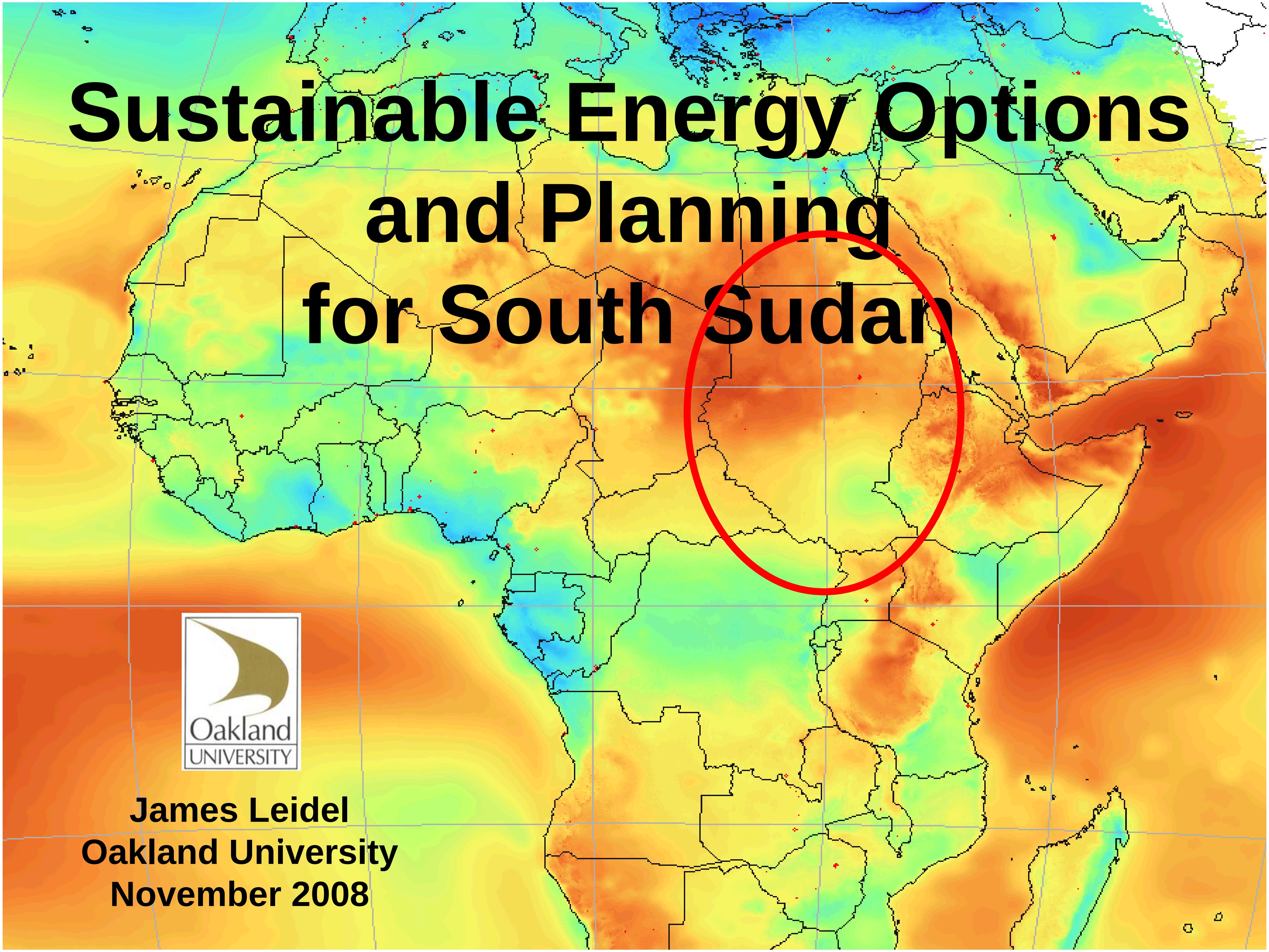
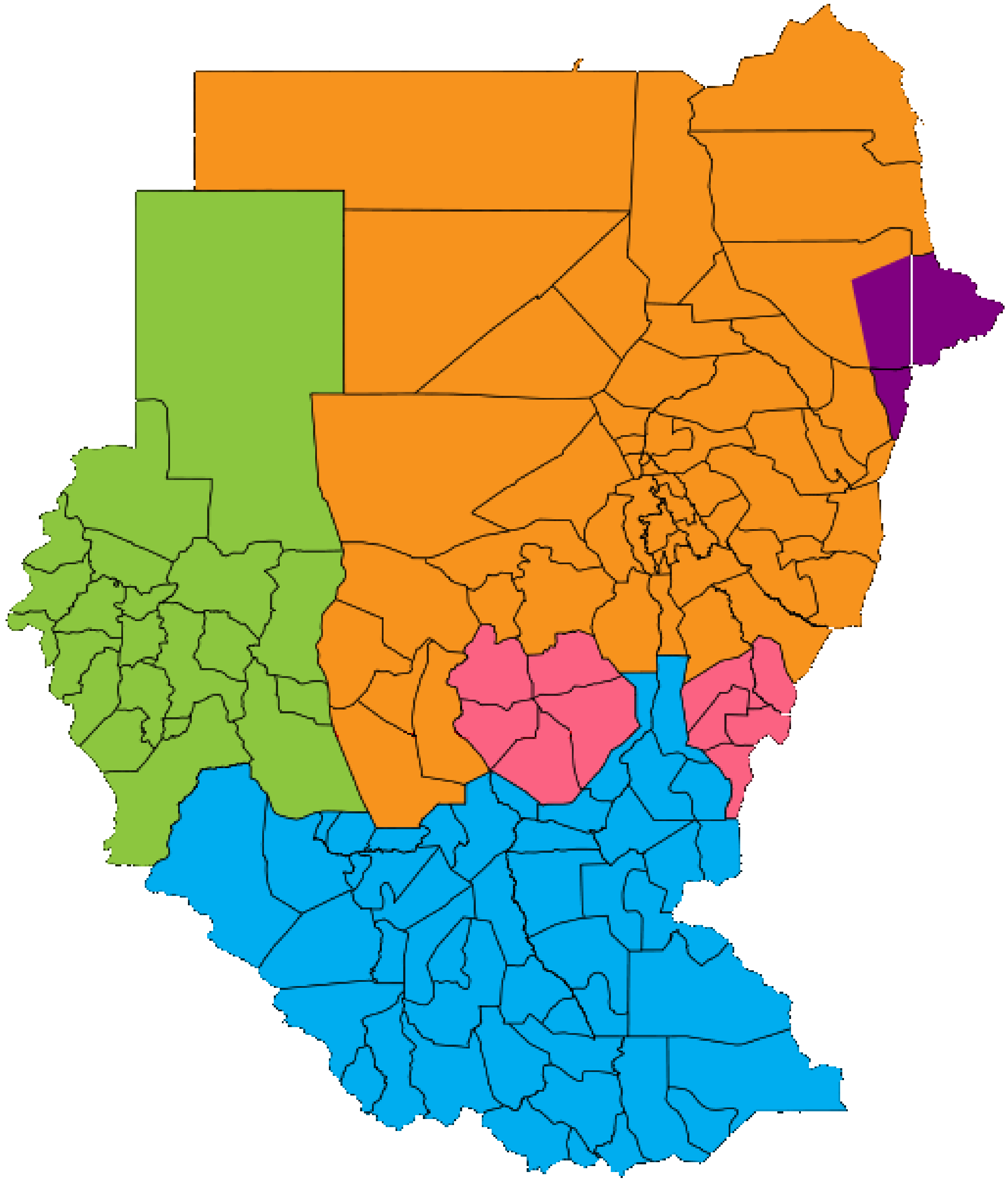
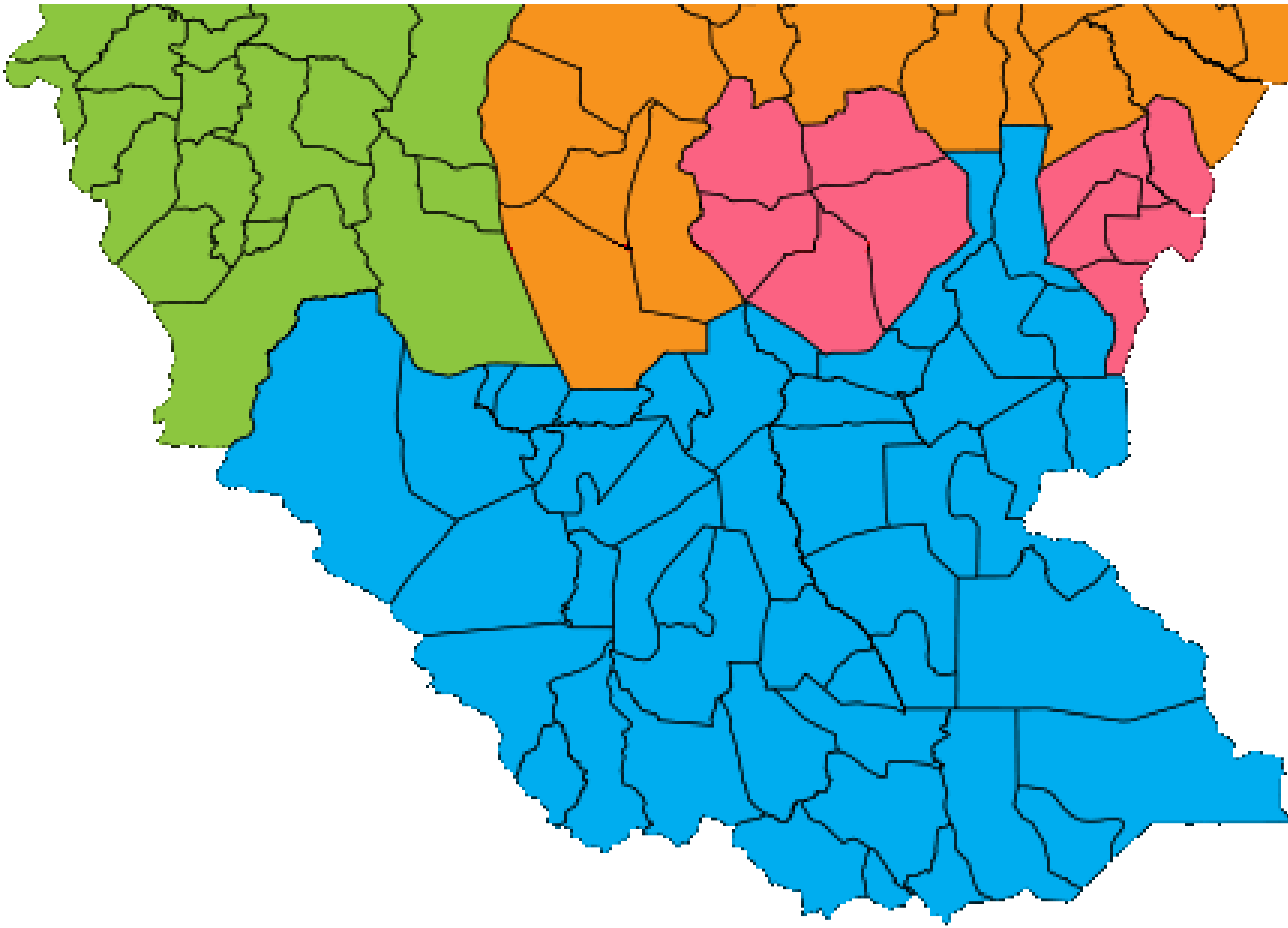
Sustainable Energy Options and Planning for South Sudan



