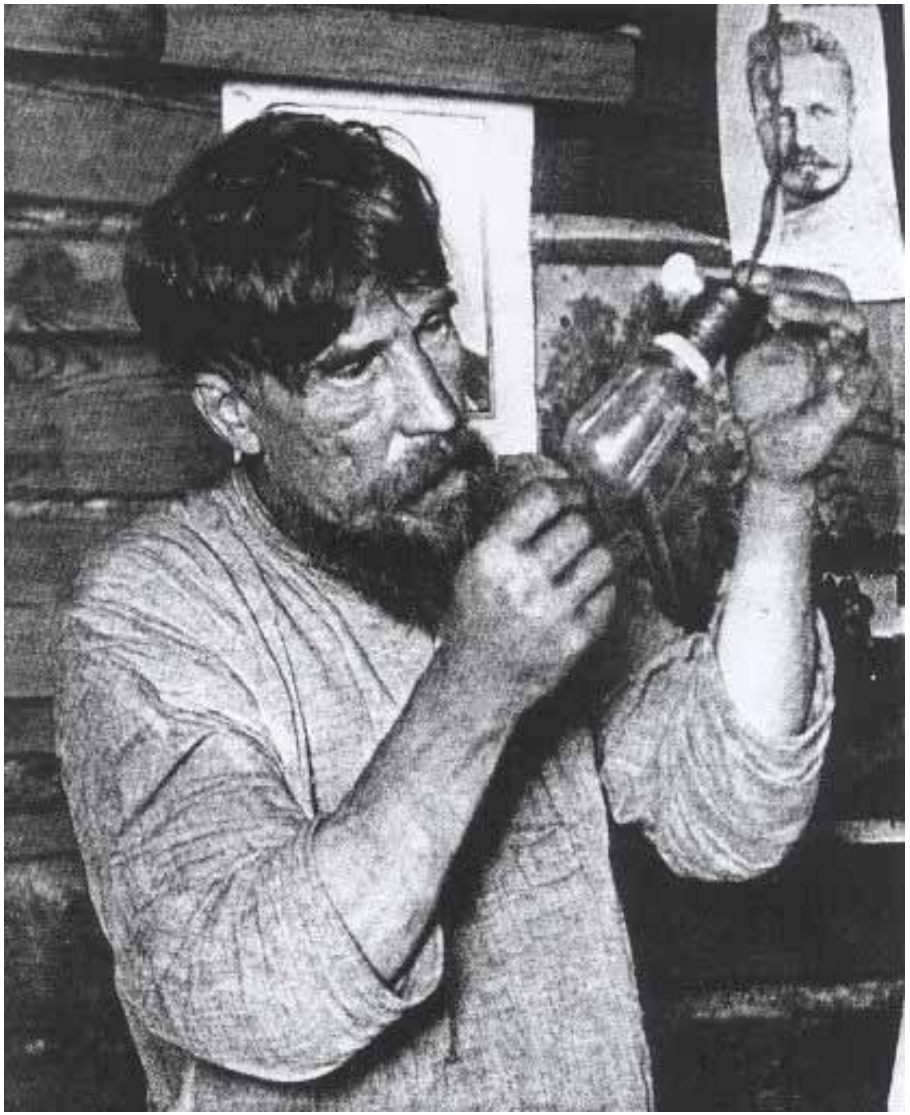
Workshop GTZ – Electrobras:
Photovoltaics in Rural Electrification
– Experiences, Opportunities and Challenges

Rio de Janeiro, Brazil, 17th of November 2006

Photovoltaics in Rural Electrification – Experiences from Other Countries

Hansjörg Gabler

Zentrum für Sonnenenergie- und Wasserstoff-Forschung (ZSW)
Baden-Württemberg



W. I. Lenin:

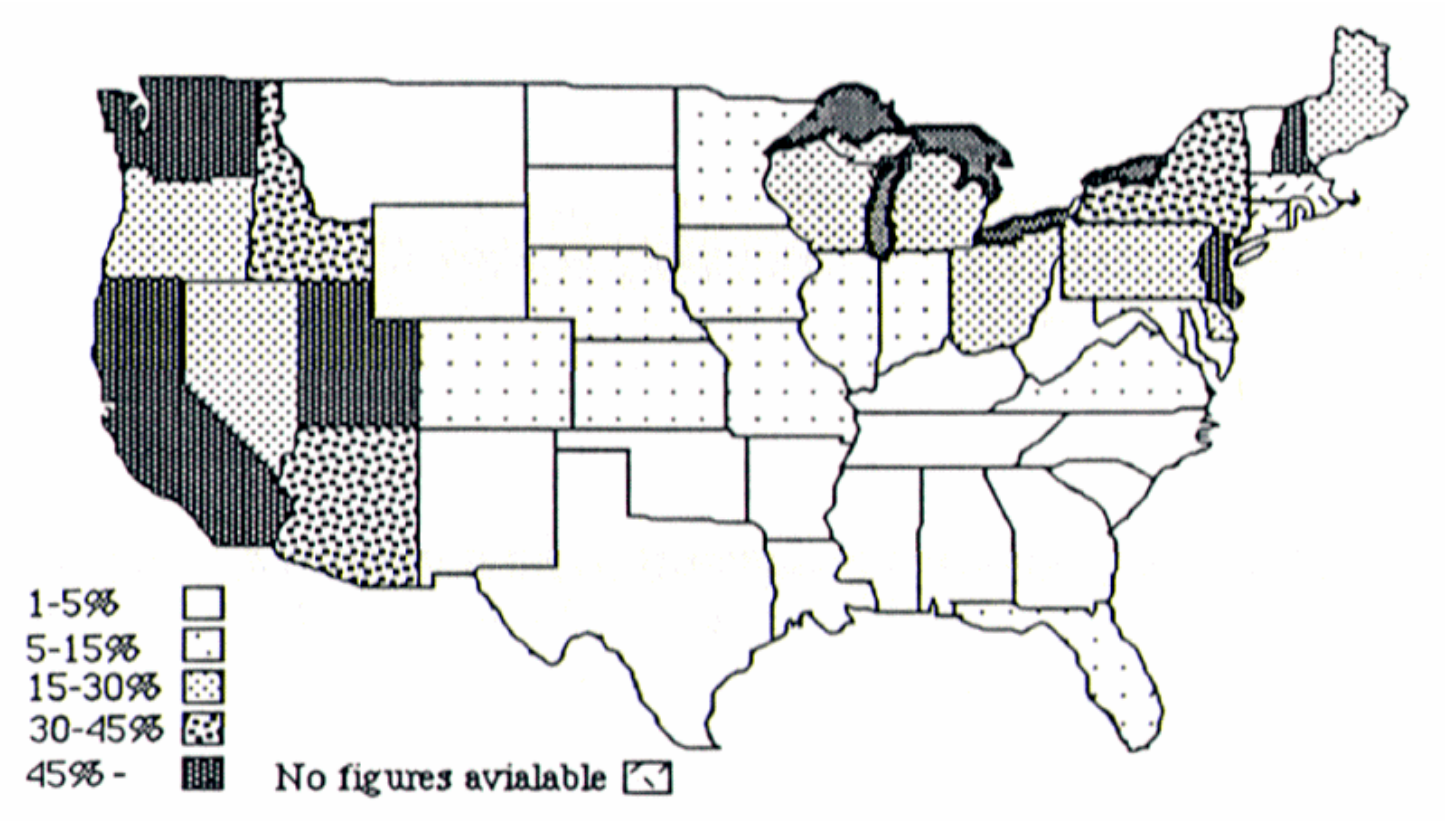
Communism - that is:

