Biomass Electricity Options for Myanmar

VIASPACE Clean Energy for a Cleaner Tomorrow

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Forum on Renewable Energy Development in Myanmar
Nay Pyi Taw, Myanmar
November 1-2, 2012

- VIASPACE is a publicly traded company on the US OTC Bulletin Board
  - VIASPACE stock symbol VSPC

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Forum on Renewable Energy Development in Myanmar: New Directions and Investment Opportunities

Subregional Energy Forum (SEF)

November 1-2, 2012, Amara Hotel, Nay Pyi Taw

Republic of the Union of Myanmar

Dr. Carl Kukkonen
CEO Biography

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1998-PRESENT VIASPACE Inc. CEO

1984-1998 NASA/Caltech Jet Propulsion Laboratory (JPL)

Director Center for Space Microelectronics Technology & Manager of Supercomputing

- **Led staff of 250 with $70 million annual budget**
- **On review boards of 14 leading universities**
- **NASA Exceptional Achievement Award 1992**
- **Space Technology Hall of Fame 2001**

1977-1984 Ford Motor Company

- **Developed direct injection diesel engine**
- **Ford's expert on hydrogen as an automotive fuel**
- **Research in Physics Department**

1975-1977 Purdue University postdoctoral fellow

1968-1975 Cornell University MS & PhD in theoretical physics

1966-1968 University of California Davis BS physics

Electricity Facts

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- Industrial and commercial electricity demand is usually largest user, and during the daytime
- Must match electricity supply to demand
  - Need backup sources on the grid that can be easily turned on and off, or whose output can be turned up or down
- There is no economical way to store electricity on a large scale
  - Batteries are small-scale and expensive
  - Cannot store solar or wind electricity for use in the nighttime or when the wind stops

Daily Electrical Load

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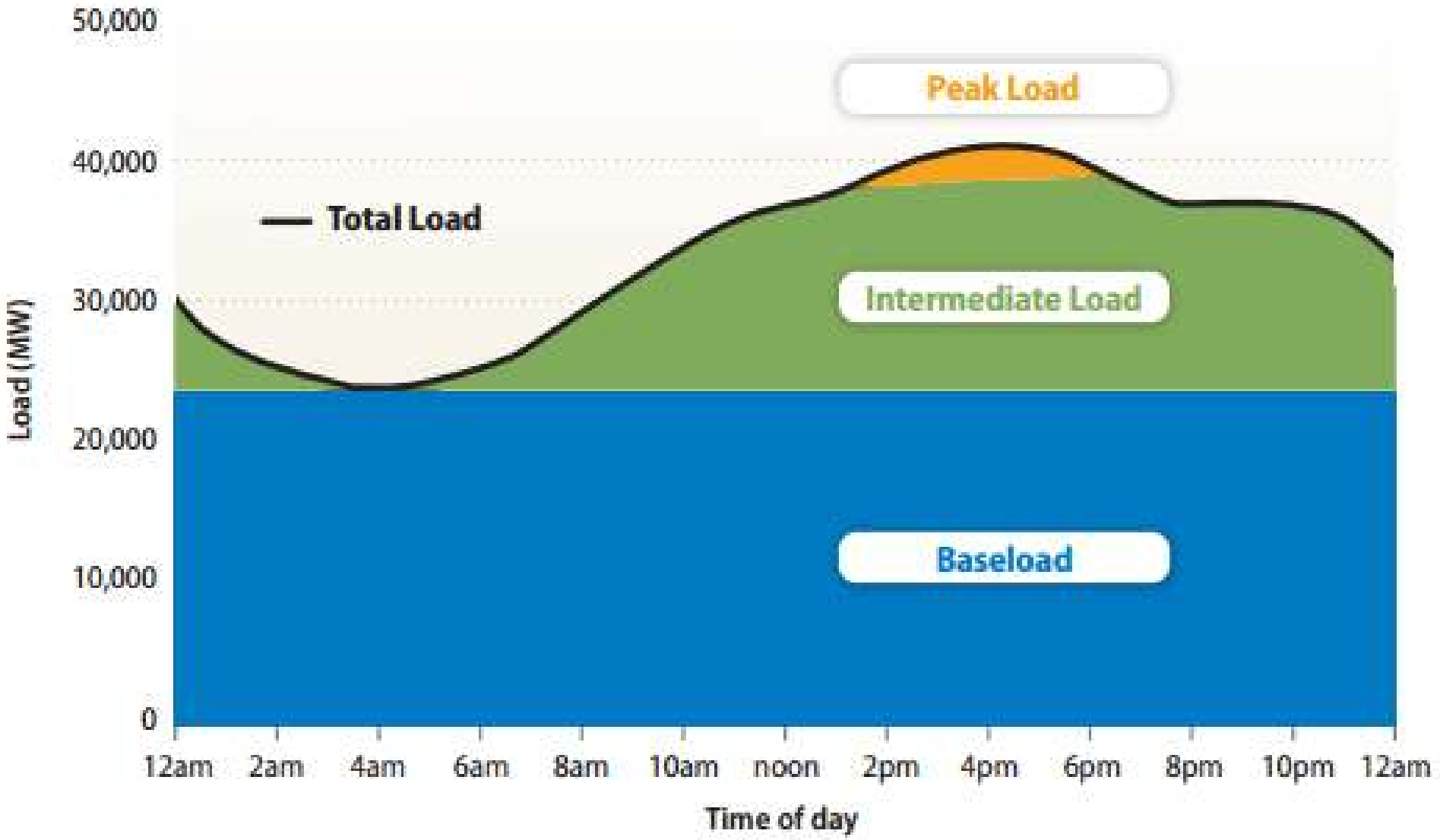
Figure 2. 2009 Summer Day Load Curve for California