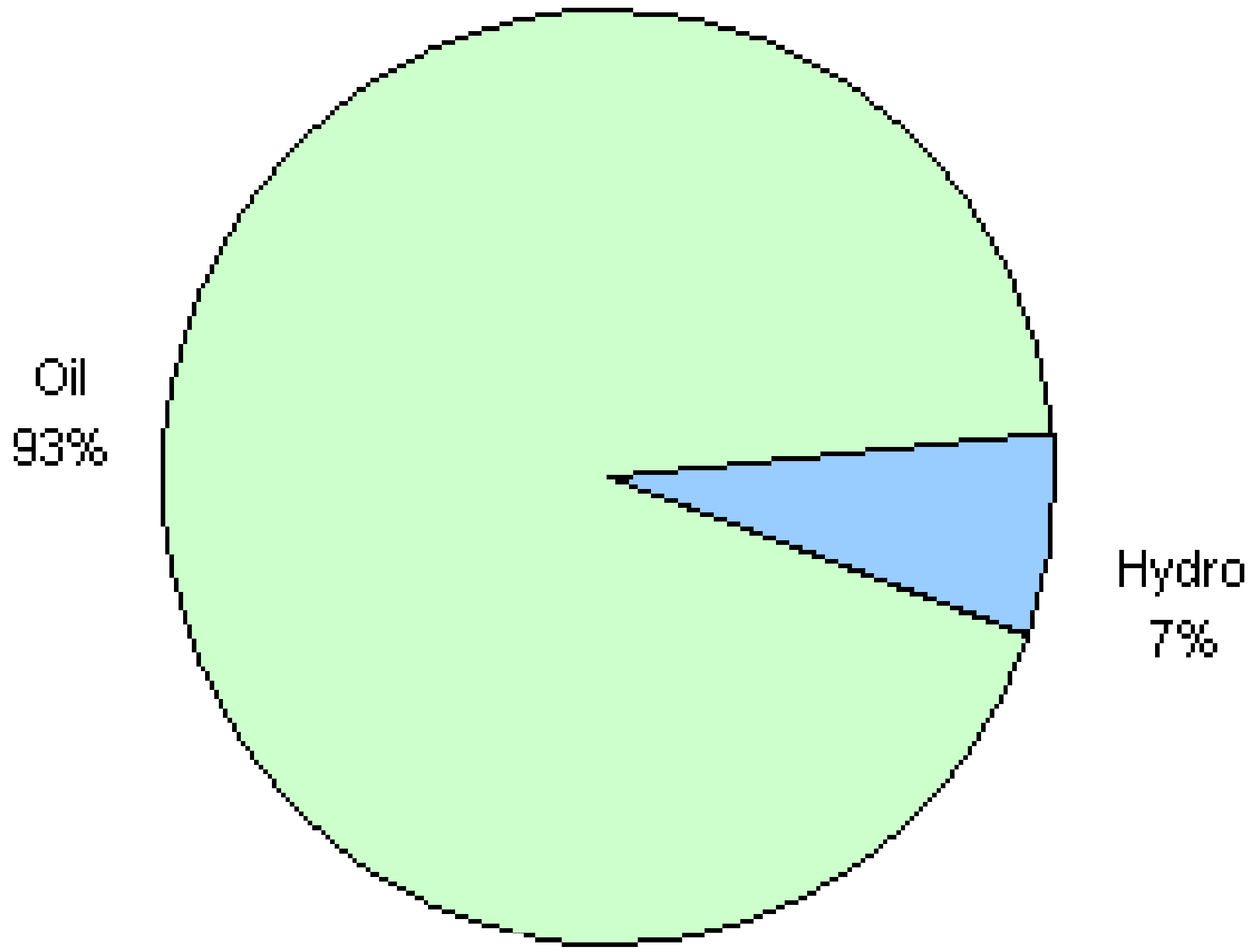
James Leidel
Oakland University
November 2008

LIBYA
EGYPT
Halā'ib Triangle
Halā'ib
SAU. AR.
Wādī Halfā'
Port Sudan
Red Sea
Sawākin
Nile
Atbara
CHAD
Omdurman
KHARTOUM
Kassala
ERIT.
Wad Madanī
Al Fāshir
Al Qaḑārif
DARFUR
Al Ubayyiḑ
Kūstī
Nyala
Blue Nile
White Nile
Malakāl
ETHIOPIA
Wāw
C.A.R.
Bor
Ilemi Triangle
Juba
Kinyeti
Nimule
DEM. REP. OF THE CONGO
UGANDA
KENYA
0 300 km
0 300 mi