Power to the councils of the people
plus
electrification of the whole country

(22. December 1920)

Arkadi Schaichet: Iljitschs Lämpchen

(Internationale Werkbundausstellung Film und Foto
Stuttgart, 1929)



Source: Map drawn from statistics in *People – Their Power: The Rural Electric Fact Book*. Washington, D. C.: National Rural Electric Cooperative Association, p. 162.

Figure 7.2: Distribution of rural electrification in 1935

From: Electrifying America – Social Meanings of a New Technology
David E. Nye, MIT-Press (1990)

Figure 8.2
Linesmen at work, c. 1938.
Library of Congress. Photograph
by Dorothea Lange.

From:
Electrifying America – Social Meanings
of a New Technology
David E. Nye, MIT-Press (1990)

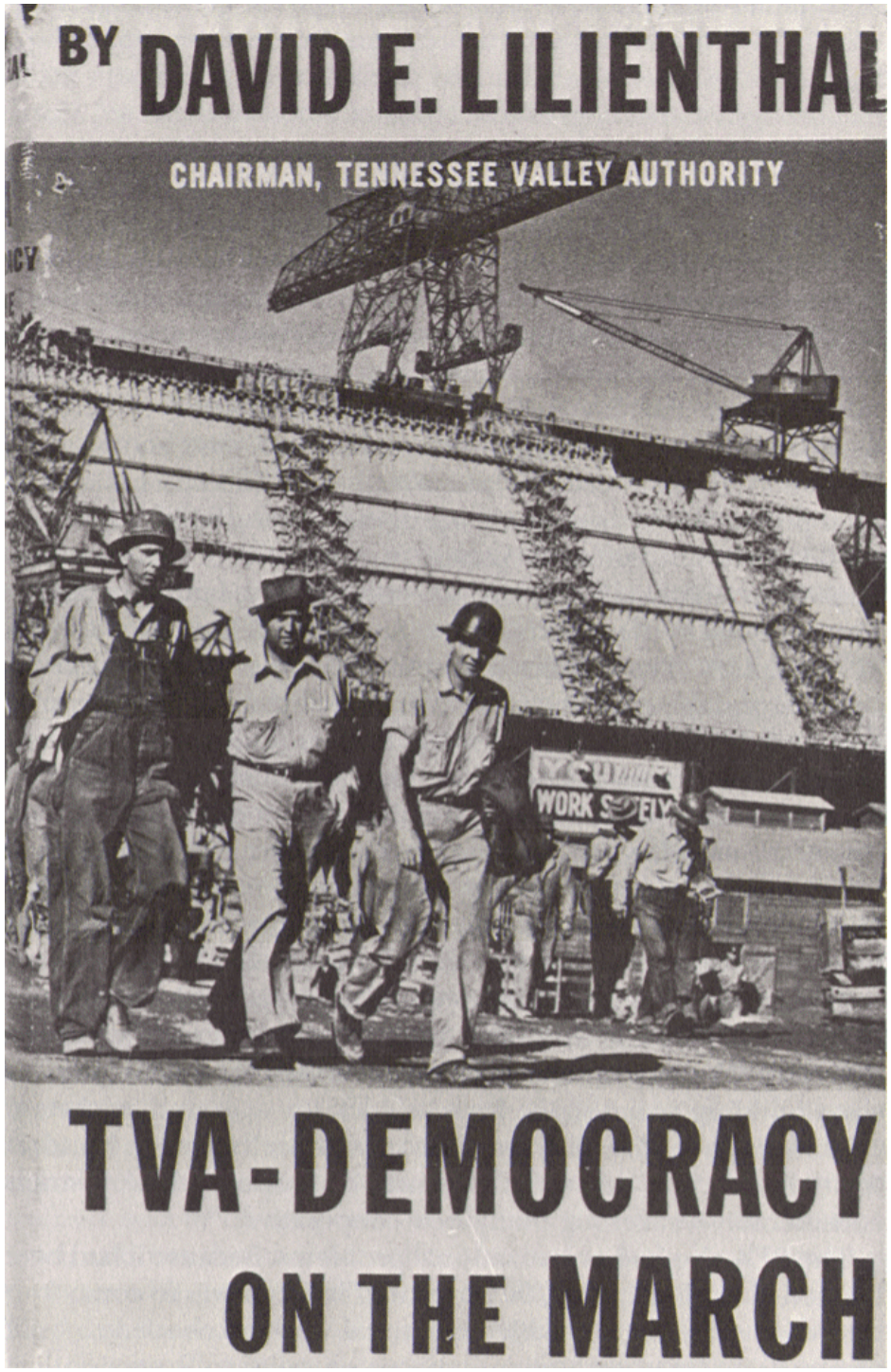


Figure 7.4
TVA-Democracy on the March, dust jacket, 1944.

