



USDA-ARS

**Conservation
& Production
Research
Laboratory**

**Bushland,
Texas**



Wind/Diesel Power Generation with Short-Term Storage

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The Team

- DOE and NREL
 - provided funding and project oversight.
- encorp
 - manufacturer of utility-grade generator power controls and energy automation software
- Northern Power Systems
 - provided hybrid system engineering
- U S D A - Agriculture Research Service at Bushland Texas
 - provided field testing and analyses

Objectives

- Construct a hybrid generation system with both inductive and resistive loads
- Develop the necessary control system for a hybrid generation system
- Evaluate the performance without storage and with storage

43 kW Diesel Gensets



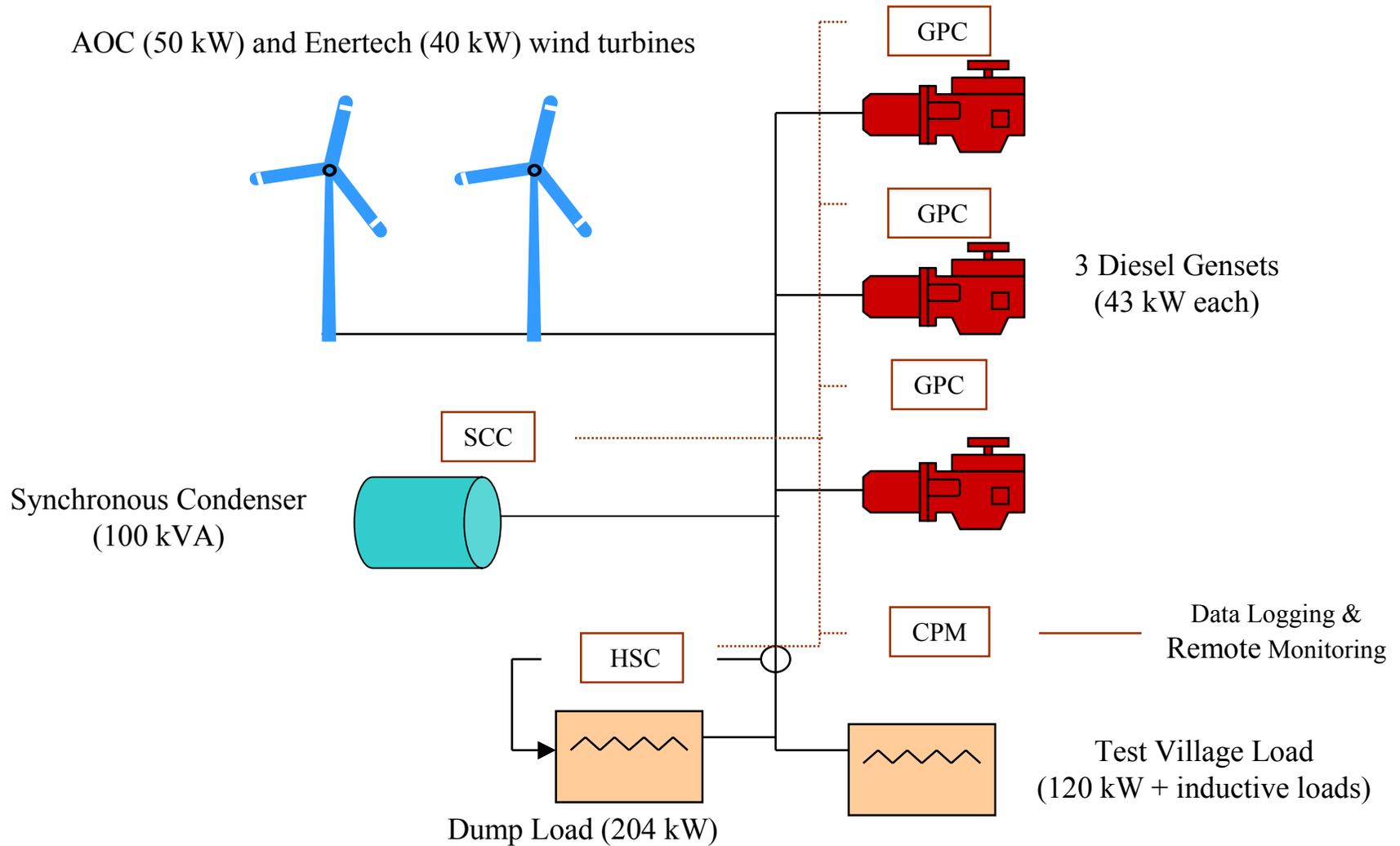
40 and 50 kW Wind Turbines



Resistive and Inductive Loads



Hybrid System Without Storage

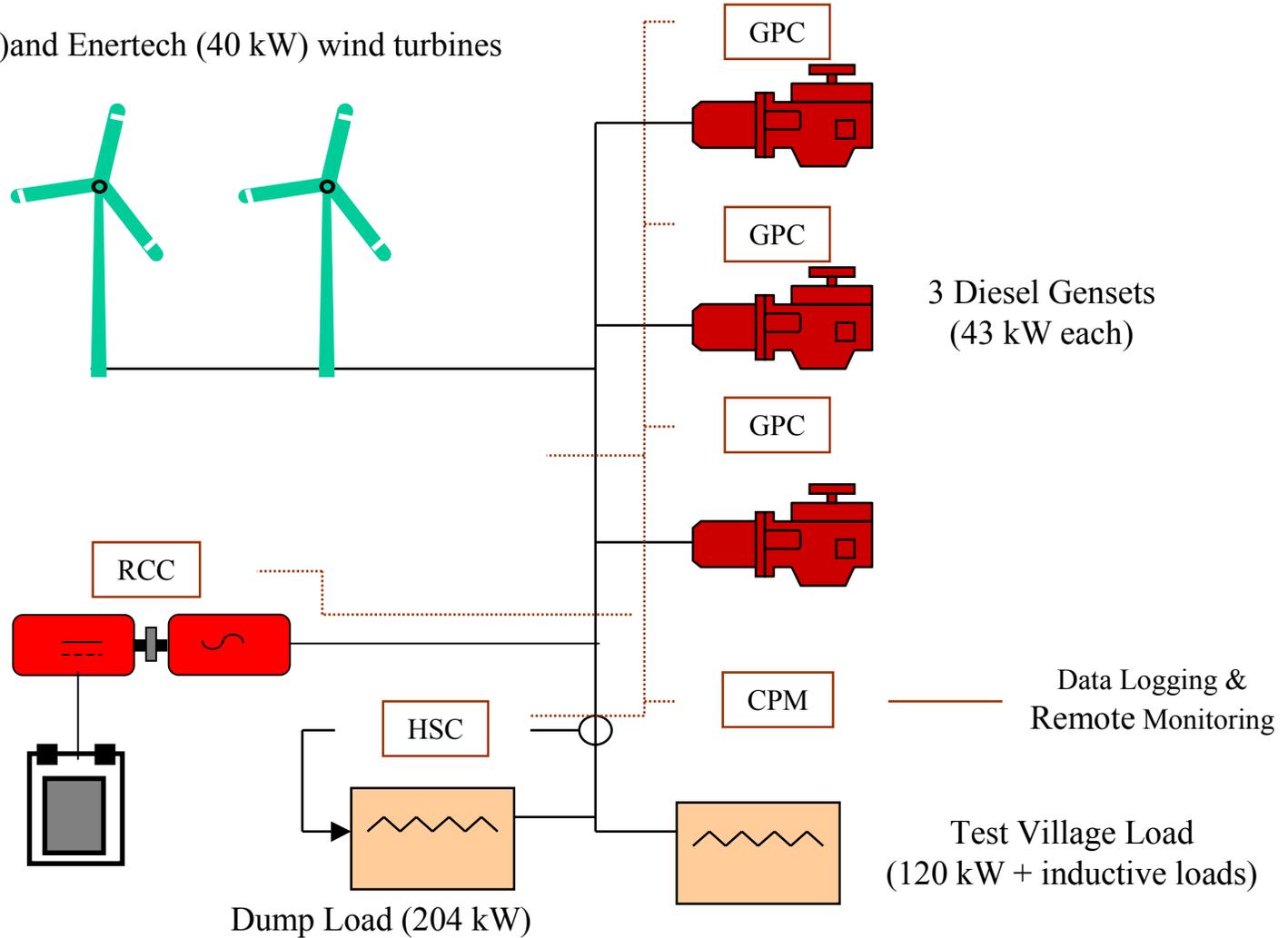


Synchronous Condenser



Hybrid System With Storage

AOC (50 kW) and Enertech (40 kW) wind turbines



Storage System

- Rotary Converter (100 kW)
- Battery: 110 kW x 10 min

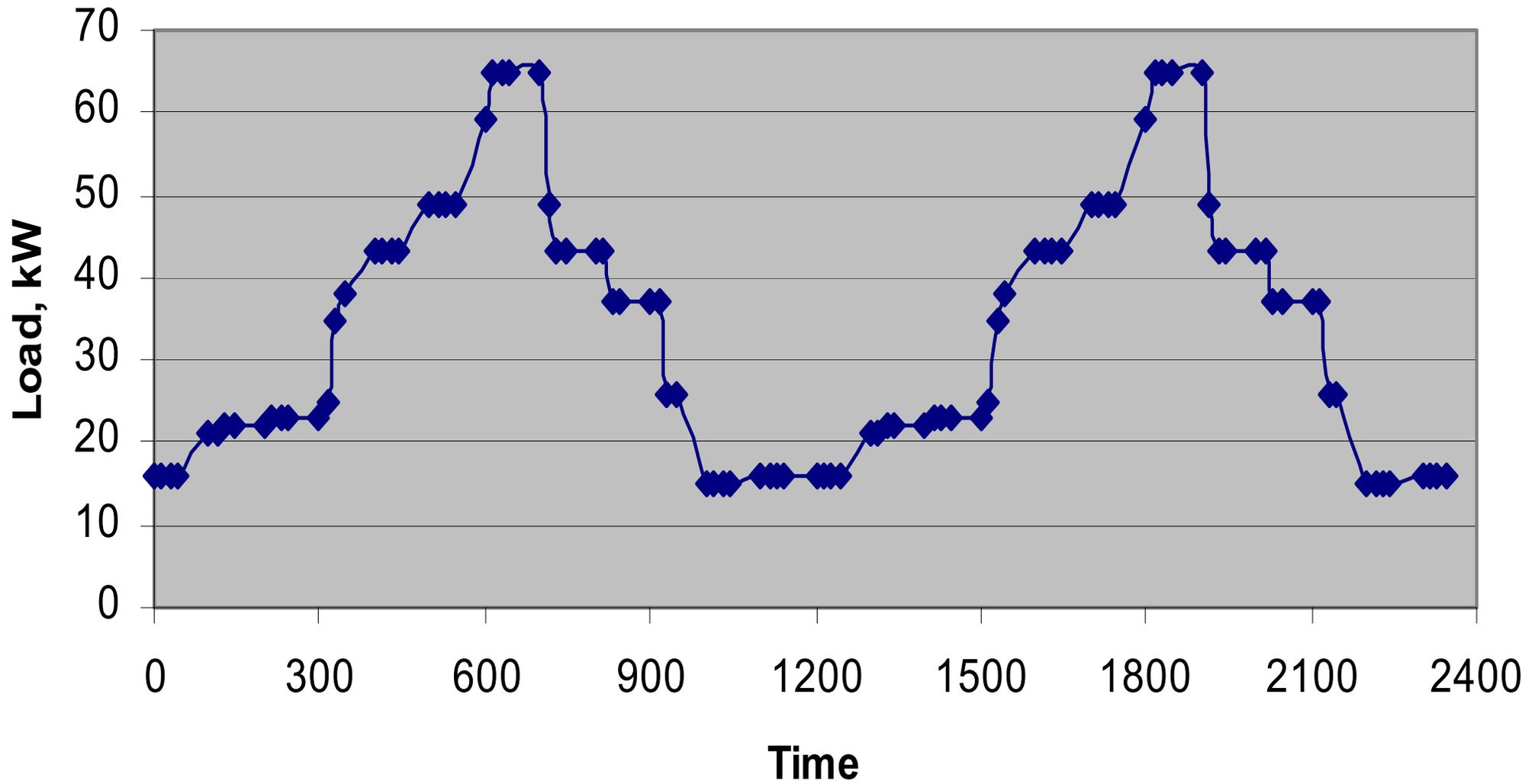