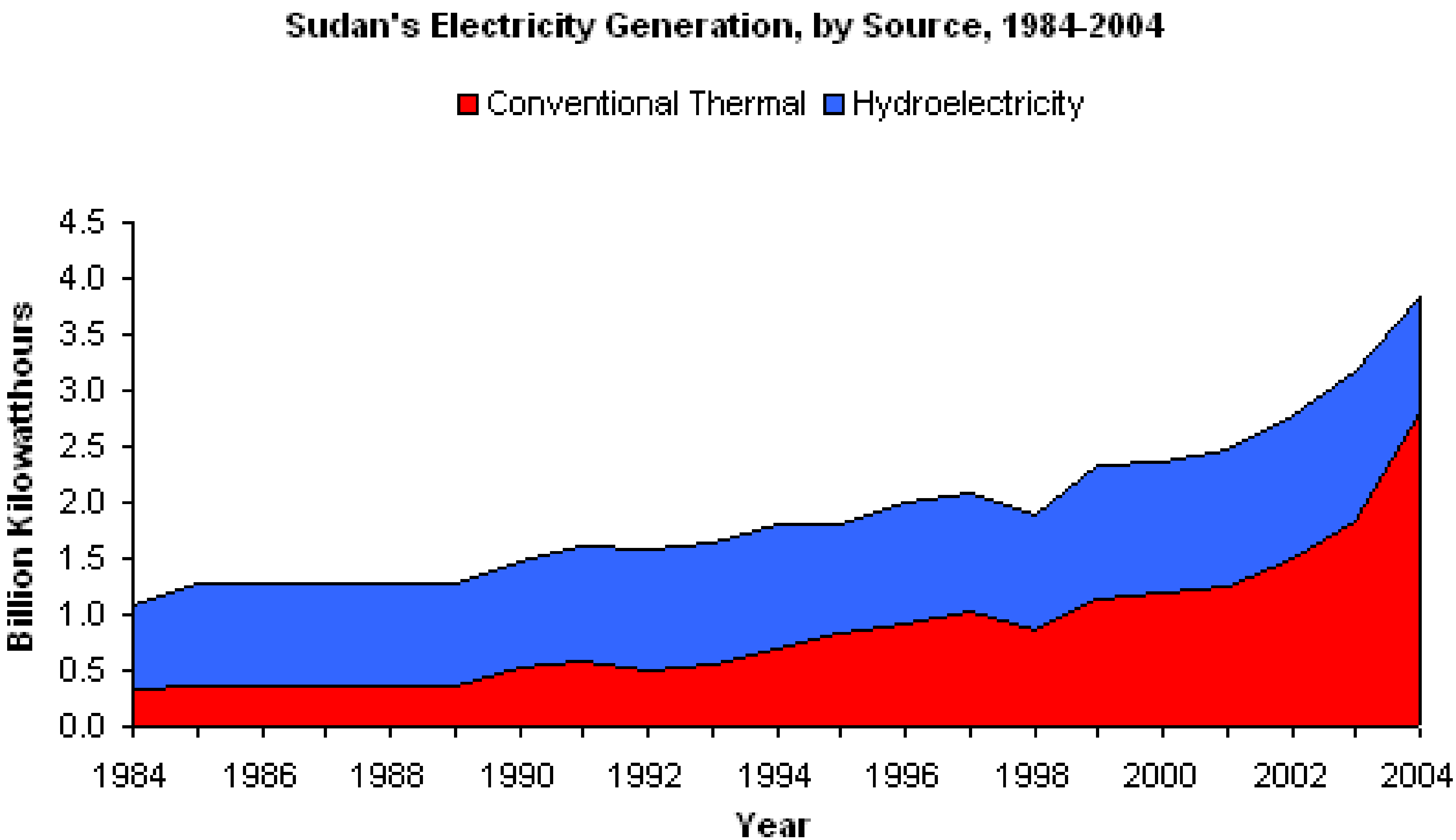




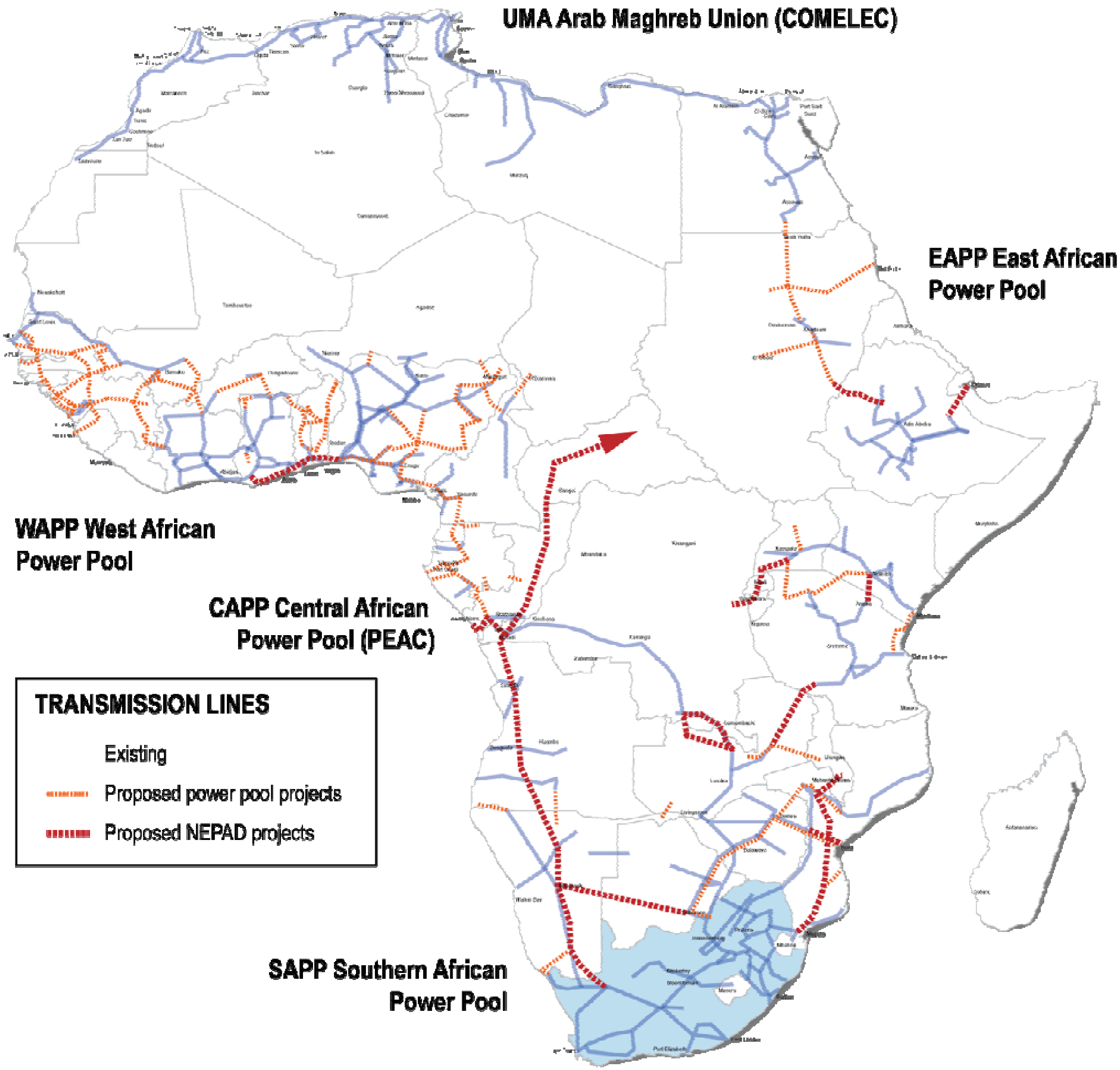
Total Energy Consumption in Sudan, by Type (2004)



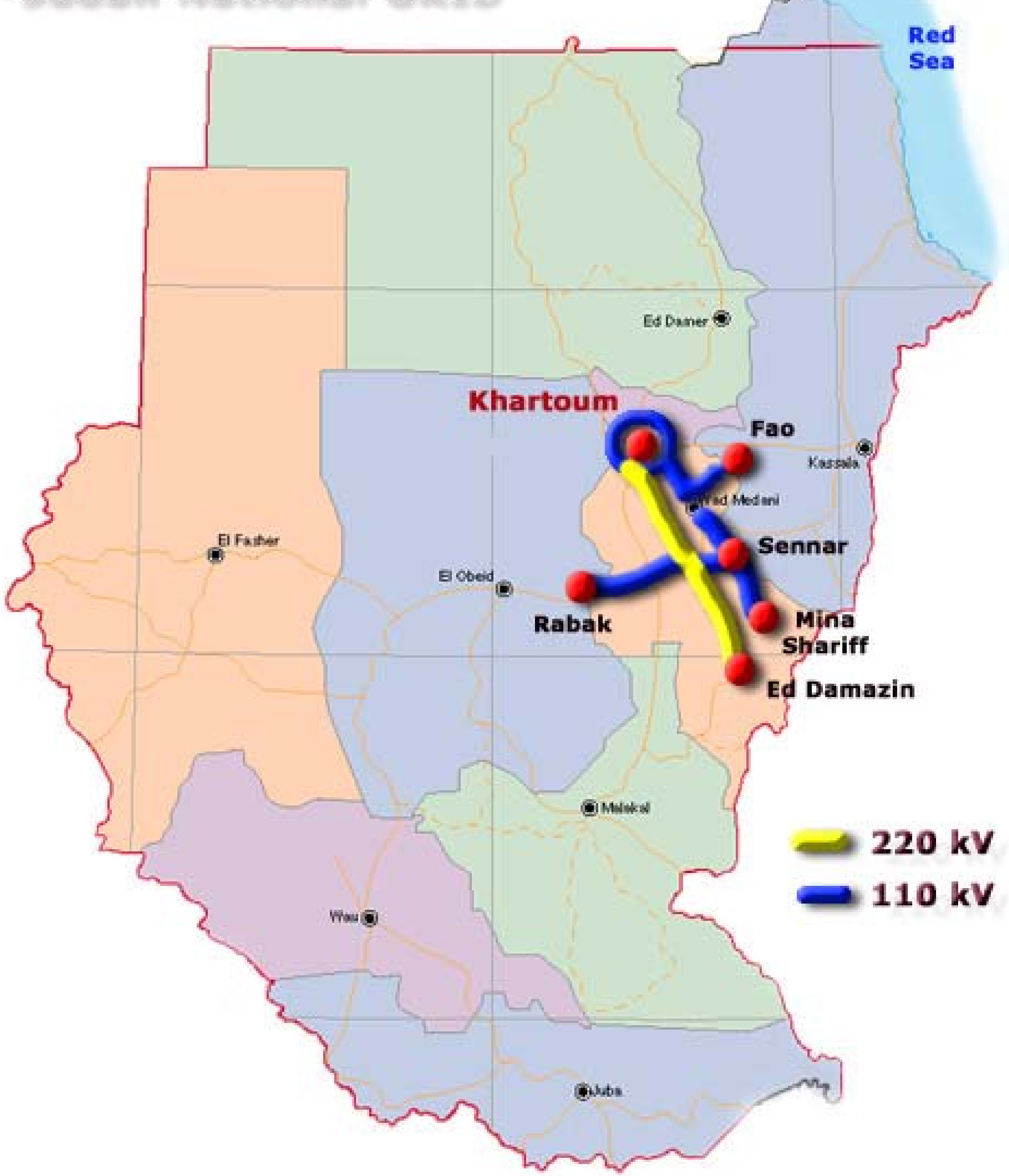
Source: International Energy Annual, 2004