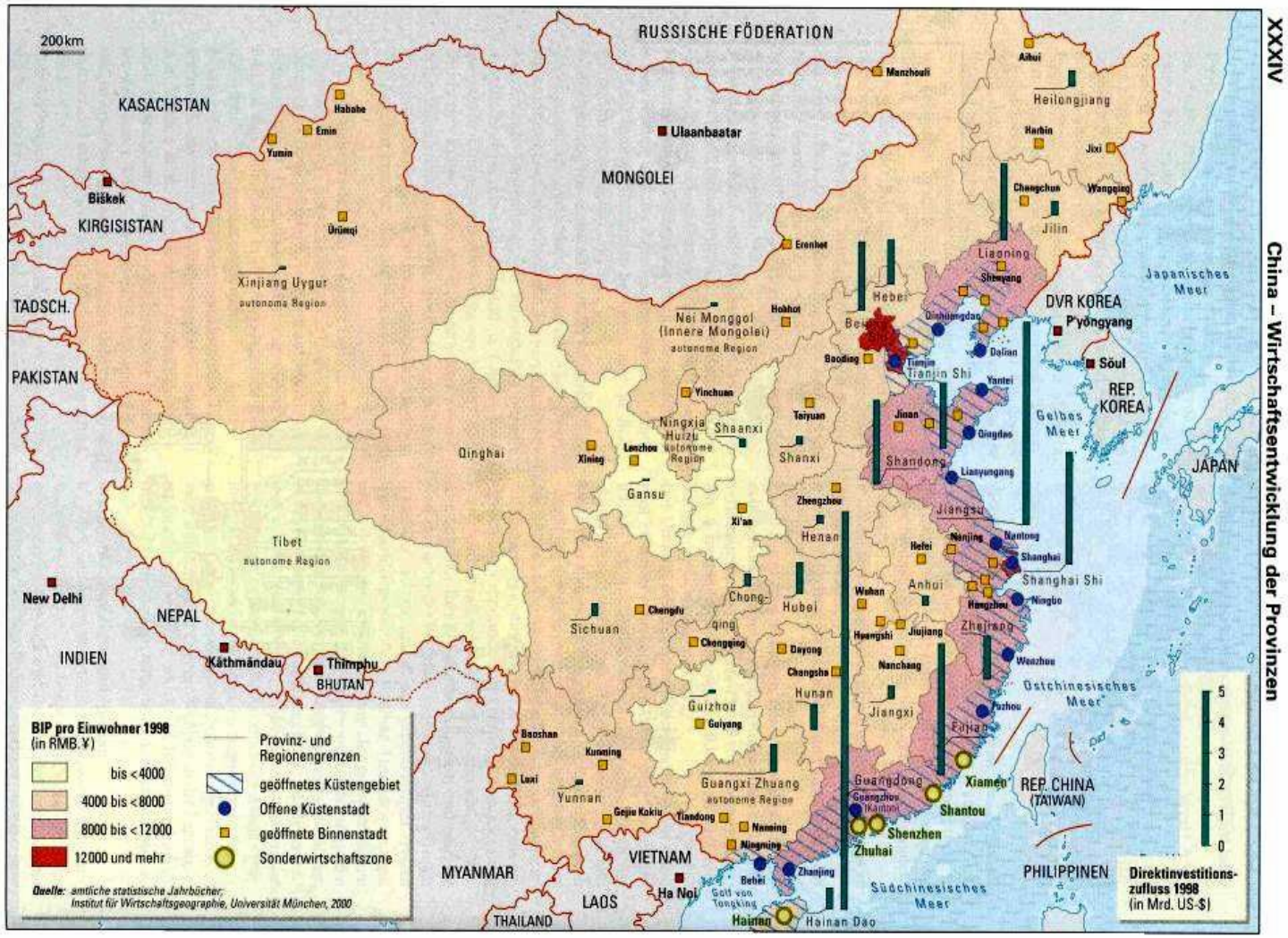
From:
Electrifying America – Social Meanings of a New Technology
David E. Nye, MIT-Press (1990)

Electrification as a symbol
of wealth in the countryside

China 1973

For a community to raise itself out of subsistence and into an upward spiral of increasing prosperity, certain basic services must be available and affordable. These include potable water, health care, education, transportation, and communication. Access to electrical power is both a precondition for the provision of many of these services, and an active agent in catalysing further advancement.

From: China Village Power Project Development Guide book:
Getting Power to the People Who Need it Most, August 2002



China, distribution of economic development

Source: Fischer Weltalmanach 2003

Non-Electrification in the P. R. of China

70 - 80 million people without electricity supply from the utility grid

„It is planned that 23 million people in remote areas shall be electrified by wind and (solar) PV-technologies till 2010."

Plan of first Brightness Programme
of China, JKD, July 1999

"Wind and solar technologies"!

Expected results of the first phase of the Brightness Program (ending 2005)

- Supply 1.78 Mio individual households, 2000 villages and 200 stationary systems
- Install realistic financing mechanisms
- Set up a system supply industry which can provide high quality products
- Set up a distribution and service network
- Install a technical training system for different levels of training

GTZ supported the Chinese government among other activities through training programmes and technical monitoring programmes.

ZSW and Fraunhofer-ISE held training courses on behalf of GTZ in China on off-grid village electrification and installed data monitoring equipment.

The Chinese National Township Program, Status of realisation by end of the year 2005

Province	Number PV/ (wind) hybrid systems	Installed power PV (kW_p)	Ø – Installed power (kW_p)	Number of installed SHS	Installed power (kW_p)
Hunan	1	20	20	0	0
Shaanxi	9	100	11.1	0	0
Qinghai	112	2715	24.2	6800	136
Gansu	23	995	43.2	0	0
Xinjiang	159	2378	14.9	7133	356
I. Mongolia	42	752	17.9	1525	610
Sichuan	46	1817	39.5	0	0
Tibet	329	6763	20.6	0	0
Total	**721**	**15540**	**21.5**	**15458**	**1102**

Sites of the photovoltaic village systems in the “Township Program”

Village (township) Naomugen, Inner Mongolia Autonomous Region

Naomugen, power house and PV generator

Naomugen: programming PV charge controller

Naomugen Village

Load:	20 - 50 households
PV generator:	4,800 W, mono-X, local
DC voltage:	48 V
Charge controller:	5 strings à 960 W
Wind turbine and wind controller:	Wenus (1995), 3.75 kW
Battery:	Maintenance free, AGM, 2 x 24 x 400 Ah = 38 kWh
AC distribution:	3 x 3.5 kVA