Roles of Different Types of Electricity Generation

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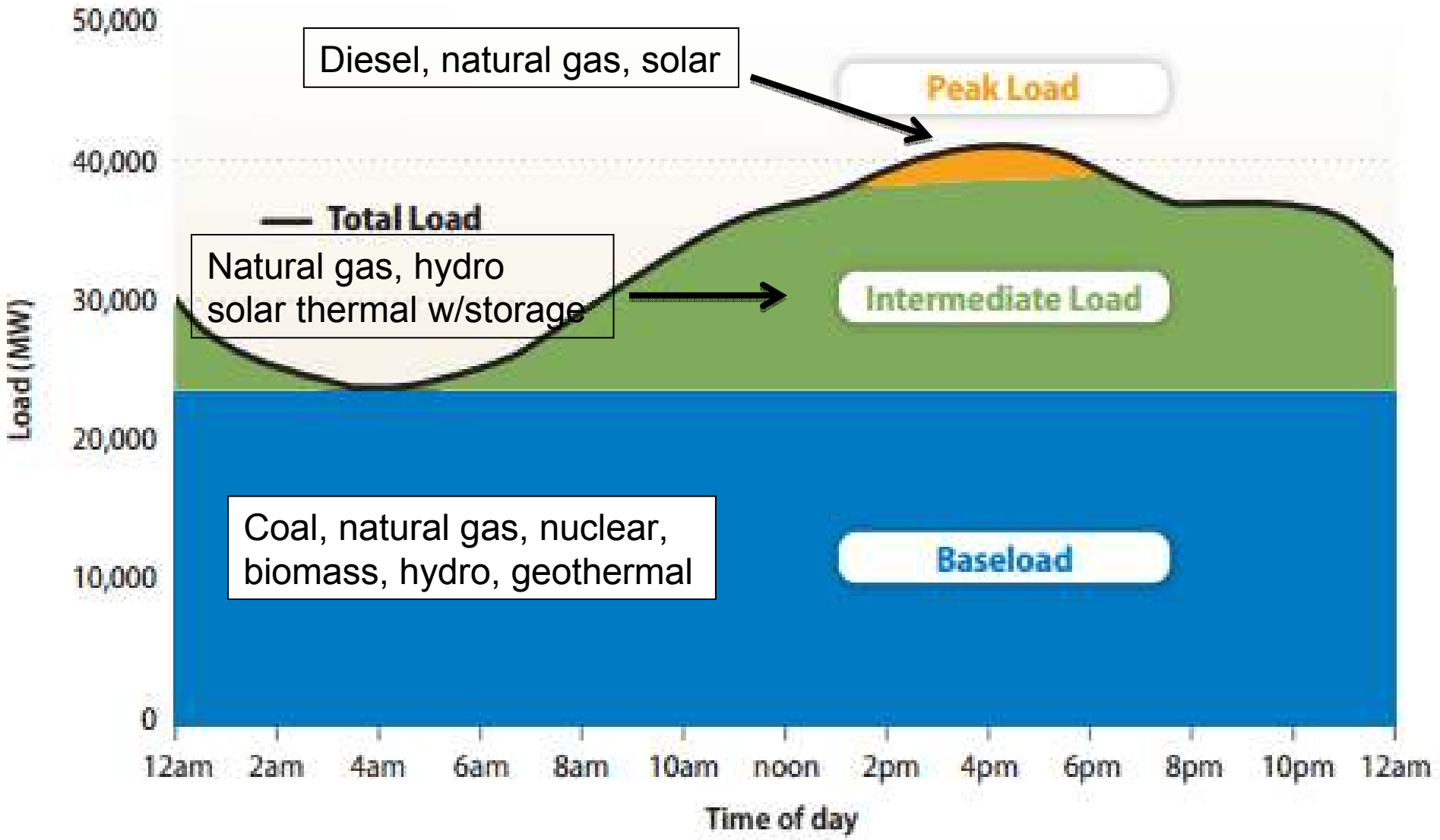
Solar daylight corresponds to peak demand