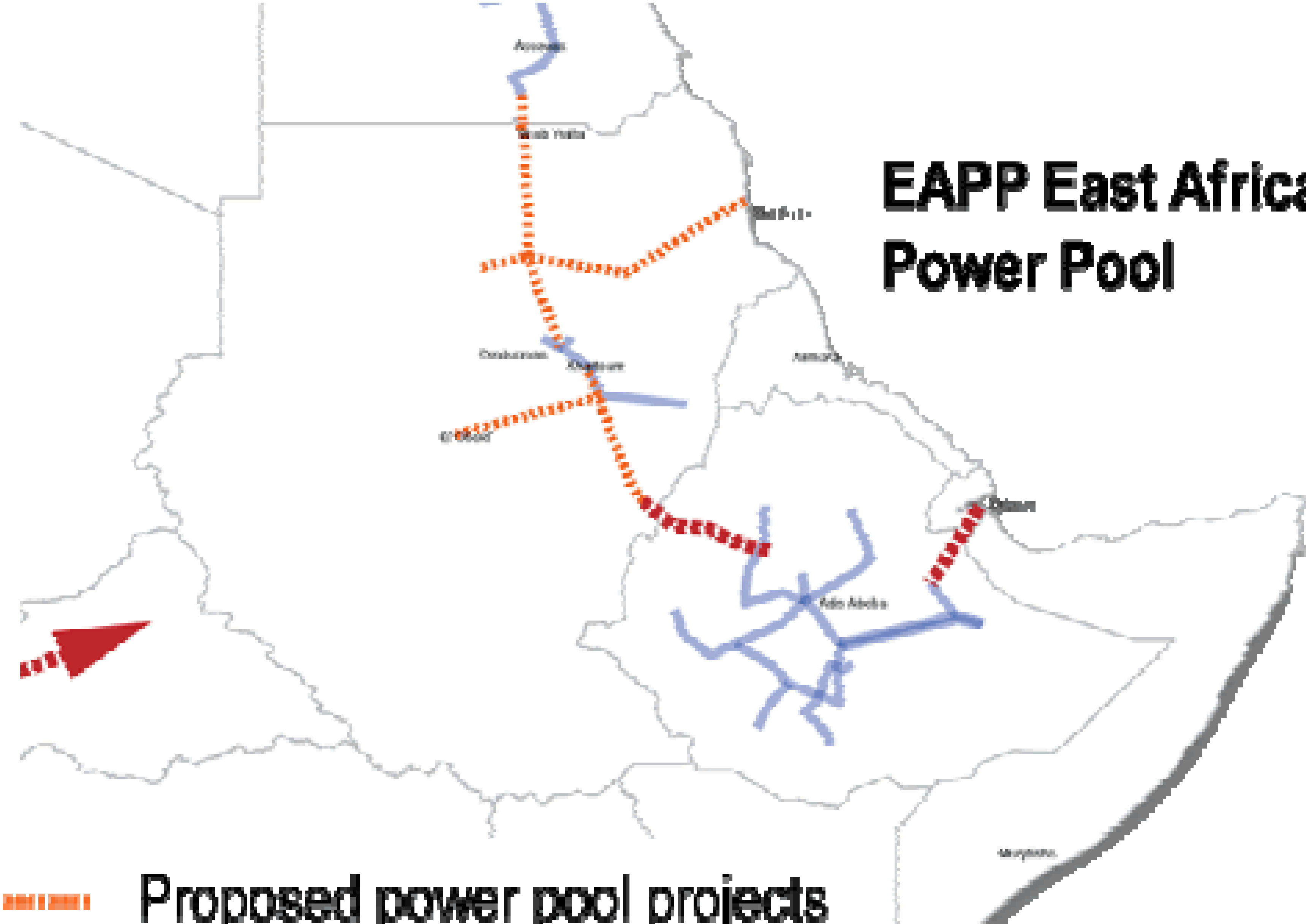
Source: International Energy Annual, 2004


UMA Arab Maghreb Union (COMELEC)
EAPP East African Power Pool
WAPP West African Power Pool
CAPP Central African Power Pool (PEAC)
SAPP Southern African Power Pool
TRANSMISSION LINES
Existing
Proposed power pool projects
Proposed NEPAD projects

Sudan National GRID



EAPP East African Power Pool

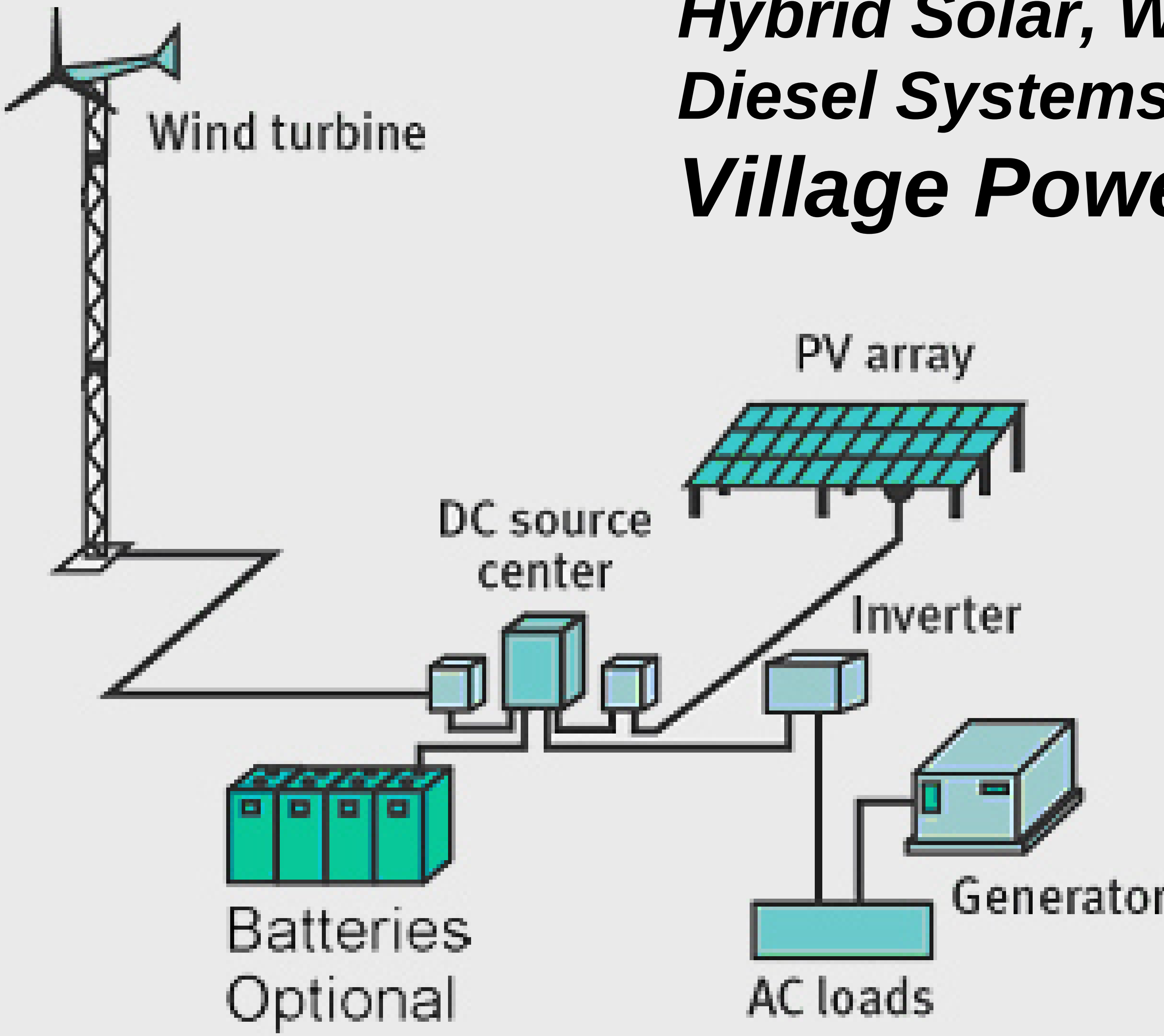


Proposed power pool projects

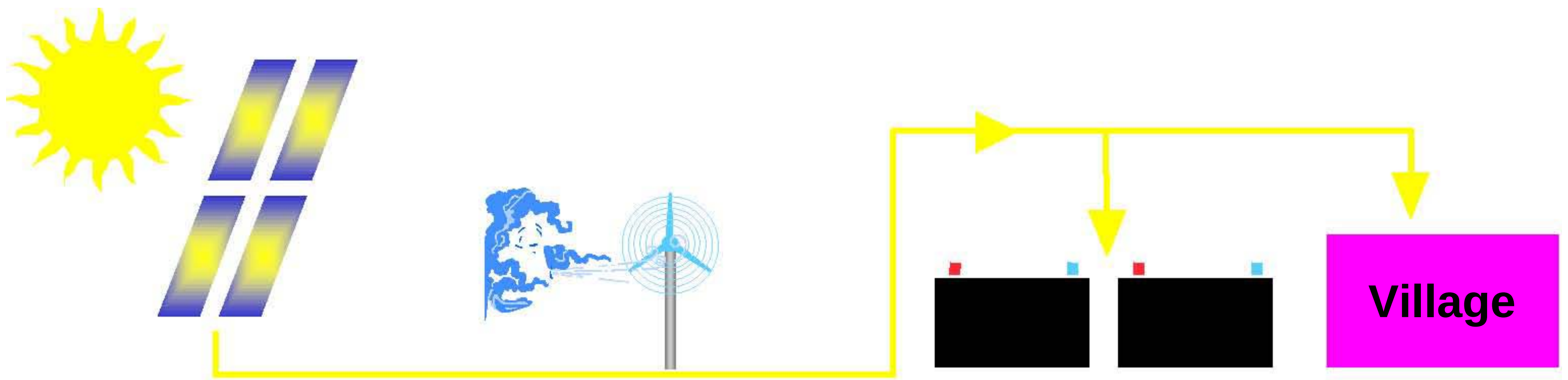
Proposed NEPAD projects

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

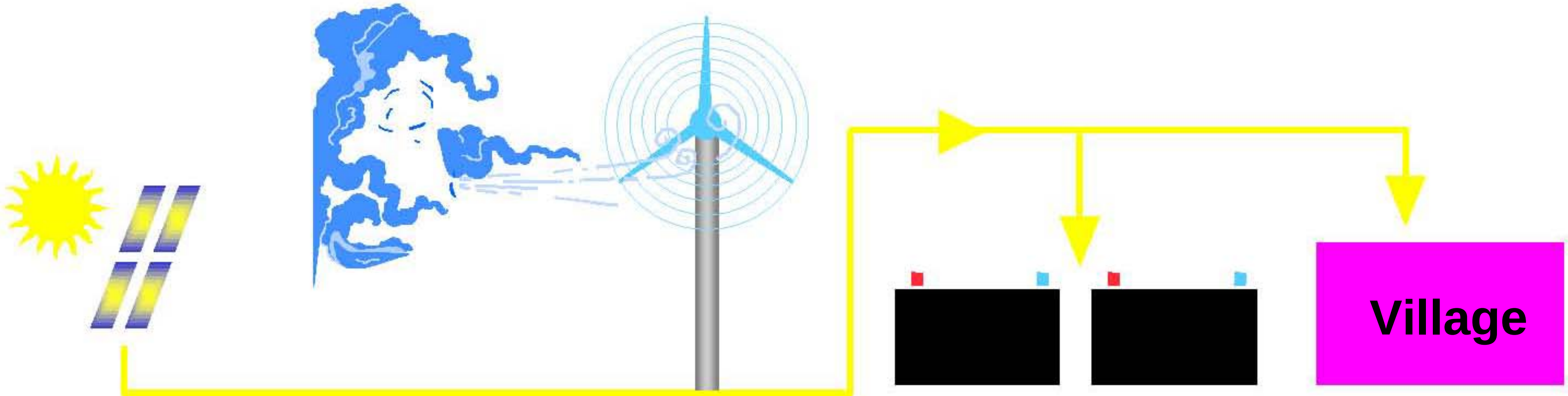
Hybrid Solar, Wind, Diesel Systems for Village Power