Rotary Converter



110 kW Battery Storage

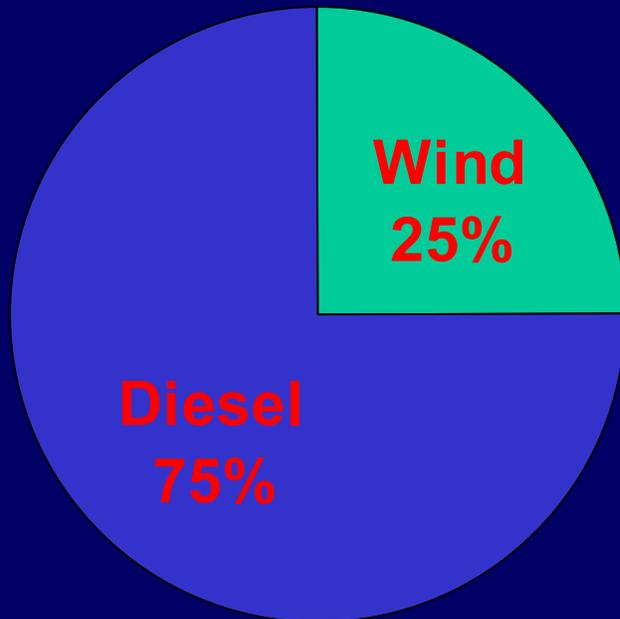


Test Village Load Profile

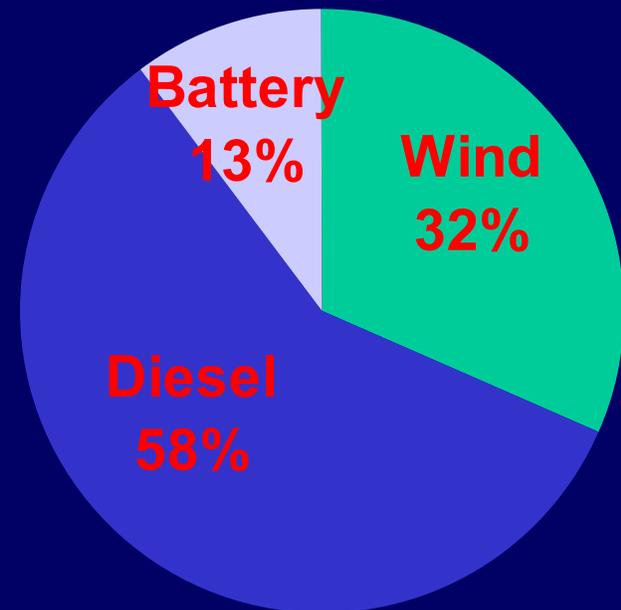


Penetration

**Without
Storage**



**With
Storage**



Diesel Only

Production/ Consumption	Without Storage	With Storage
Total - kWh	15652	2745
Village – kWh	15470	2551
Dump – kWh	0	88
Overhead - kWh	182	106
Fuel Eff – kWh/liter	2.63	2.64