Biomass Electricity

Low Cost, Renewable, Low Carbon Option That Provides 24/7 Base Electricity and Employment for Farmers & Power Plant Workers

Biomass is "Low Carbon Fuel"

Plants Breathe Carbon Dioxide

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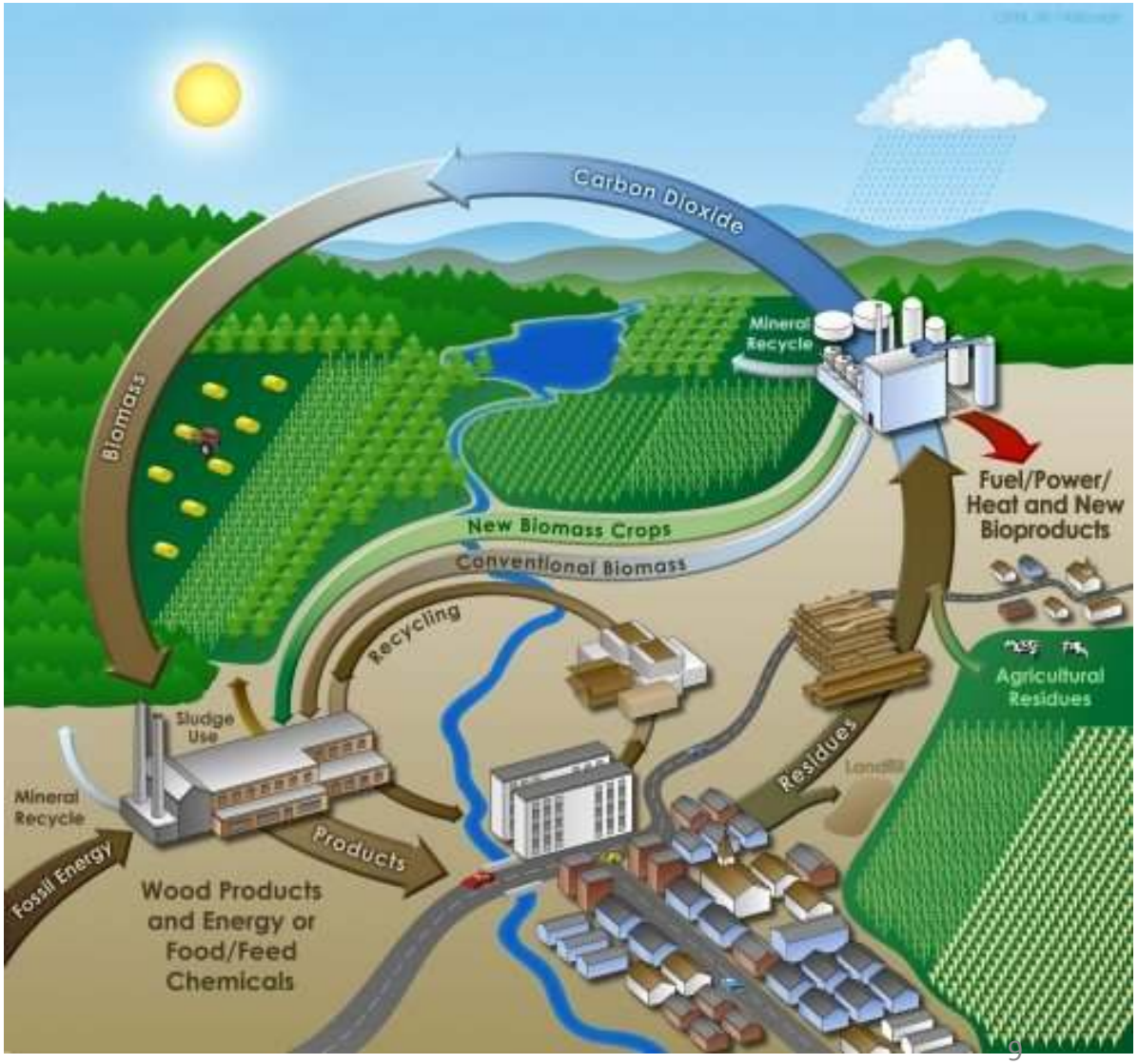
- Plants use sunlight & CO_2 to grow. Carbon is stored in the plant
- Burning biomass or biofuels simply recycles the CO_2 stored in the plant
  - Time can be 6 mos - grass to 20 yrs-trees
- Biomass is carbon neutral except from
  - Fertilizer, harvesting, & delivery



Biomass Fuel
Agricultural and Forestry Waste

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- Agricultural and forestry waste—corn/rice straw or husks, branches etc.-- seems an attractive fuel but experience shows many problems
  - Fuel supply quantity and price is seasonal
  - Different biomass at different times of year
  - Long term fuel supply contracts not available
  - Fuel prices have increased dramatically
  - Many biomass power plants have gone out of business
- Today banks and investors will not finance biomass power plants without a long term fuel supply contract

Dedicated Energy Crops

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- Dedicated energy crops are grown entirely for energy use
  - Not tied to a food harvest which reduces seasonality
  - A single reliable fuel all year allows optimization
  - High yield is crucial to make biomass electricity affordable
    - Price can be even lower than agricultural waste
  - Power plant can grow its own fuel or enter into a long term fuel supply contract with grower
    - This is crucial to obtain project financing
- Dedicated energy crops can be used together with agricultural waste
- Example energy crops include perennial grasses and specialty trees similar to those for pulp and paper—Will use Giant King Grass as example