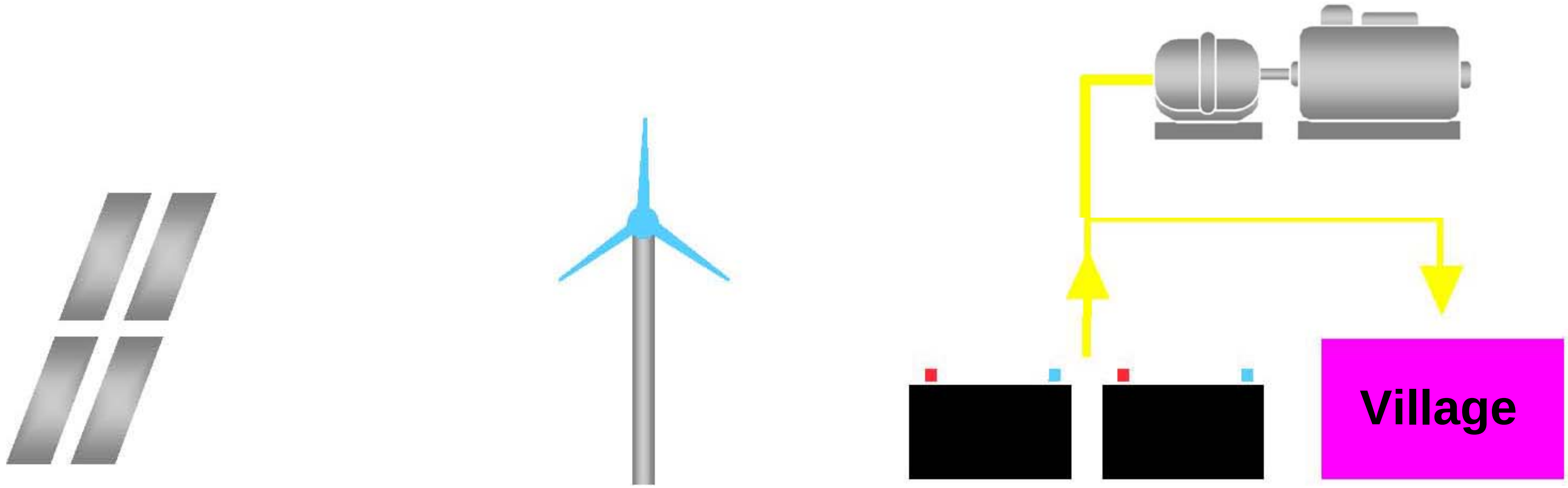
Sunny days produce energy from the solar arrays



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

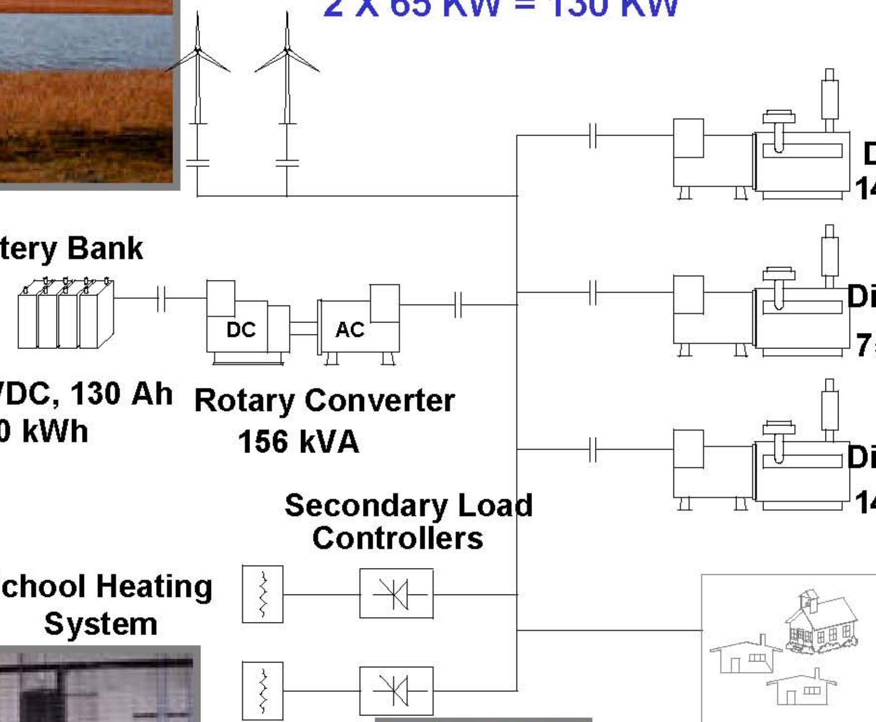
Remote installation

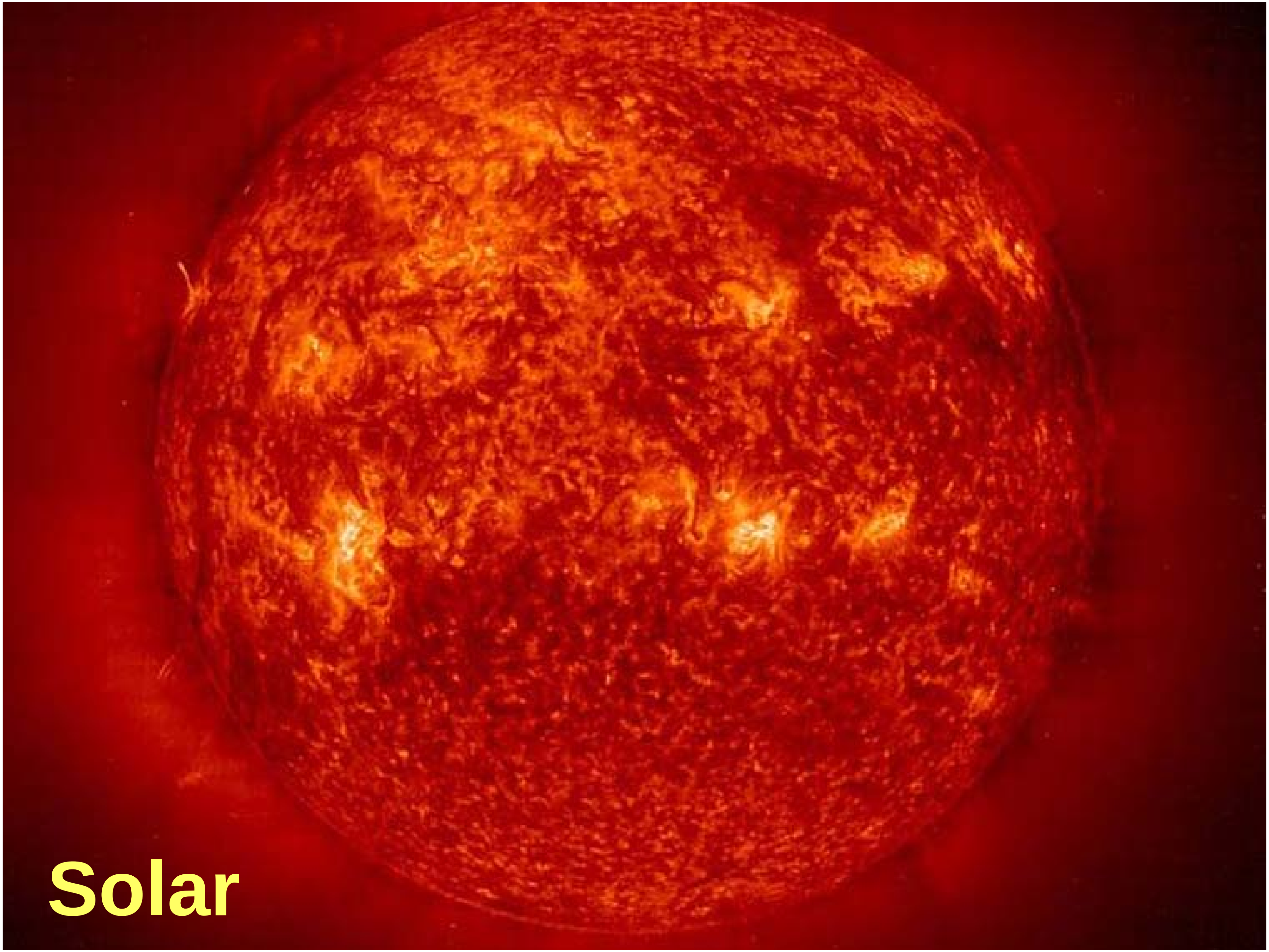
EDELAYSEN S.A.