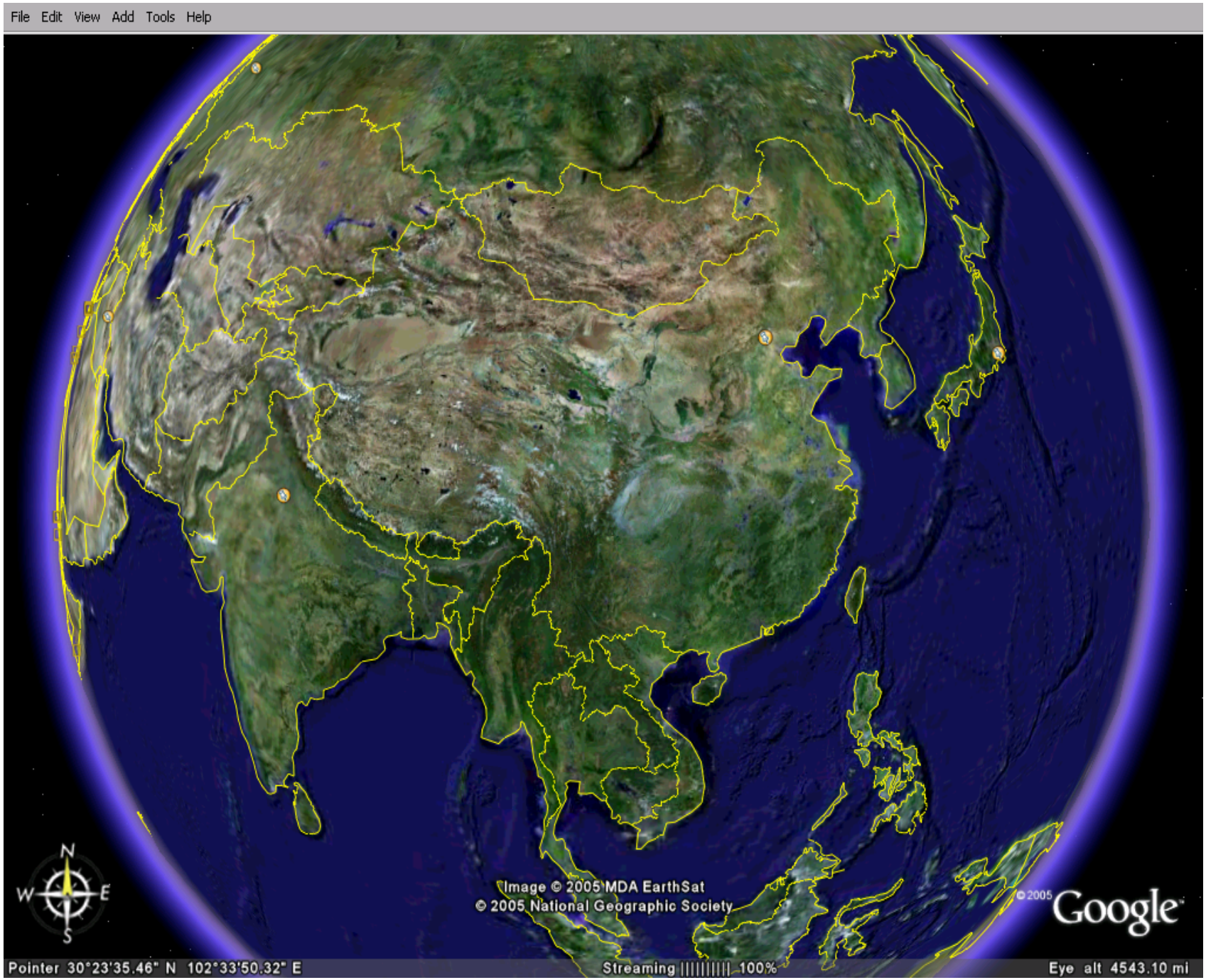

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Image © 2005 MDA EarthSat
© 2005 National Geographic Society
© 2005 Google
Pointer 30°23'35.46" N 102°33'50.32" E
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Suohourima township in November 2005,
Qinghai Province

Photovoltaic generator, 40 kW, in front of the new power house in Suohourima

Battery bank in the power house, AGM type, lead acid

Cabinets with inverters and AC-distribution. Typical chest freezer to the right

Suohourima Township

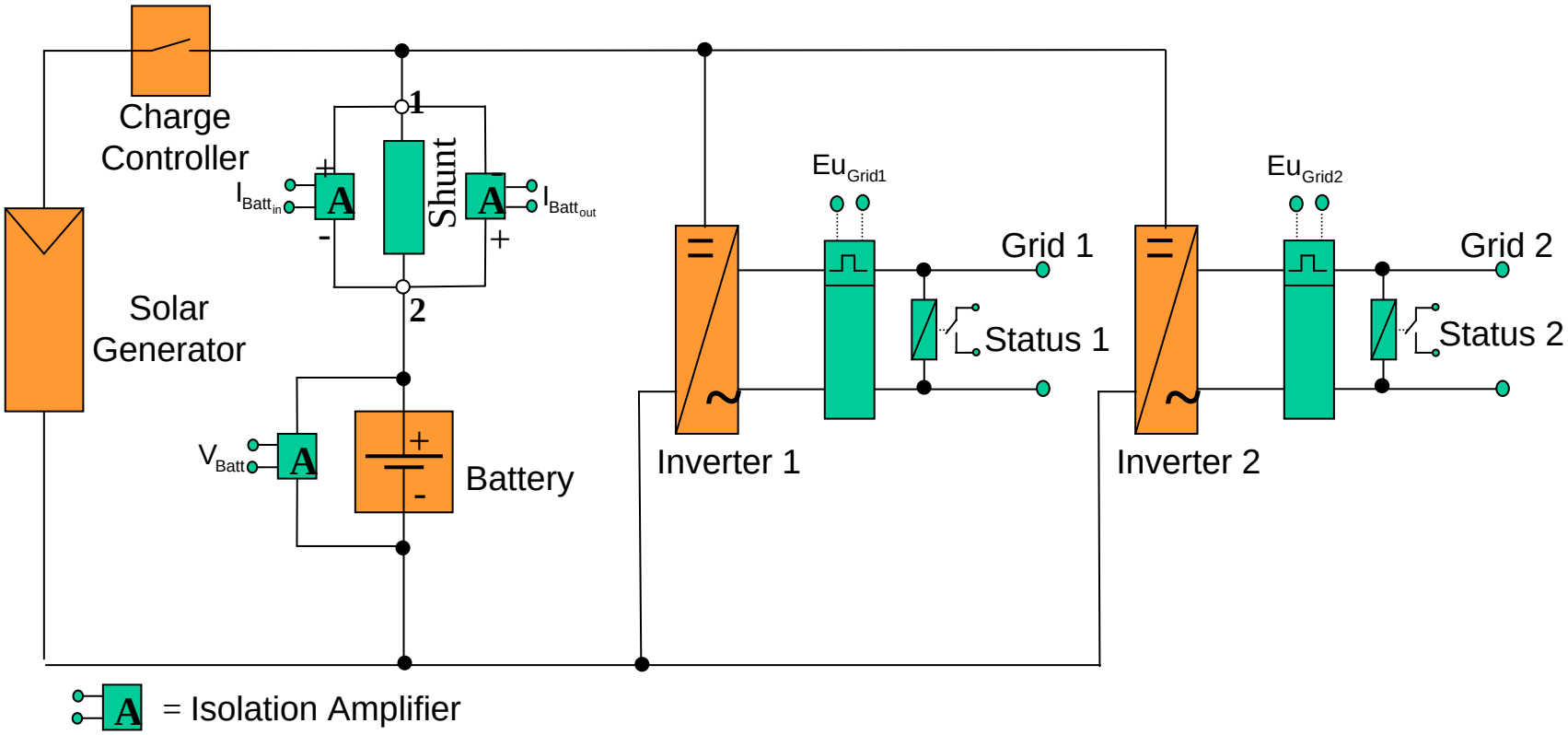
200 households and the public buildings (school, clinic, mayors office) are connected to the village grid

PV-generator	40 kW, 26 parallel strings with 18 modules, 85 W per module, manufacturer Qinghai Gaofai, cells from Astropower, US
Charge controller	13 channels, µC-controlled, sub arrays are switched off at the end of charge voltage of the battery, manufacturer Hefei Sunlight Power
Battery	Sealed (AGM) lead acid battery, cells 2 V/1300 Ah, 3 parallel strings with 110 cells, 858 kWh, manufacturer Enersys Huada Solar