Closed Loop Biomass Power Plant

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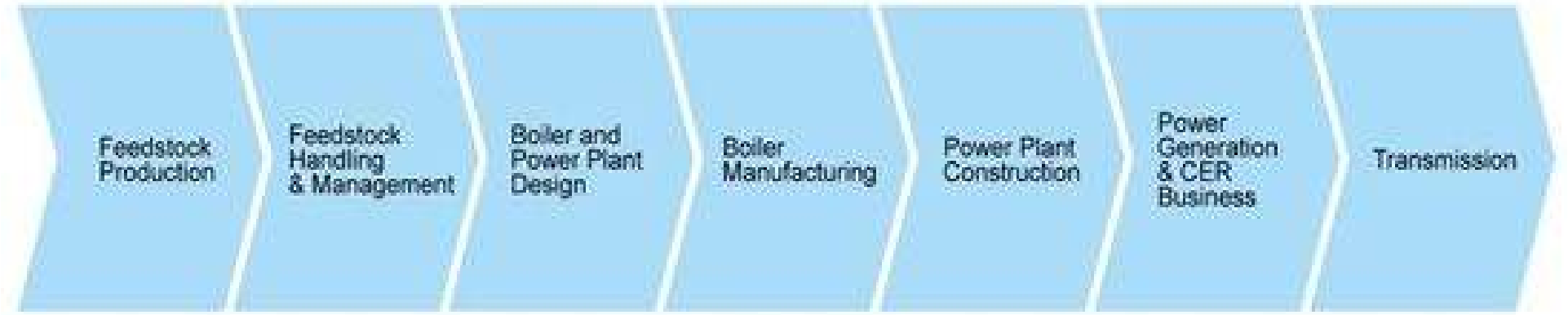
- Power plant co-located with Giant King Grass (or other biomass) plantation
- Sunshine and water in–clean, low carbon electricity out



VIASPACE ⟵ Power Plant Partner ⟶ EPC ⟶ Customer

Biomass Options to Produce Clean Electricity

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- Direct combustion--Dry Giant King Grass and burn in a boiler to produce high pressure steam which turns a generator
  - Sizes from 10 – 35 MW
- Anaerobic digestion of Giant King Grass to produce biogas which is burned in an engine or turbine which turns a generator
  - Typical sizes from 0.5 – 3.0 MW
- High temperature gasification to syngas
- Co-fire pellets in existing coal power plant to reduce carbon dioxide emissions

VIASPACE Giant King Grass Grow Your Own Electricity

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Giant King Grass
Dedicated Energy Crop

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- Very high yield
  - 100 dry mt/ha/year (44 US t/acre)
- Sustainably grown, not a food crop, grows on marginal land
- Perennial grass, harvest 2x/year
- Not genetically modified
- Not an invasive species
- Needs sunshine, warm weather & rain or irrigation
  - no freezing or standing water
- Fertilizer use is modest
- No pesticide

Giant King Grass and Factory

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110 ha (270 acre) test site provides
-seedlings for large energy projects
-demonstration of production
-sample quantities for customers

Note CEO standing at lower right . Giant King Grass is 4 m tall

Manual Harvesting

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Mechanical Harvesting

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Biomass Power Plant
Burns Plant Material Instead of Coal

