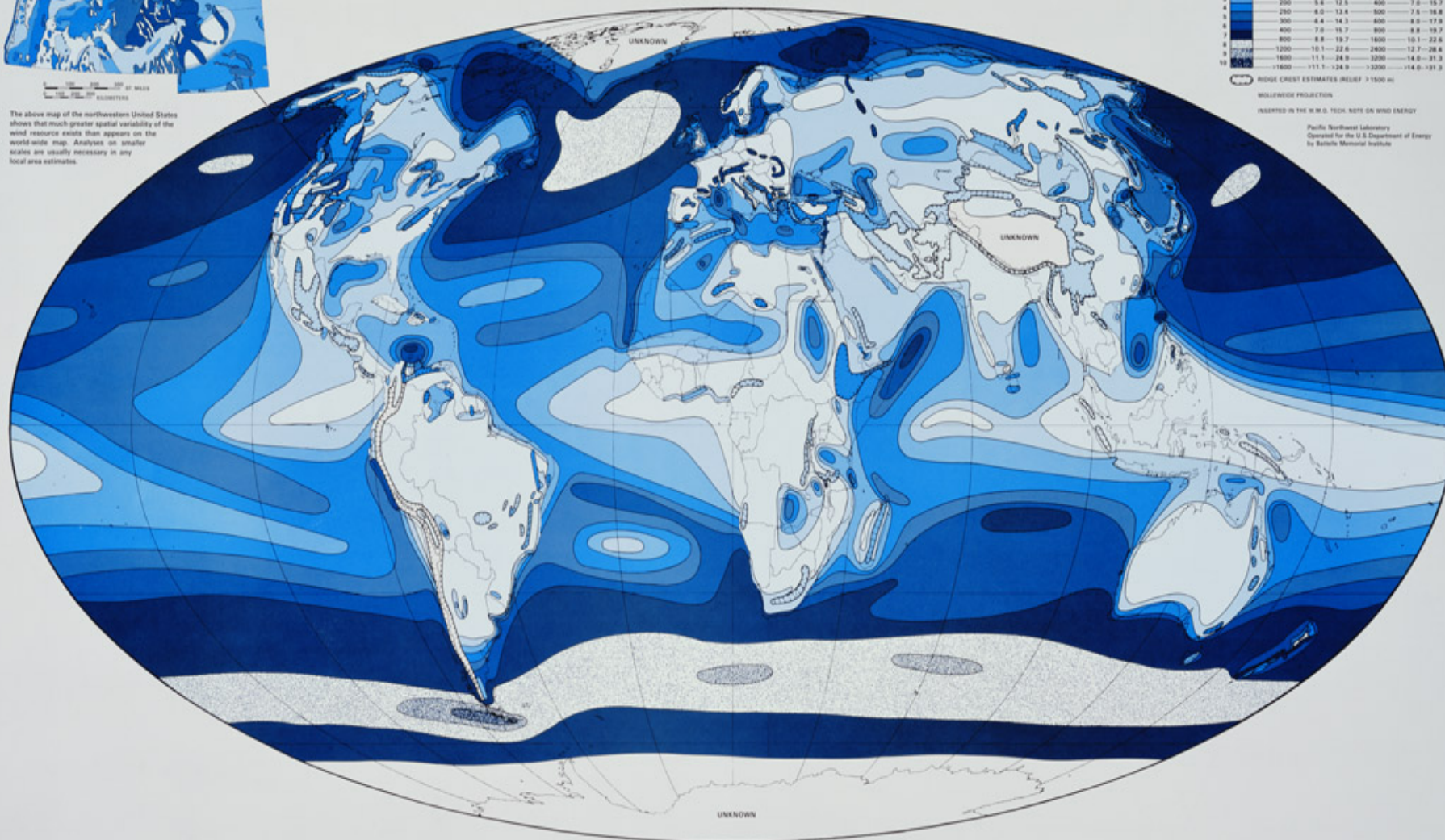
The Wind



WORLD-WIDE WIND ENERGY RESOURCE DISTRIBUTION ESTIMATES



The above map of the northwestern United States shows that much greater spatial variability of the wind resource exists than appears on the world-wide map. Analyses on smaller scales are usually necessary in any local area estimates.