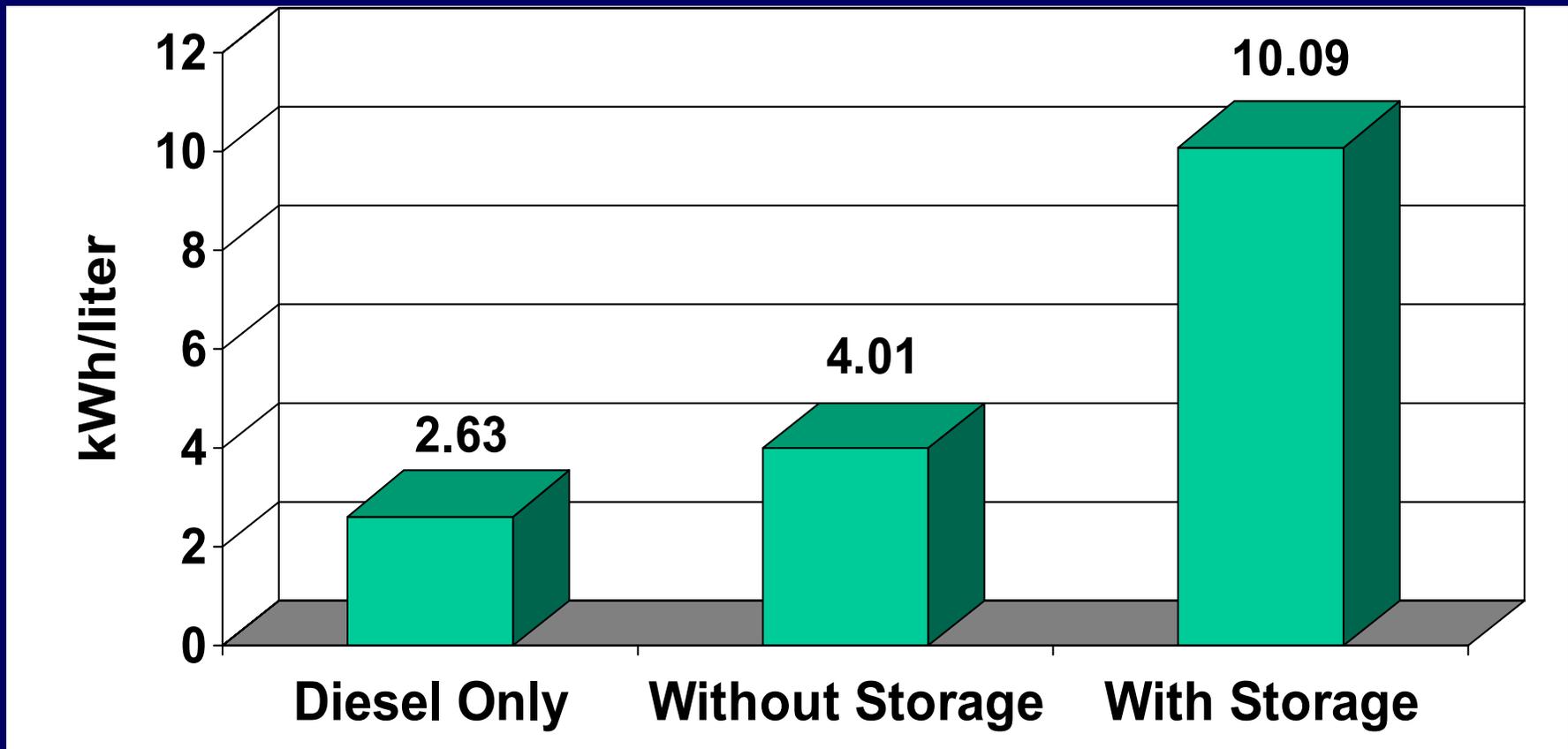
Wind - Diesel

Production/ Consumption	Without Storage	With Storage
Total - kWh	31278	3401
Village – kWh	15043	1913
Dump – kWh	14302	754
Overhead - kWh	1818	733
Fuel Eff – kWh/liter	4.01	10.09

Wind Only

Production/ Consumption	Without Storage	With Storage
Total - kWh	1485	2941
Village – kWh	348	893
Dump – kWh	992	1335
Overhead - kWh	145	713
Fuel Eff – kWh/liter	***	***

Fuel Efficiency



Conclusions

- Frequency (60 Hz, +/- 0.2 Hz) and voltage (480 VAC, +/- 20 V) were within these specified limits
- Fuel efficiency increased from 2.63 kWh/liter for diesel only to 4.01 kWh/liter for wind-diesel without storage to 10.09 kWh/liter for wind-diesel with storage
- In higher winds, the system ran smoothly and stable with all engines off and running entirely on wind