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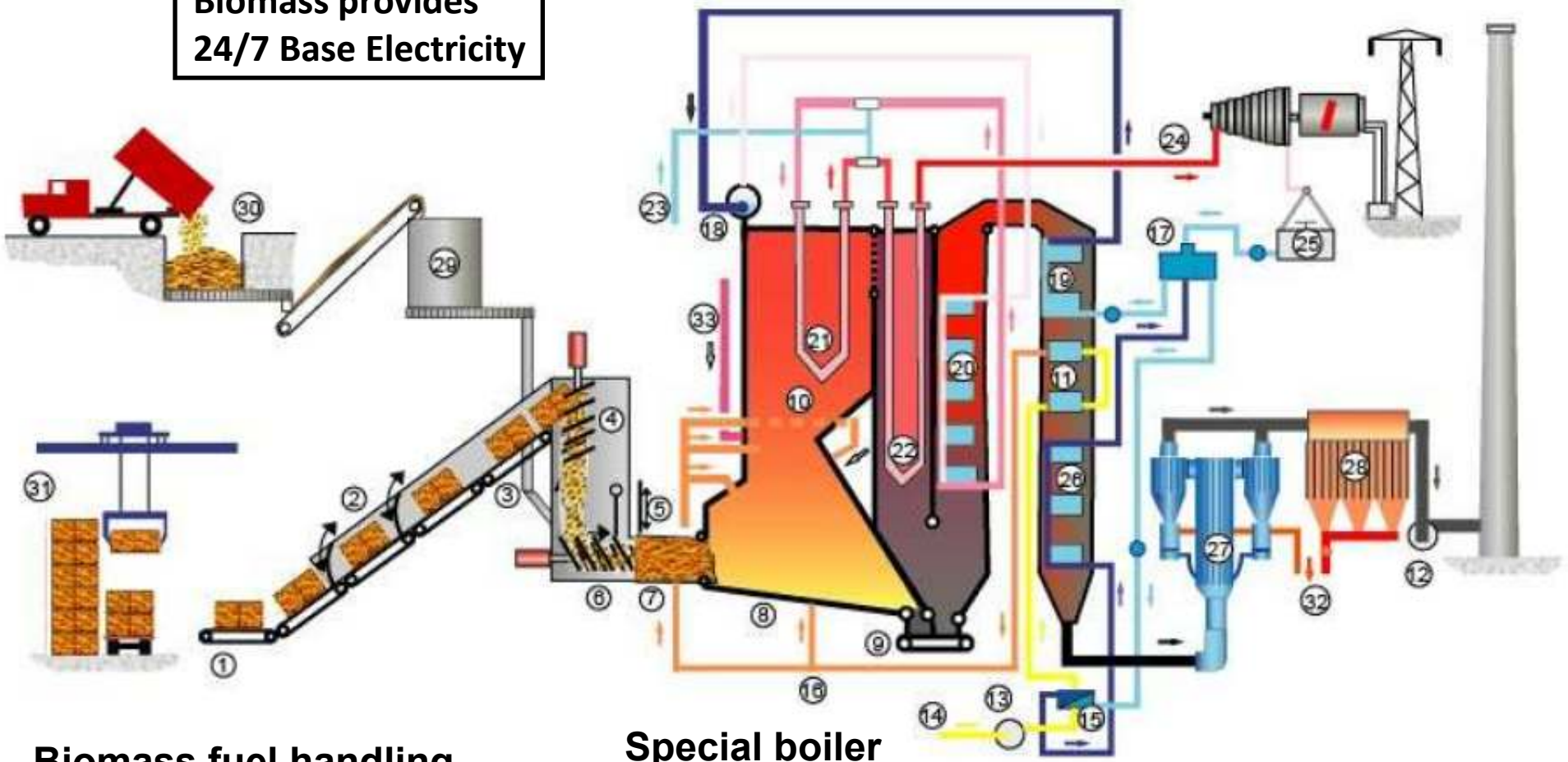
Biomass provides 24/7 Base Electricity



Biomass fuel handling

Special boiler burns biomass to create steam

High pressure steam turbine turns generator to make electricity

30 MW Biomass Power Plant Uses Agricultural Waste Today

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Biomass Power Plant

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Giant King Grass Has Been Extensively Tested With Consistent Results

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Proximate Analysis	Unit	Sun Dried As Received	Giant King Grass Bone Dry
Total Moisture	**%**	**14**	**0**
Volatile Matter	**%**	**65.68**	**76.37**
Ash	**%**	**3.59**	**4.17**
Fixed Carbon	**%**	**16.74**	**19.46**
Total Sulfur	**%**	**0.11**	**0.13**
HHV	**MJ/Kg**	**15.85**	**18.43**
LHV	**MJ/Kg**	**14.52**	**-**