CLASSES OF WIND ENERGY FLUX (WEF)

WIND ENERGY CLASS	10 m (33 ft)		50 m (164 ft)	
	WEF W/m²	SPEED m/s mph	WEF W/m²	SPEED m/s mph
1	0 — 0	0 — 0	0 — 0	0 — 0
2	100 — 4.4	9.8 — 200	5.6 — 12.5	
3	150 — 5.1	11.5 — 300	6.4 — 14.3	
4	200 — 5.8	12.5 — 400	7.0 — 15.7	
5	250 — 6.5	13.4 — 500	7.8 — 16.8	
6	300 — 7.2	14.3 — 600	8.6 — 17.9	
7	400 — 7.9	15.7 — 800	9.8 — 19.7	
8	500 — 8.8	16.7 — 1000	10.1 — 22.4	
9	1200 — 10.1	22.4 — 2400	12.7 — 26.4	
10	1800 — 11.1	24.9 — 3200	14.0 — 31.3	
11	1800 — 11.1	24.9 — 3200	14.0 — 31.3	

RISE CREST ESTIMATES (RELIEF > 1500 m)

INTERPOLATED IN THE W.M.O. TECH. NOTE ON WIND ENERGY

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

MAP DESCRIPTION

This map is a preliminary estimate of the annual mean wind energy available at typical well-exposed locations throughout the world. The average energy in the wind flowing in the layer near the ground is expressed as a wind energy class. The greater the average wind energy, the higher the wind energy class, and the darker the shade of blue on the map. The colors corresponding to classes of wind energy are defined in the table at the upper right.

The wind energy class is defined in relation to the mean wind energy flux (WEF) at 50 m above ground level. The WEF is the

rate of flow of wind energy through a unit vertical cross-sectional area perpendicular to the wind direction. At 10 m, the WEF estimate represents large areas that are relatively free of obstructions. Local terrain features can cause the mean wind energy to vary considerably over short distances, especially in coastal, hilly and mountainous areas. There will be local areas of higher or lower wind energy than can be shown on a world-wide map. This is demonstrated by the smaller scale map at the upper left.