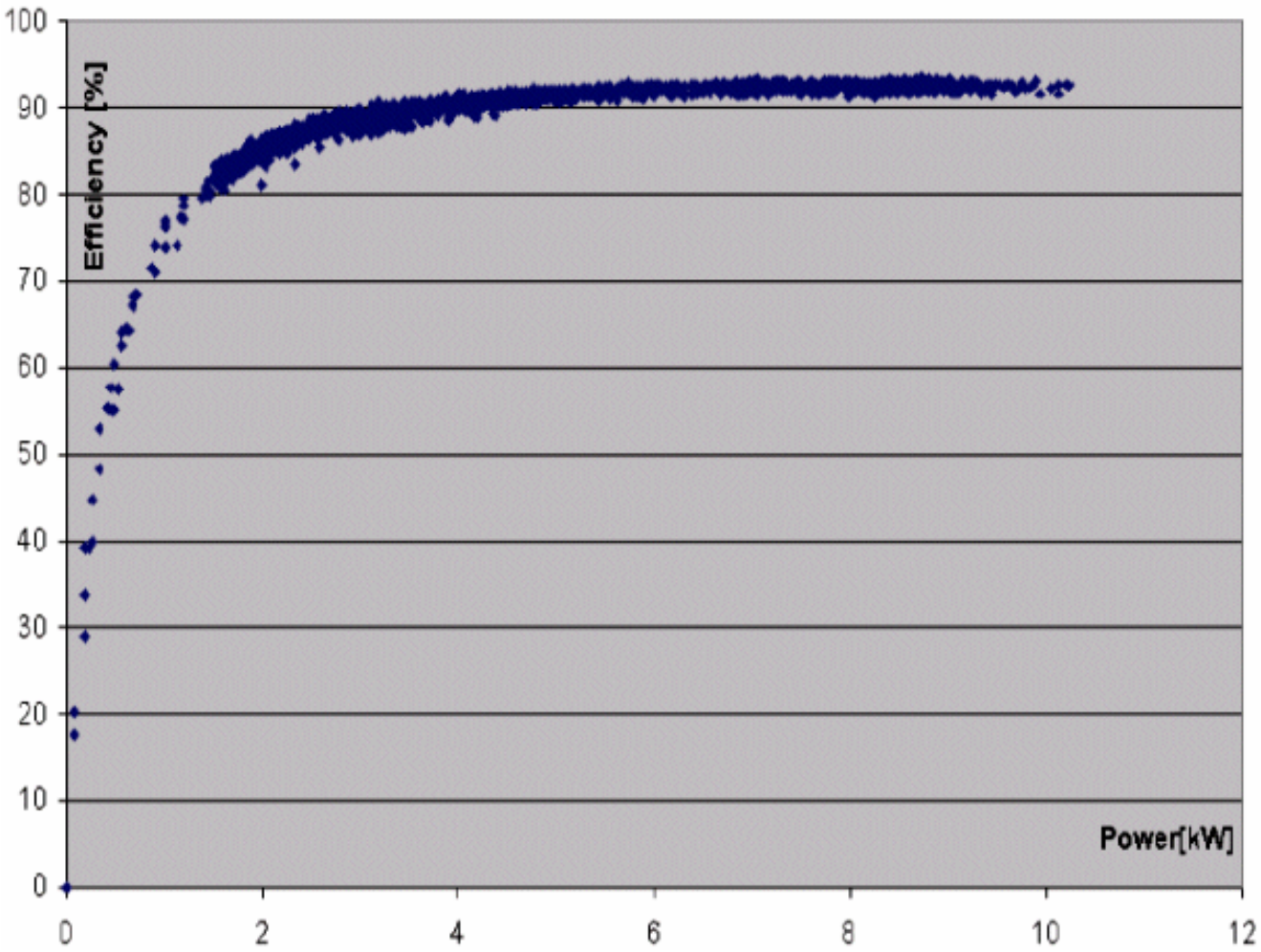
Inverters	PWM with transformer and µC-control, 220 VDC/220 VAC, 1 inverter with 16 kW, 1 inverter with 24 kW, manufacturer Hefei Sunlight Power
AC Distribution	2 isolated and not grounded single phase grids supply different parts of the township. The single households have electronic energy meters
Households	All electrified households have electric light (fluorescent lamps (9W) or incandescent lamps (40W)), 90 % of the households have colour TV + satellite receiver + DVD player, and chest freezer to store meat, more and more households have electric heating blankets and pillows, some have washing machines (for external hot water supply)

Street scene in Suohourima. Washing machine to the left

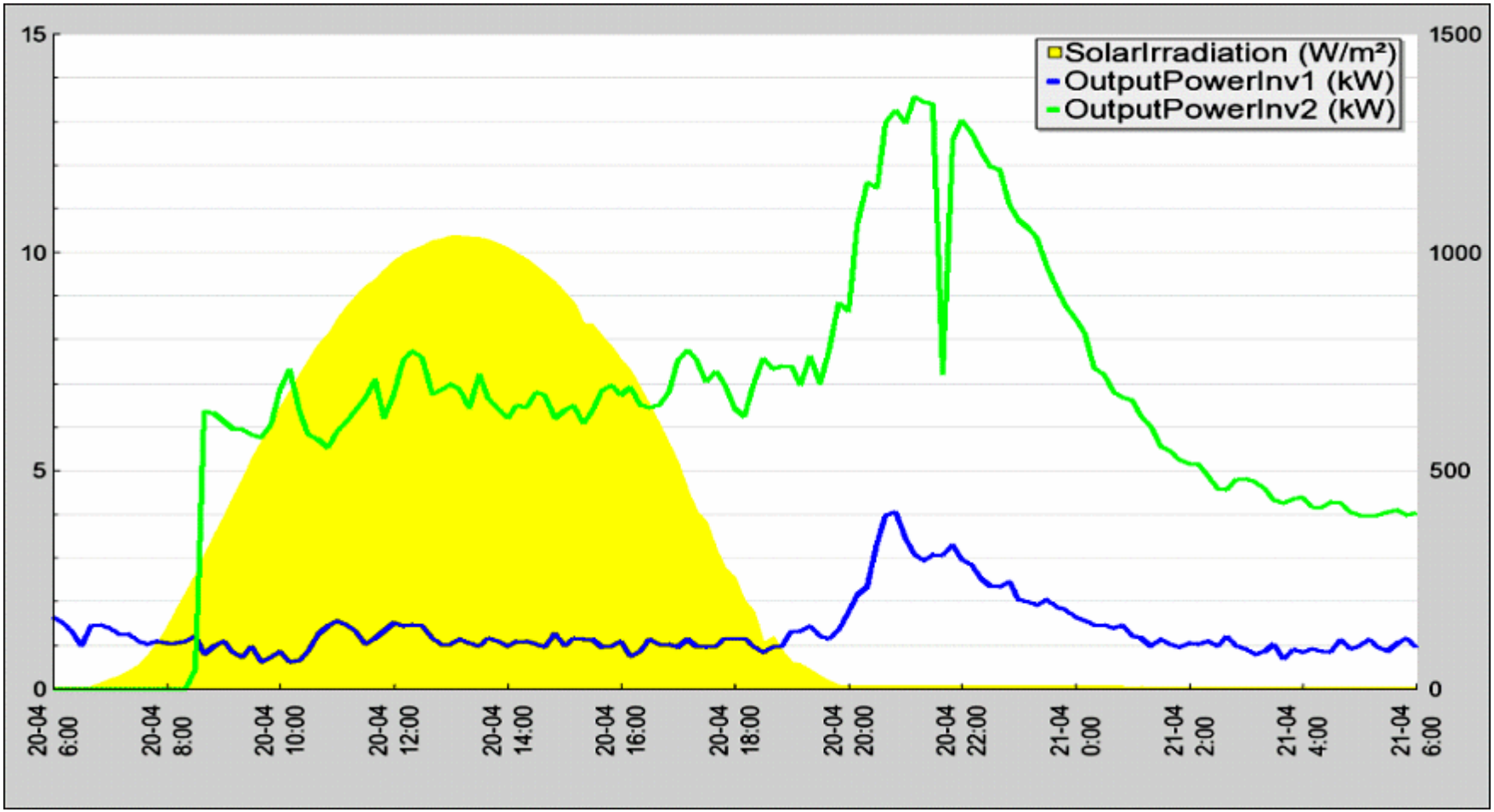
View into a living room of a school teacher: radio, TV with DVD, personal computer