saesa

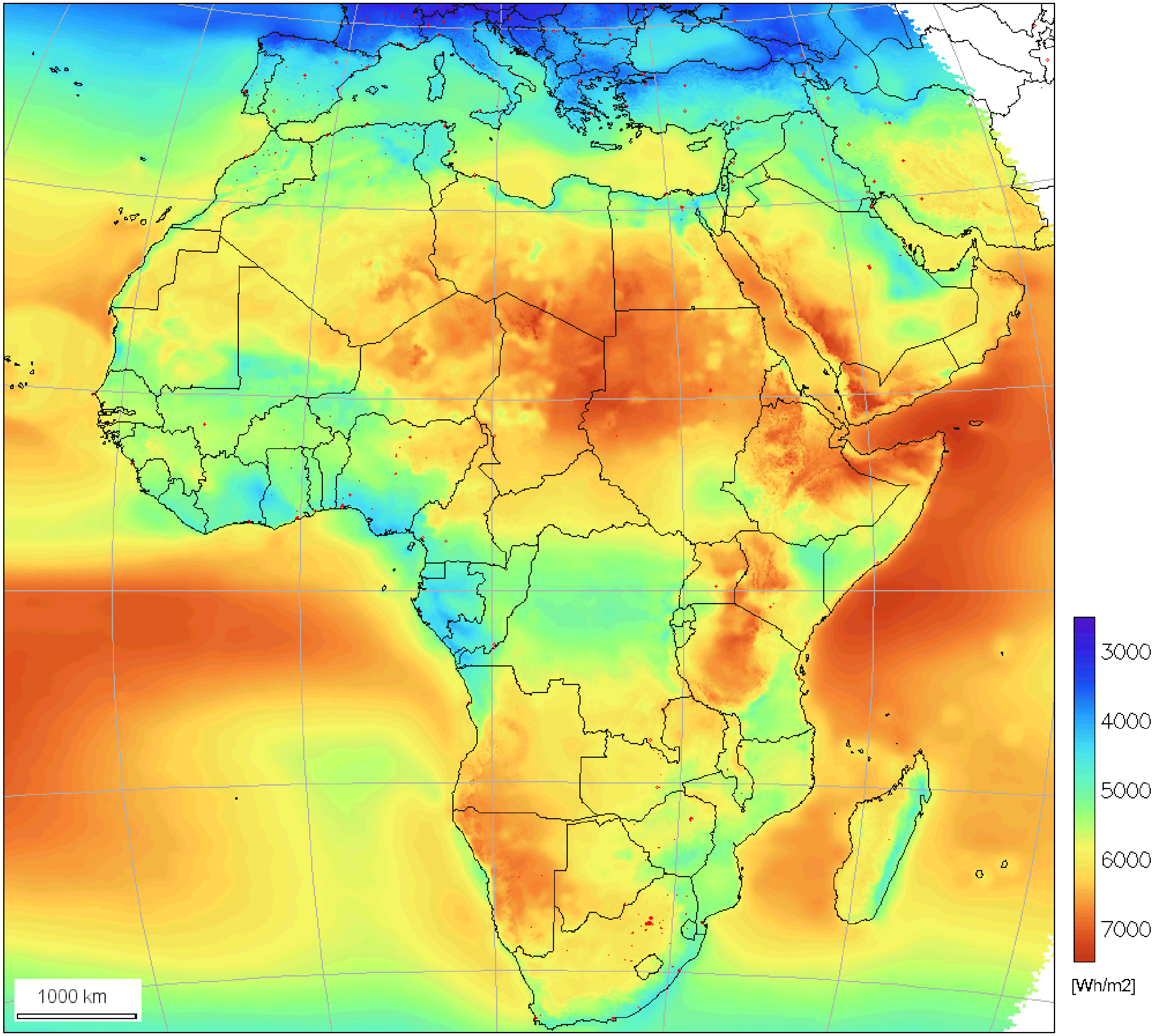
LA LUZ DEL SUR

Wales Alaska

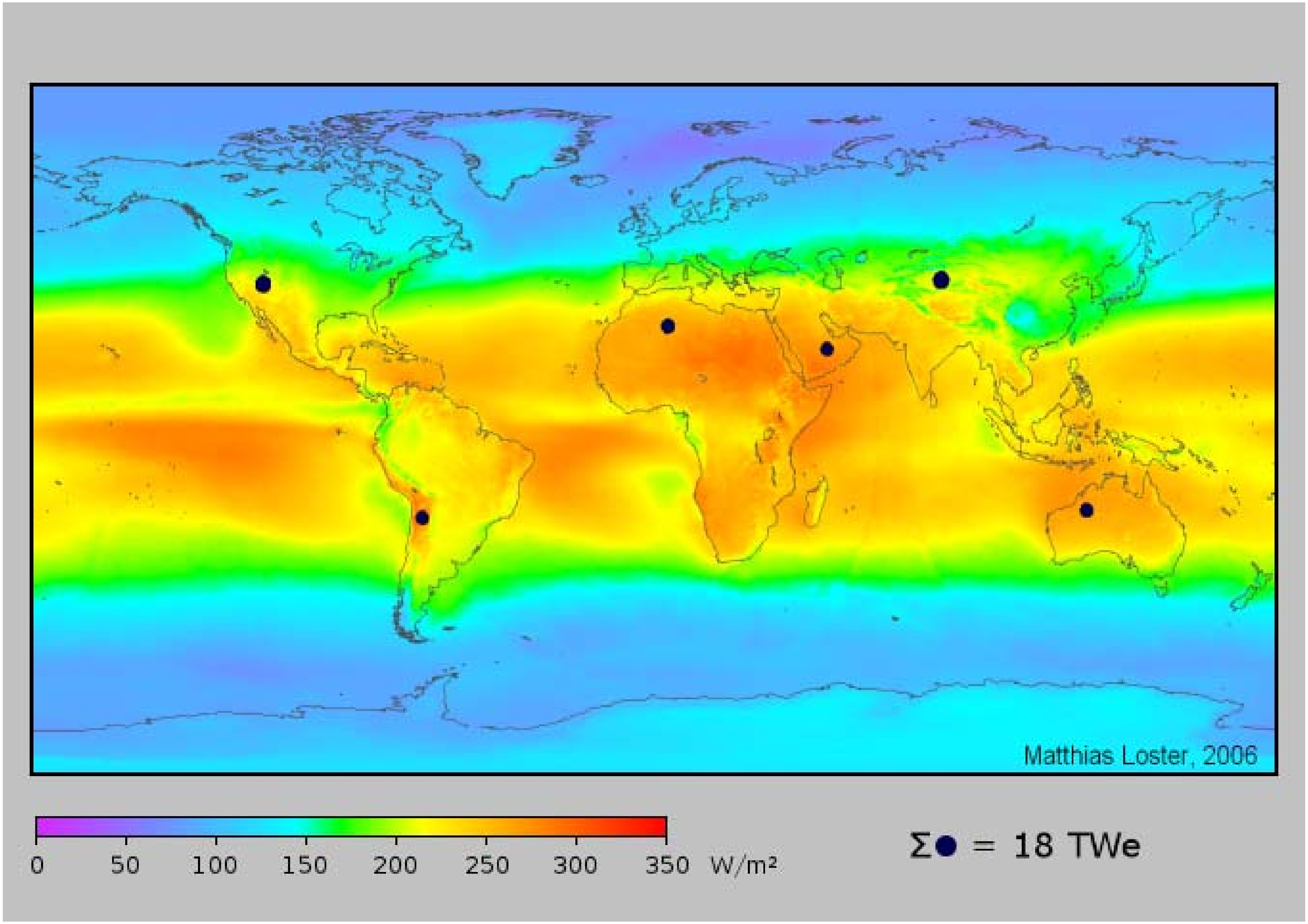


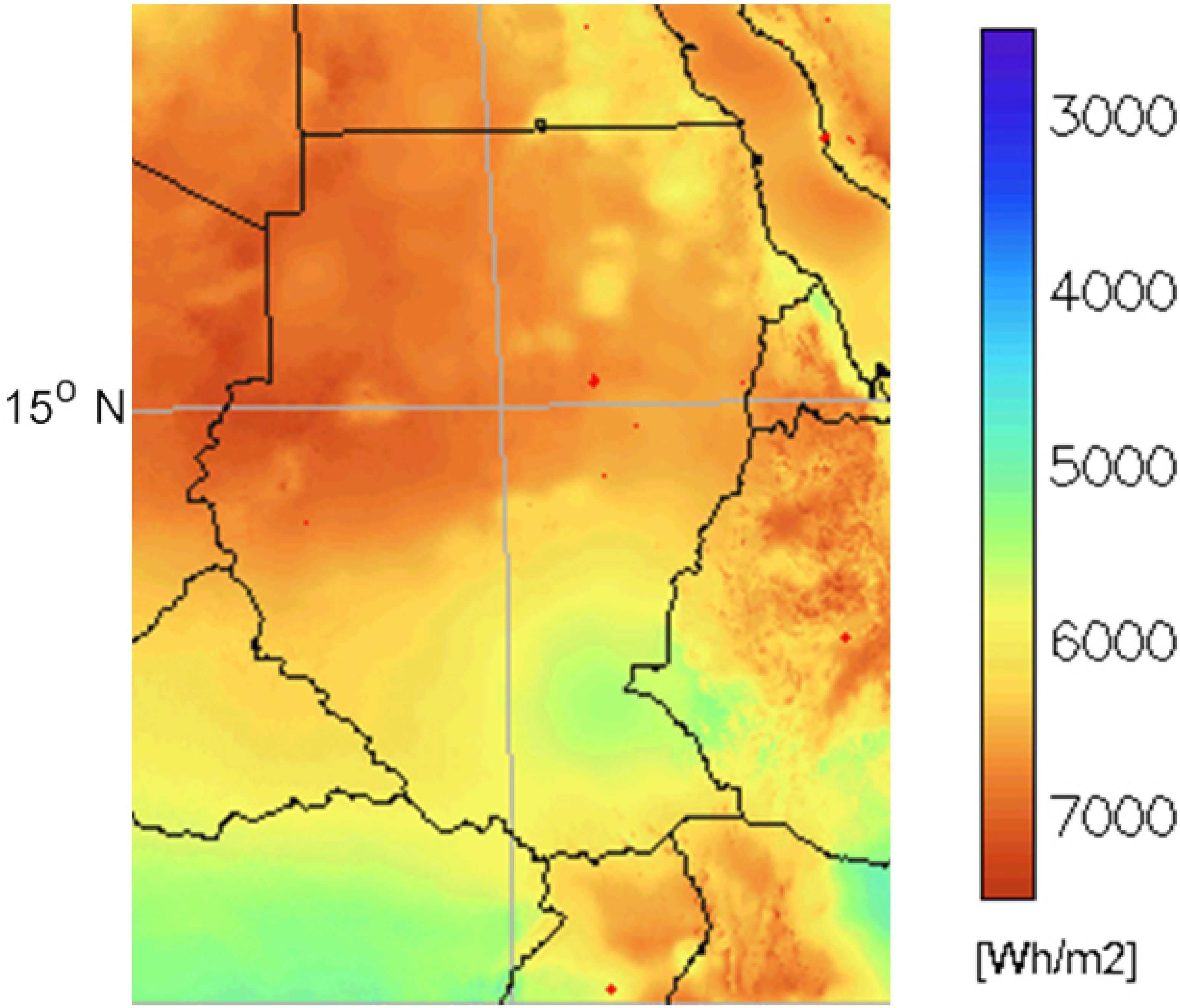

Solar

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



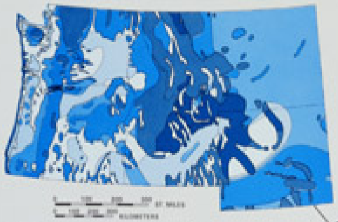
PV-GIS (c) European Communities 2002-2006
HelioClim-1 (c) Ecole des Mines de Paris/ARMINES 1985-2005
http://re.jrc.cec.eu.int/pvgis/pv/


Matthias Loster, 2006
0
50
100
150
200
250
300
350
W/m²
Σ● = 18 TWe


15° N
3000
4000
5000
6000
7000
[Wh/m2]

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)