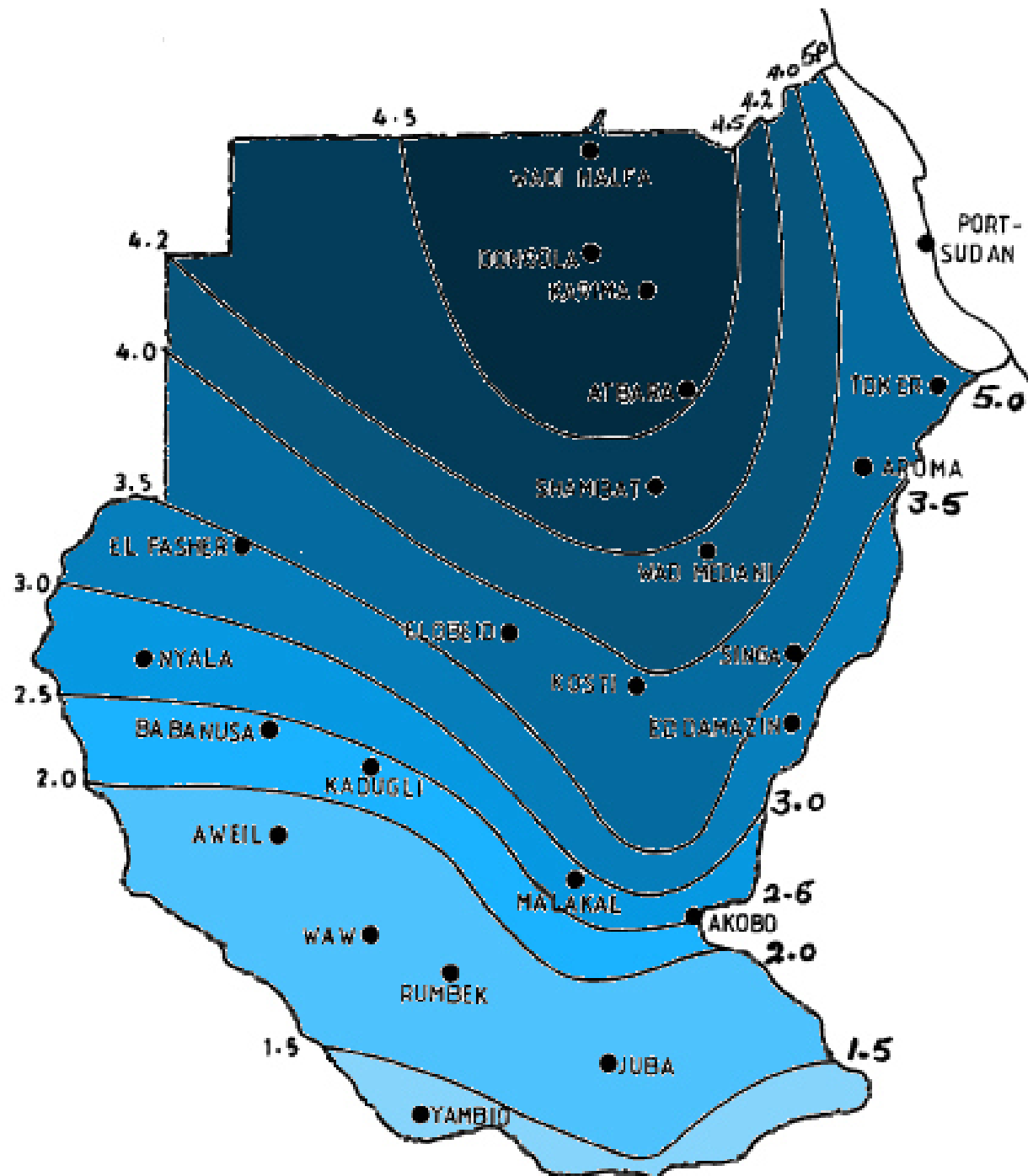
BACKGROUND INFORMATION

The relationship between the mean WEF and the mean wind speed in the table at the upper right assumes a Rayleigh Distribution (Weibull with k=2) for the wind speed frequency distribution. A 1/7 power law for mean wind speed and a 3/7 power law for mean WEF relates the 50 m estimates to the 10 m estimates.

Because the wind energy estimate generally applies to typical well-exposed locations, the fraction of the land area represented by the wind energy class depends on the physical characteristics of the land surface form in the region. For example, on a flat open plain close to 100% of the area will have a similar wind energy class, while in hilly and mountainous areas the wind energy class will only apply to a small proportion of the area that is well exposed. On the map, areas where mountainous relief generally exceeds 1500 m are shown using lines with tick marks. Within these areas wind resource estimates are for exposed ridge crests.

The mean wind energy may vary considerably with time of year and time of day. Thus, regions with the lowest wind energy class may have considerably higher wind energy during part of the year and/or day. Conversely, regions with the highest wind energy may experience considerably lower mean wind energy throughout part of the year. Only a few areas of the world have persistent high wind energy throughout an entire year.

Vast areas of the world have little or no wind data, and there is disturbingly little data from exposed sites in many windy regions of the world. Of the large amount of wind data available from specific areas at the time of preparation of the map, only a small proportion of the stations had information on anemometer height above ground level or on site exposure. Thus regional climatological information, upper air wind data and other appropriate information, where available, were used in the assessment.