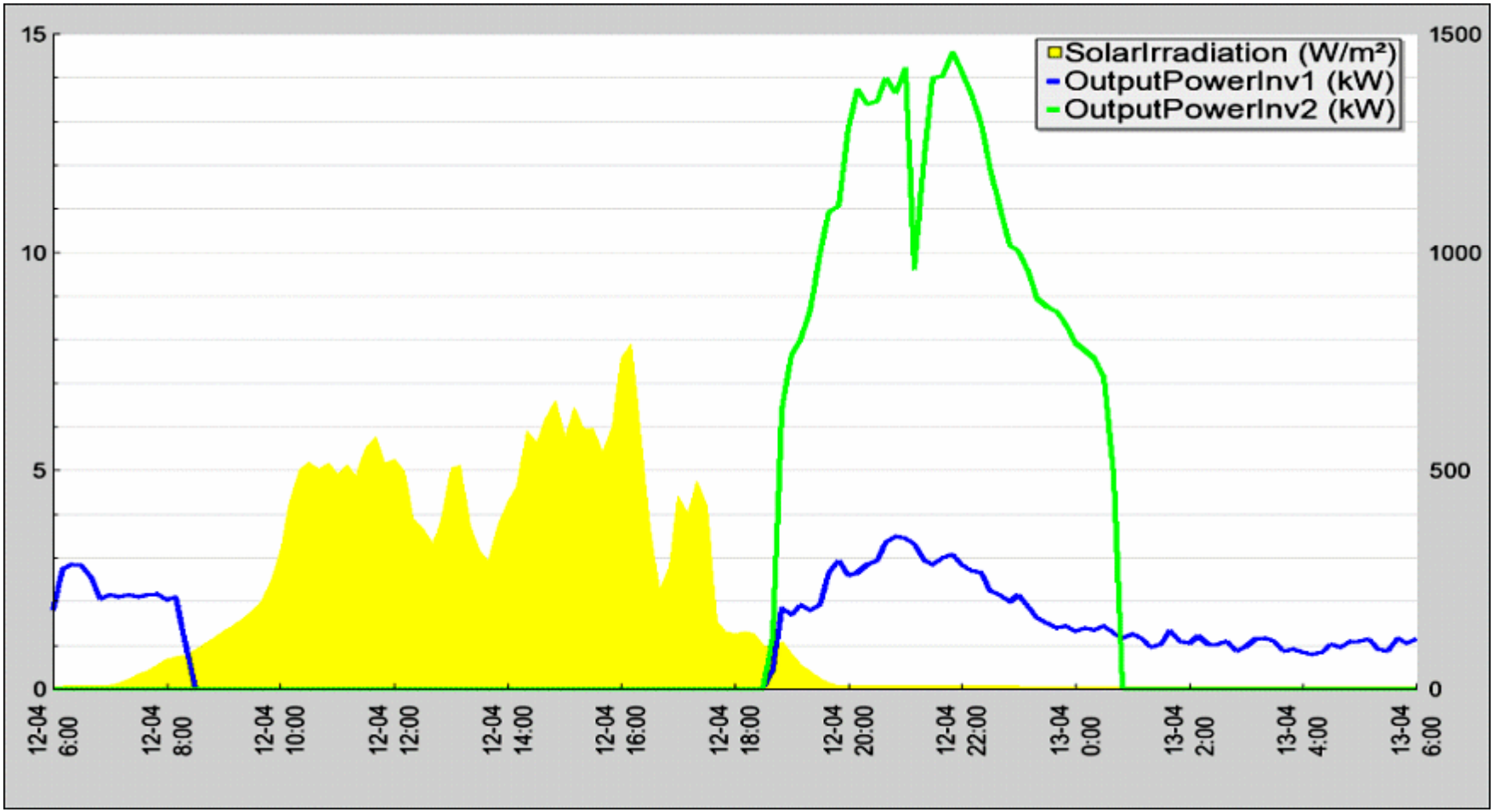
Basic layout a PV-battery village system.
The “small” data logging system, block diagram of measuring points.