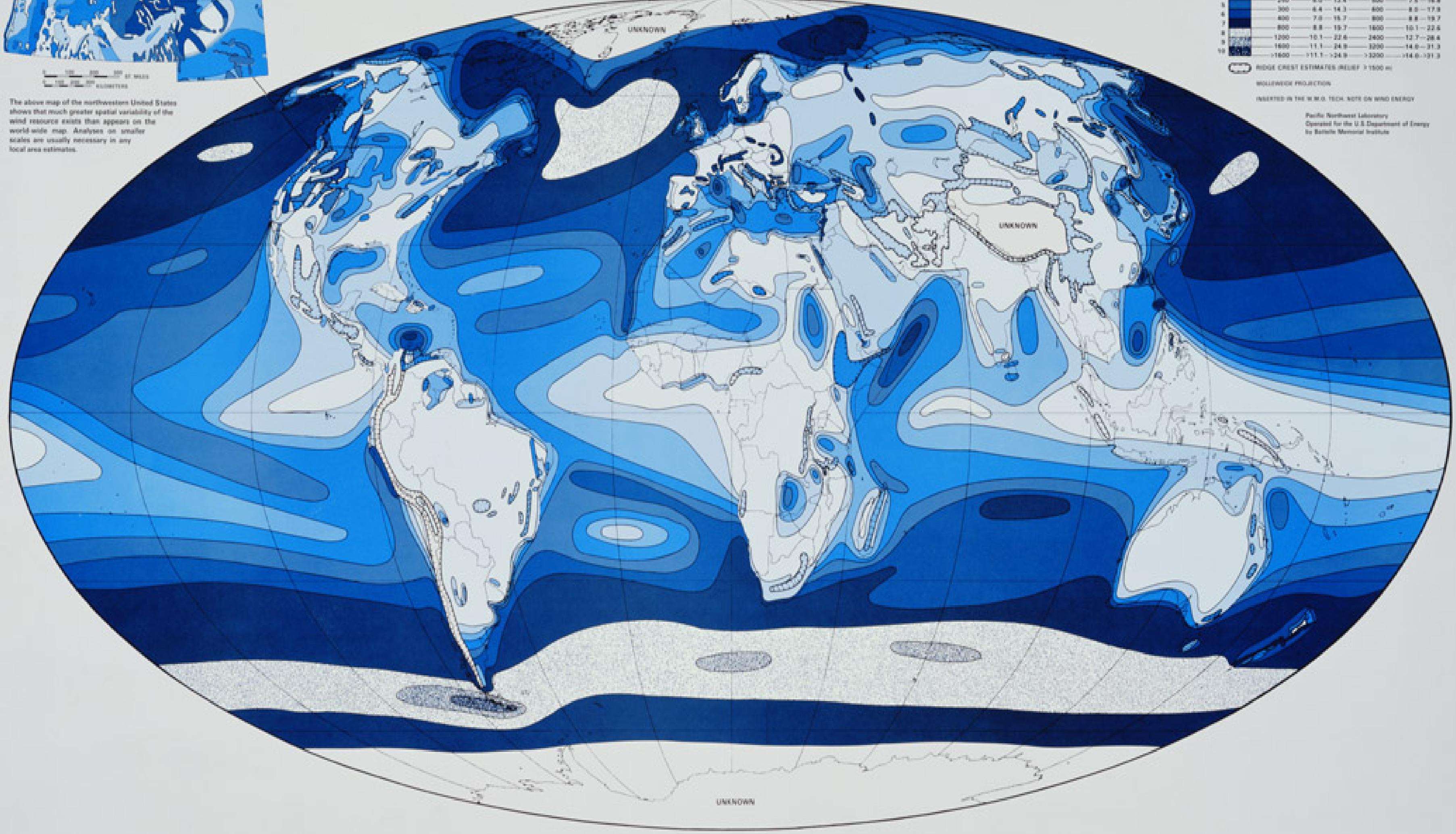
WIND ENERGY CLASS	10 m (33 ft) WEF W/m²	10 m SPEED m/s	10 m SPEED mph	50 m (164 ft) WEF W/m²	50 m SPEED m/s	50 m SPEED mph
	0	0	0	0	0	0
1	100	4.4	9.8	200	5.6	12.5
2	150	5.1	11.5	300	6.4	14.3
3	200	5.6	12.5	400	7.0	15.7
4	250	6.0	13.4	500	7.5	16.8
5	300	6.4	14.3	600	8.0	17.9
6	400	7.0	15.7	800	8.8	19.7
7	800	8.8	19.7	1600	10.1	22.6
8	1200	10.1	22.6	2400	12.7	28.4
9	1600	11.1	24.9	3200	14.0	31.3
10	>1600	>11.1	>24.9	>3200	>14.0	>31.3

RIDGE CREST ESTIMATES (RELIEF > 1500 m)

MOLLWEIDE PROJECTION

INSERTED 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.