**Annual
Average
Wind
Speed
(m/s)
at 10m
height**

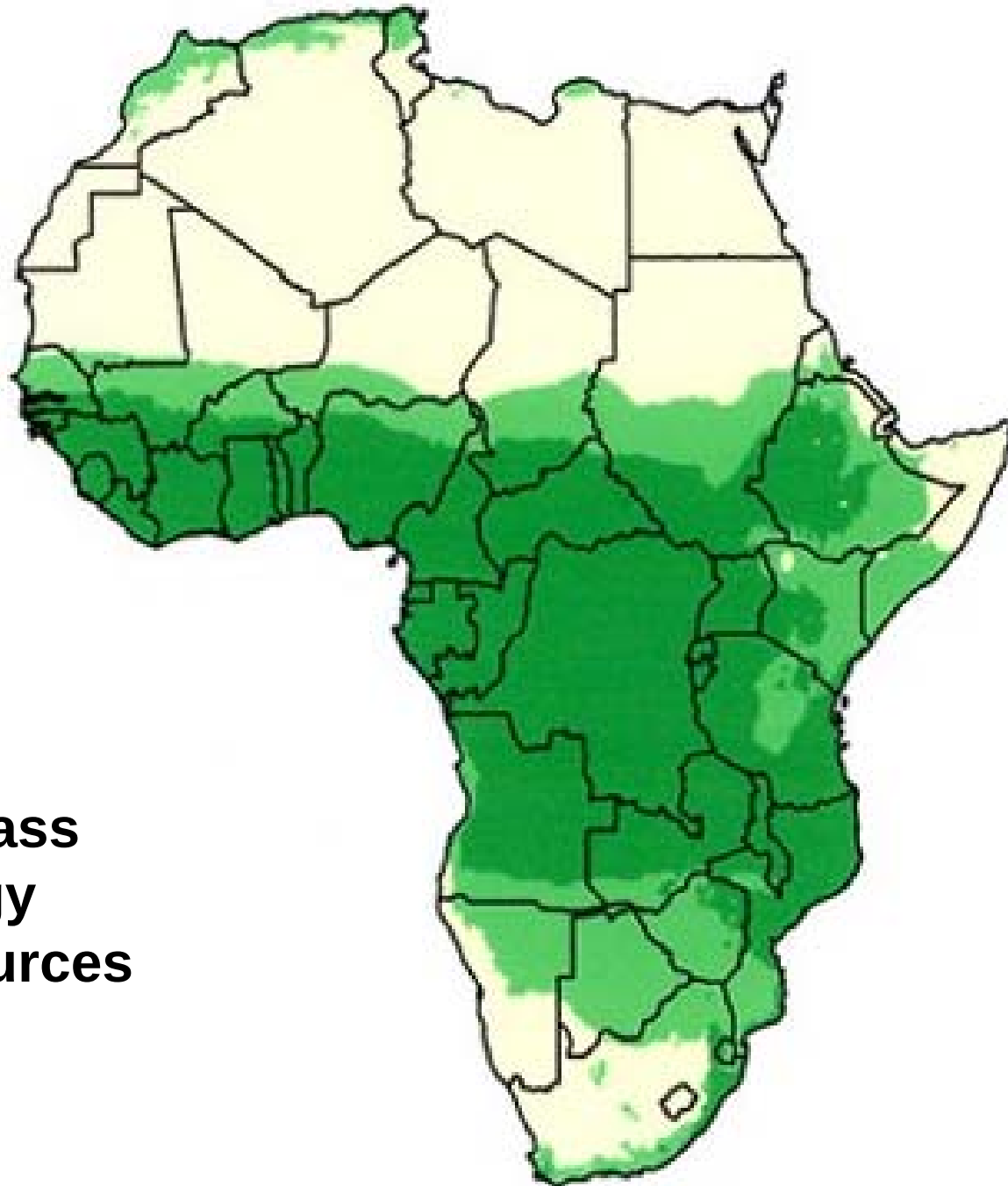
Station	Altitude (m)	Annual wind speed (V) ms^{-1}
Wadi Halfa	190	4.6
Port Sudan	5	5.0
Karima	250	4.7
Atbara	345	4.2
Shambat	380	4.8
Khartoum	380	4.8
Kassala	500	4.0
Wad Madani	405	4.8
El Fasher	733	3.4
El Geneina	805	3.1
El Obeid	570	3.4
Kosti	380	4.0
Abu Na'ama	445	3.1
Malakal	387	2.8
Wau	435	1.7
Juba	460	1.5

Photosynthesis: Nature's way to convert sunlight, CO_2 , water and nutrients into chemical energy