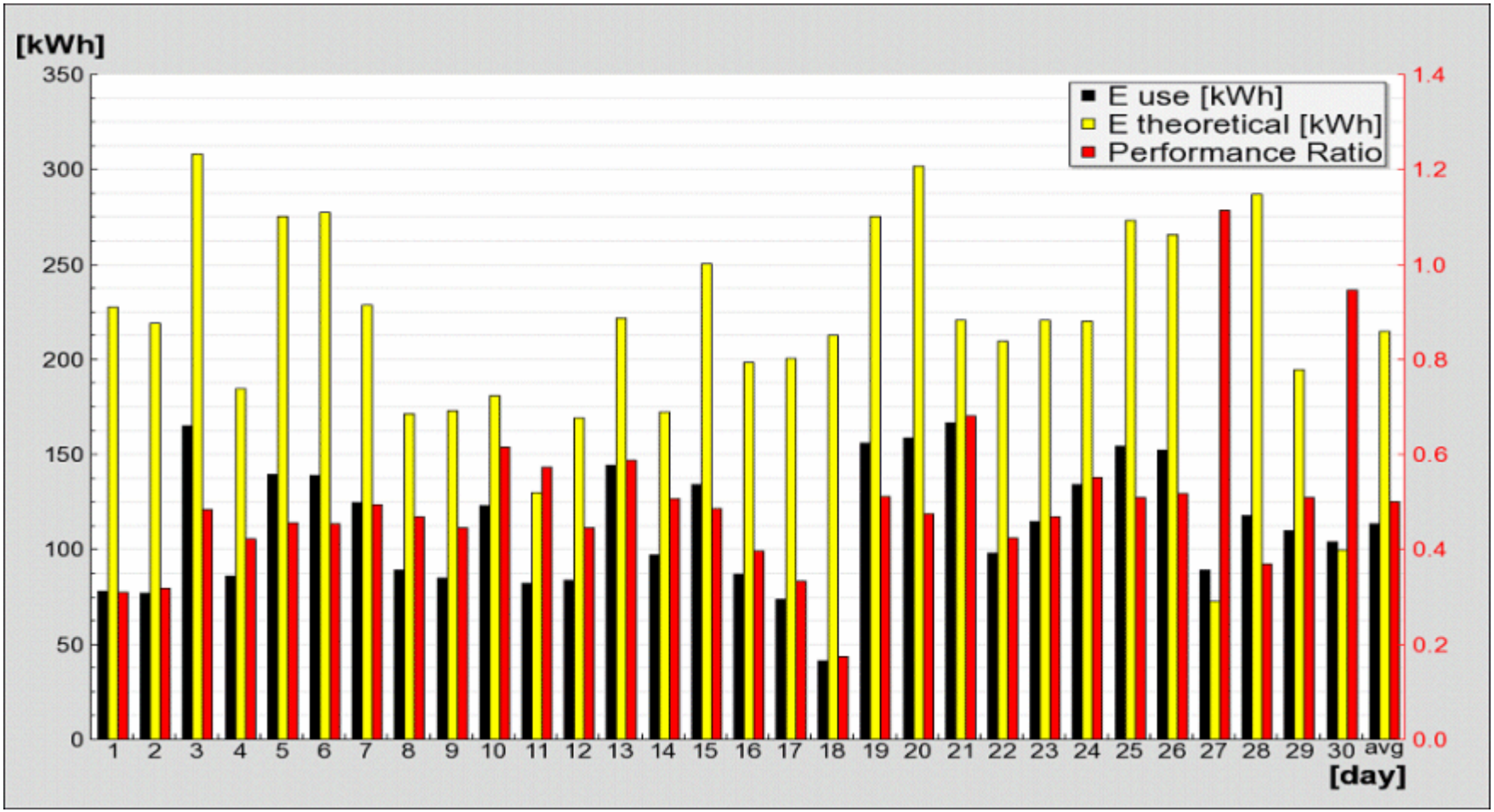
Efficiency of the 24 kW inverter at Suohourima, 10 min averages from one month



Solar irradiation and AC-output of the system Kesheng, 20.04.2006, clear day



Solar irradiation and AC-output of the system Kesheng, 12.04.2006, cloudy day



Daily values for utilized energy, nominal production and performance ratio, Kesheng, April 2006

Lessons learned

- Village supply systems work to satisfaction.
- Electricity is delivered according to energy availability (not for 24/24 hours).
- Electricity consumption in the households is between 0.3 and 1.0 kWh/day with considerable differences between the single villages. Consumption is comparable to grid electrified rural households.

“Normal” light bulbs found in many houses

There is not enough information and help (availability of products, financial help ...) for the users concerning appliances.

Example: Comparison of ‘Compact fluorescent lamps’ (CFL) of highest quality and ‘normal’ incandescent light bulb

	Price of lamp	Life time	Efficiency	Price of light
Bulb	1	1	1	5
CFL	10	10	5	1

Source: P. Adelmann, Geringer Preis – Hohe Kosten, Effiziente Verbraucher in Solar Home Systemen, 21. Symposium Photovoltaische Solarenergie (2006)
(Simplified seriously by the author of this paper)

Lessons learned (continued)

- There is room for optimisation: Reduce parasitic losses, make better use of “theoretical” energy availability through better instrumentation or automatic energy management.

- Necessary maintenance / component replacement (batteries) is not yet quantified.

- Long term regulations for system ownership, operation responsibility, financing mechanisms for component replacement not clarified in all provinces and in all details.

Economic analysis

Connection cost (grid extension) for a village 30 km from electricity grid incl. high voltage line, transformer, low voltage lines, substation, installation, project development, spare parts:

Households	Unit Investment Cost
300	1,000 US$/hh
100	2,500 US$/hh
30	7,700 US$/hh

Source: China village power project development handbook

Sino-German Financial Cooperation: Chinese Ministry for Finance / KfW

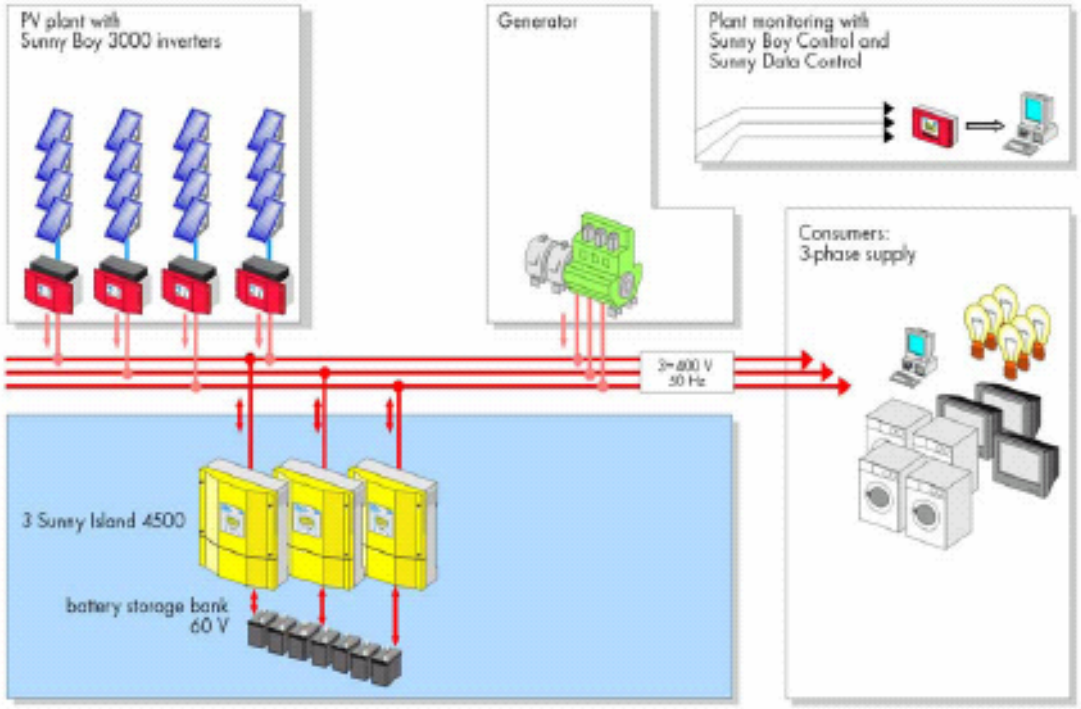
In four provinces of Western China 26 PV-Diesel Hybrid systems have been realised, 73 systems are under construction, ca. 40 systems are in the planning phase.