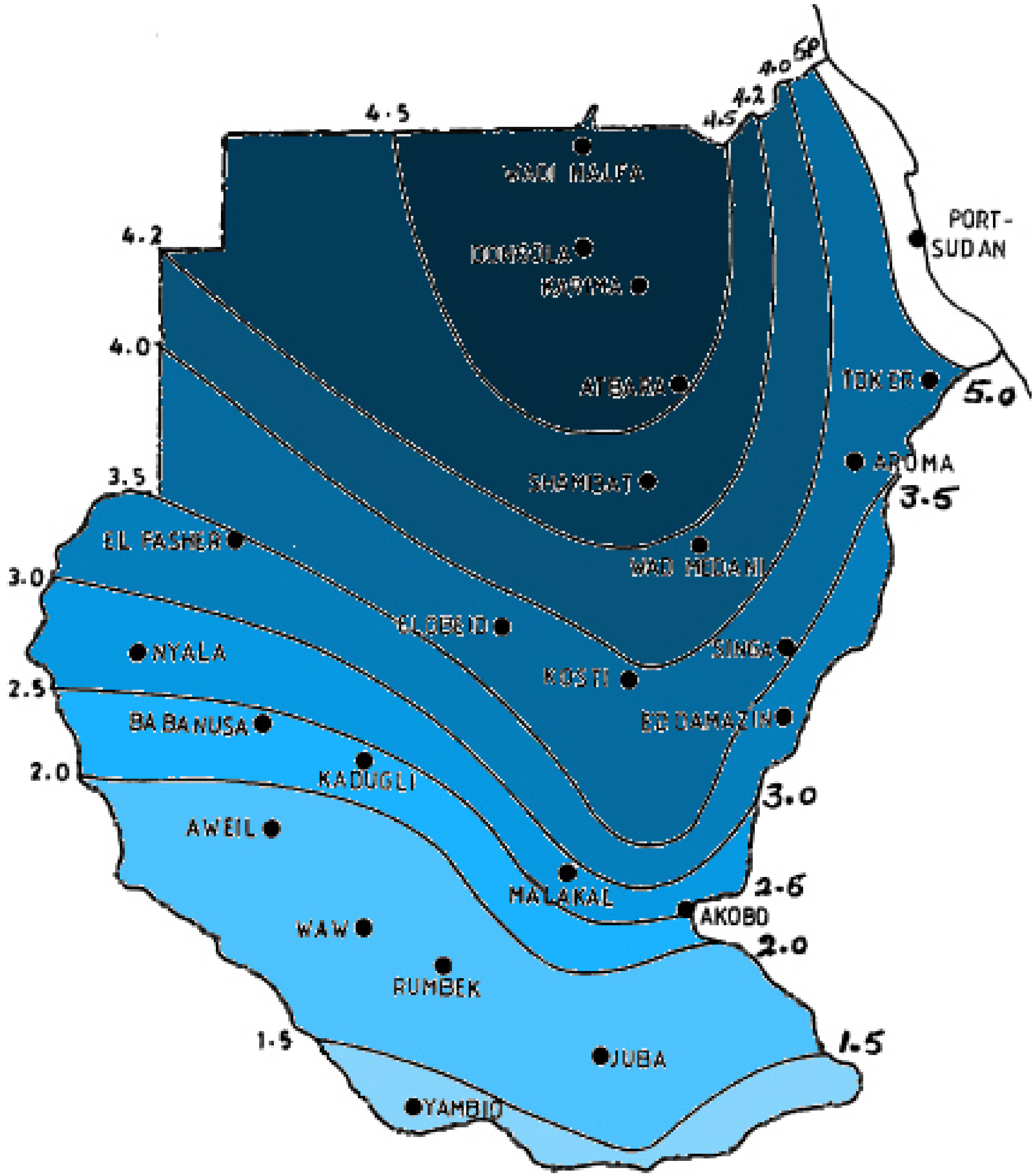
BACKGROUND INFORMATION

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 persistently 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.

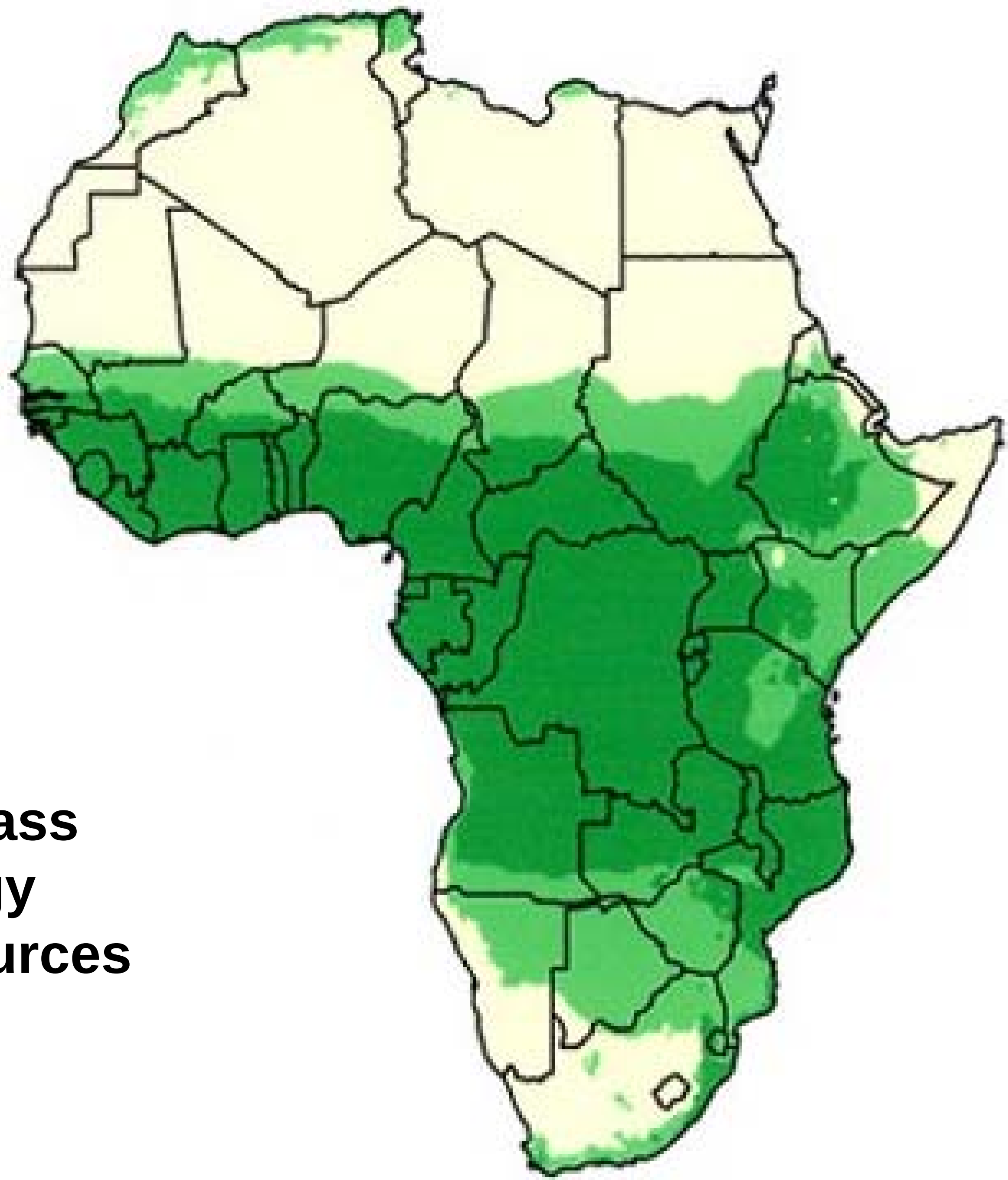


Annual Average Wind Speed (m/s) at 10m height

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

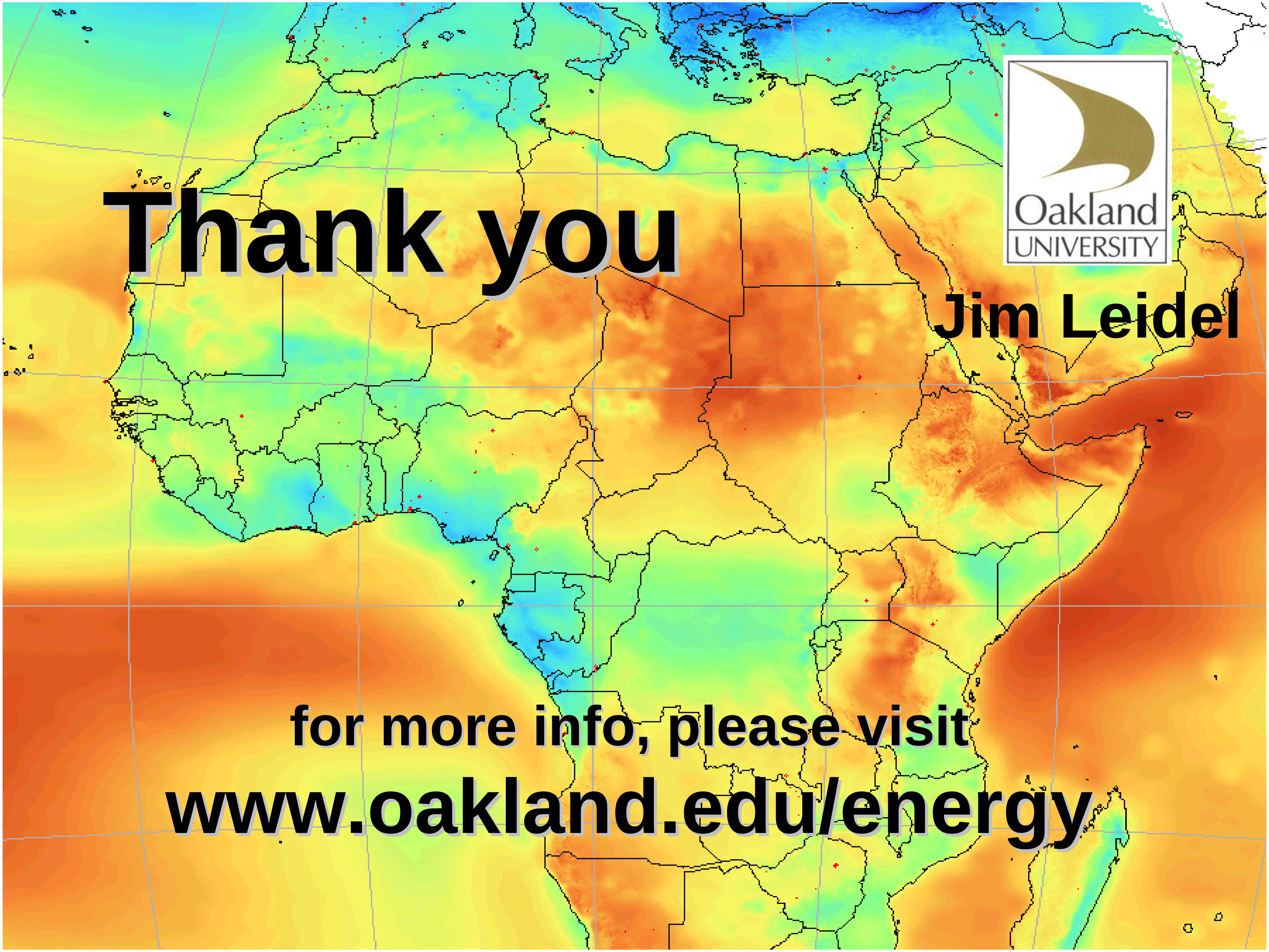
BioMass



Biomass Energy Resources

Jatropha for Bio-Oil





Thank you
Oakland UNIVERSITY
Jim Leidel
for more info, please visit
www.oakland.edu/energy