BioMass



**Biomass
Energy
Resources**

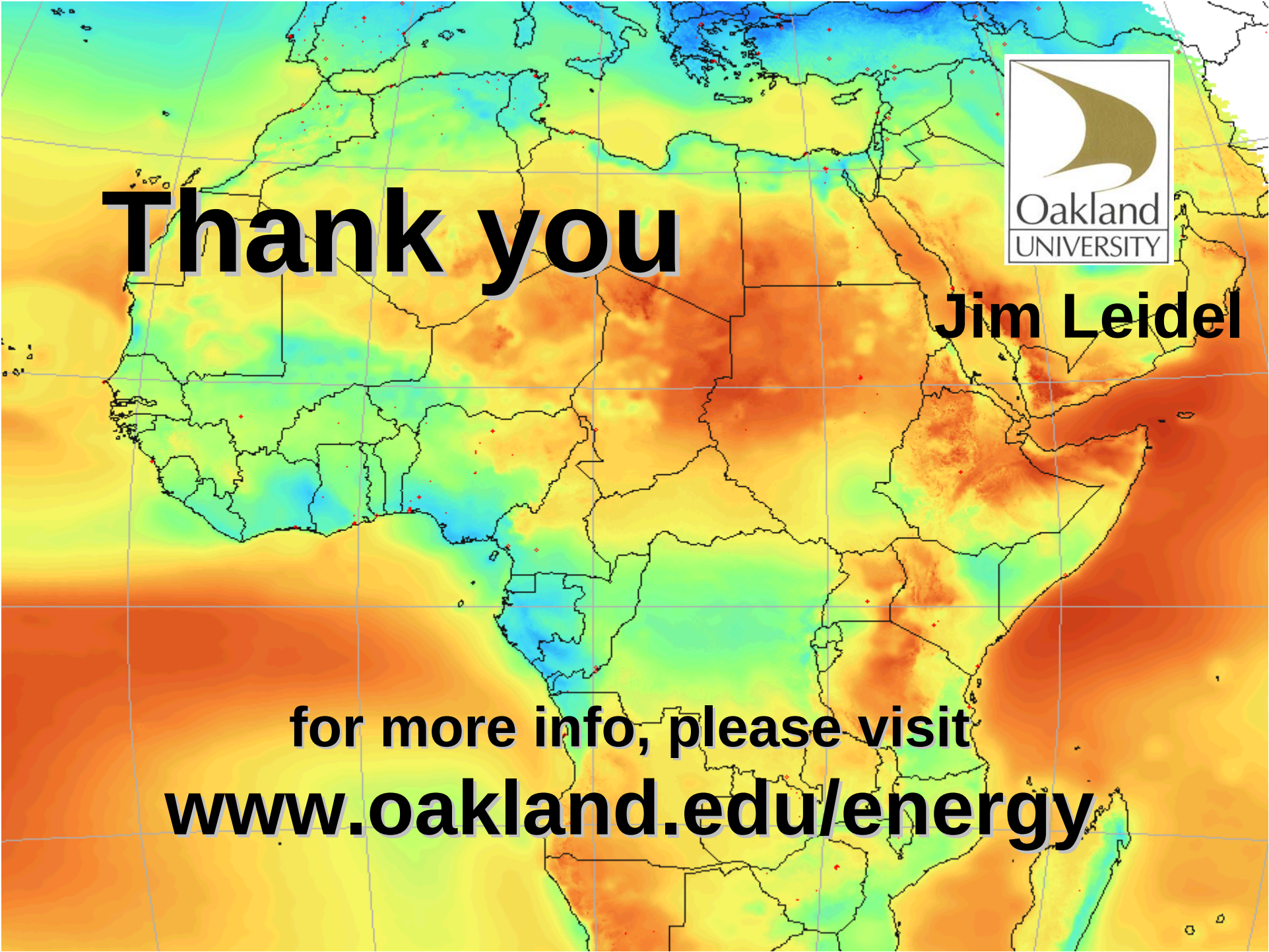




Jatropha for Bio-Oil







Thank you



Jim Leidel

**for more info, please visit
www.oakland.edu/energy**