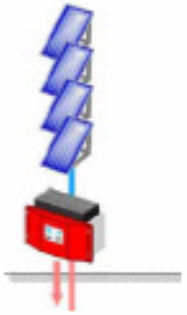
PV-modules and BOS components from German companies.

Village Power System in province of Xinjiang (3-phase)

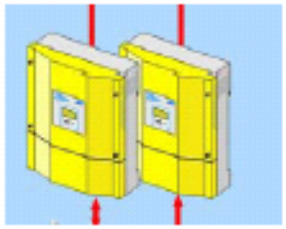
- Village with 52 households and 250 inhabitants

PV-Hybrid in province of Xinjiang (3-phase)

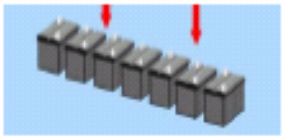




P_V= 9 kWp

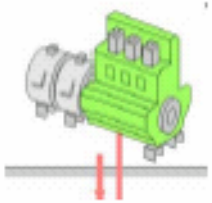


P_{AC}= 13,5 kW



E_{BAT}= 96 kWh

Altitude:	1500 m
Solar radiation:	2268 kWh/m²/a
Sunshine:	3240 h/a
Village area:	700x500 m



P_{GEN}= 15 kW

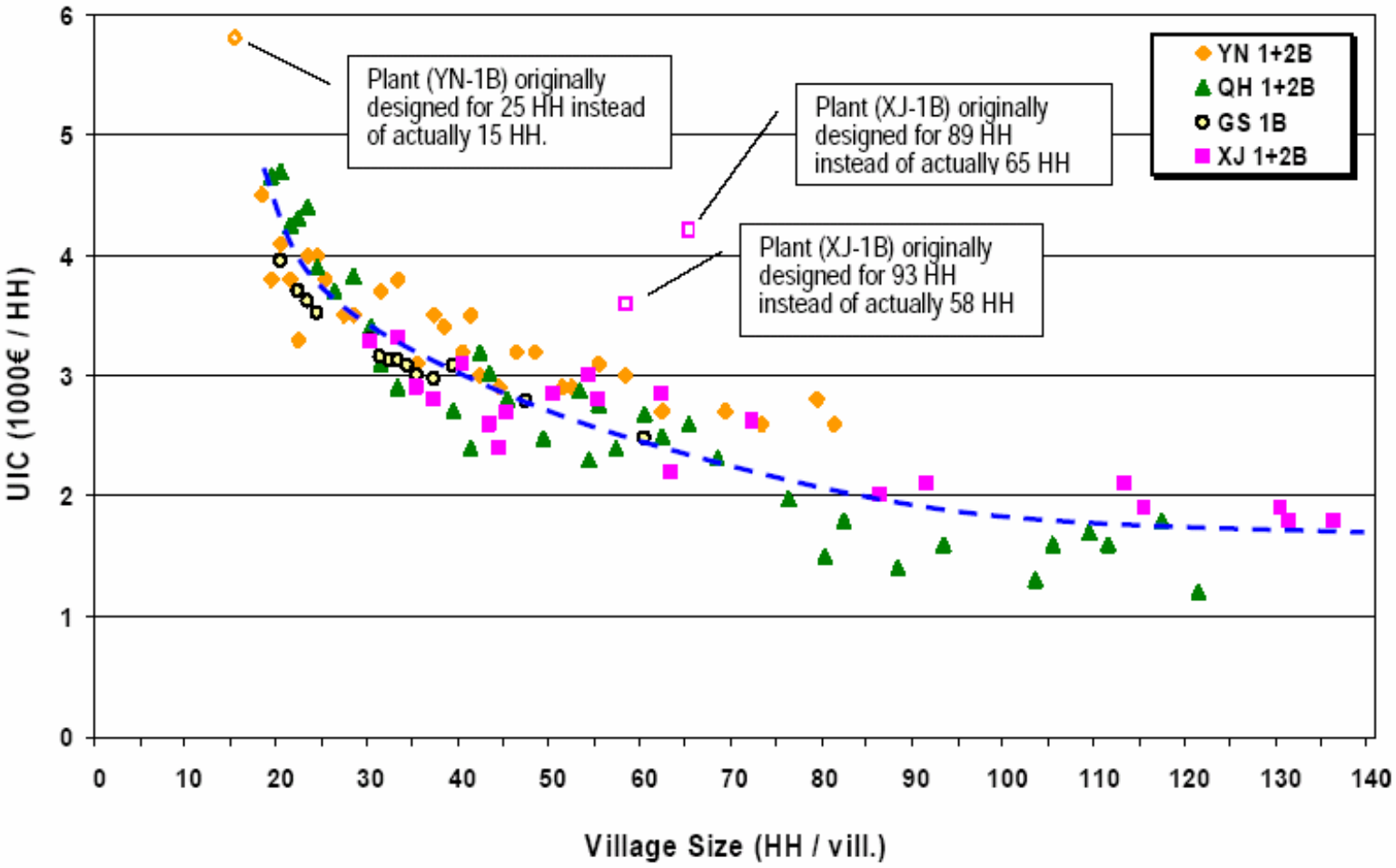


Figure 3: **Unit investment cost vs. village size in the Solar Energy Program of the Sino-German Financial Cooperation**

From: Constructing Village PV Hybrid Power Systems on a wide-scale in Western China: Experience gained
W. Klinghammer, K. Nörenberg, PV-Hybrid and Mini-Grid Conference, Aix en Provence (2006)

Souhourima, street scene with individual solar modules

Prayer flags on the mountain pass

The yak is the basis of the economy in the mountain areas of Qinghai / Tibet

Tent of herdsmen with solar modules

Picture: Bopp

Capital town of the county: Dawn

Shop in countytown selling Solar Home Systems and components

Another shop in countytown selling Solar Home Systems and components

Cash Sales of Solar Home Systems: The “Natural Market”

Example: Kenya

4 Million rural households
5 % have access to grid electricity
5 % have bought solar electricity systems

Annual sales: 20,000 to 30,000 solar modules for household application

⇨ Solar electrification grows faster than grid electrification, a national scheme of solar component importers, local manufacturers of batteries and components as well as hundreds of retailers has evolved.

Mr. James Wafula, PV system installer, and Mr. Japhet Diru, house-owner, in front of a newly electrified home at Kitale, Kenya

Office building of Mr. James Wafula, Solar Home System retailer and owner of a computer school at Kitale, Kenya

Computers, the World Wide Web and Mobile Phones

- Information and Communication - are changing our world,

just as Electric Light and (later) Radio and TV

already changed our lives.

Photovoltaic Solar Electricity,

available in large quantities and in small quantities,

at any remote point on earth,

may be one of the energies that will power that change.