Biogas from Giant King Grass

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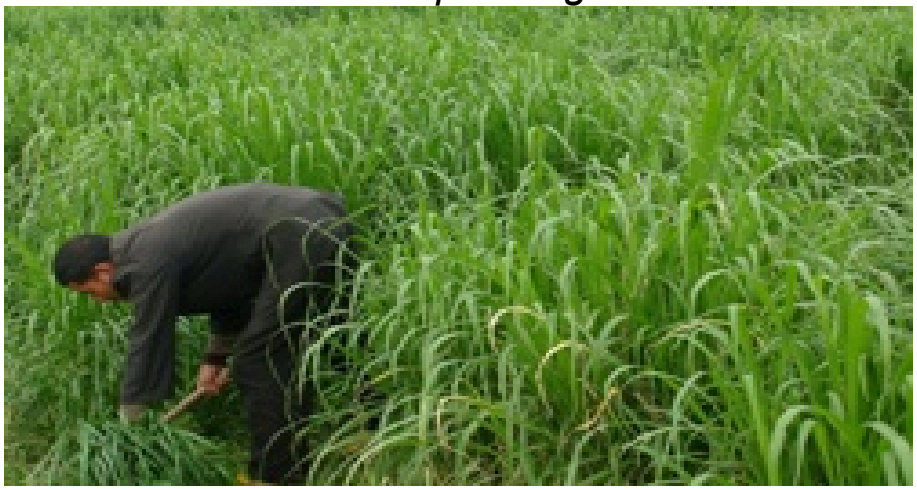
Biogas plant generating 1 MW of electricity and 1 MW of heat plus organic fertilizer



Giant King Grass is cut every 30-60 days at 3-5 feet tall for biogas

- Biogas is produced when Giant King Grass decomposes without oxygen (anaerobic digestion)
- Biogas is composed of methane (55%) and carbon dioxide and used to generate electricity and heat
  - Organic fertilizer is the byproduct
- Giant King Grass has been independently tested for biogas yield and the results are excellent
- Thousands of biogas power plants in Europe

Giant King Grass Pellets Export Opportunity for Myanmar

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- Giant King Grass pellets can replace up to 20% of coal in an existing coal-fired power plant
  - Burning coal and biomass together is called cofiring
  - Requires small modification
- Preserves large capital investment in existing power plant with 30 year additional life
- Meets carbon reduction targets
- 16M tons of pellets used globally today
  - 46M tons by 2020
- Grass is grown, dried and pressed into pellets and shipped in bulk like shipping grain
- Large global demand
  - Particularly in Europe
  - Korea, China, Japan emerging

Applications of Giant King Grass

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- **Direct combustion in electric power/ heat/steam plant**
- **Biogas /anaerobic digestion**
- **Pellets for co-firing with coal**
- **Briquettes for boilers**
- *Cellulosic liquid biofuels-- ethanol/butanol*
- *Biochemicals and bio plastics*
- *Pyrolysis to bio oil*
- *Catalytic coversion to bio diesel*
- *High-temperature gasification*
- *Torrefaction to bio coal*
- *Pulp for paper and textiles*

Applications that are commercial today with agricultural & forestry waste that can use Giant King Grass instead

Low cost of Giant King Grass will allow commercial applications in future

Advantages of Giant King Grass

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- "Platform" energy crop for many bioenergy applications
  - Electricity, pellets, biofuels, biochemicals & bio plastics
- Lowest cost because of high yield--Can meet cost targets for energy & biofuels applications
  - Less expensive than agricultural waste in most cases
  - Can be used in combination w/ agricultural waste
- Perennial crop
  - Do not have to plant every year, just harvest
  - Short rotation—first harvested in 6.5 months
- Provides reliable, well documented, consistent quality fuel or feedstock with predictable, affordable price
  - Fuel supply reliability required for project financing

Cost of Electricity

The cost information is based on the US except where indicated, and assumes high quality equipment that will be guaranteed for a certain period of time, meets environmental standards, and that requires minimum repair and maintenance. The cost of capital equipment can be lower if you choose lower quality equipment .

The costs reported here should be viewed as approximate, but are accurate on a relative basis when comparing one generation approach with another.

Cost Summary

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- Main factors in cost of electricity
  - Initial capital cost (CAPEX)
  - Utilization rate
    - Available every day for 24 hours?
    - Or on sunny daytime or windy days only
  - Fuel cost
  - Operations & maintenance—usually a small factor
  - Transmission & distribution
- Other important issues
  - Fuel & electrical grid connection availability
    - Example--natural gas is not an option where there is not a natural gas pipeline. May choose biomass in that case.
    - If the national grid is not available, can install a local micro-grid

Fuel Contribution to the Cost of Electricity

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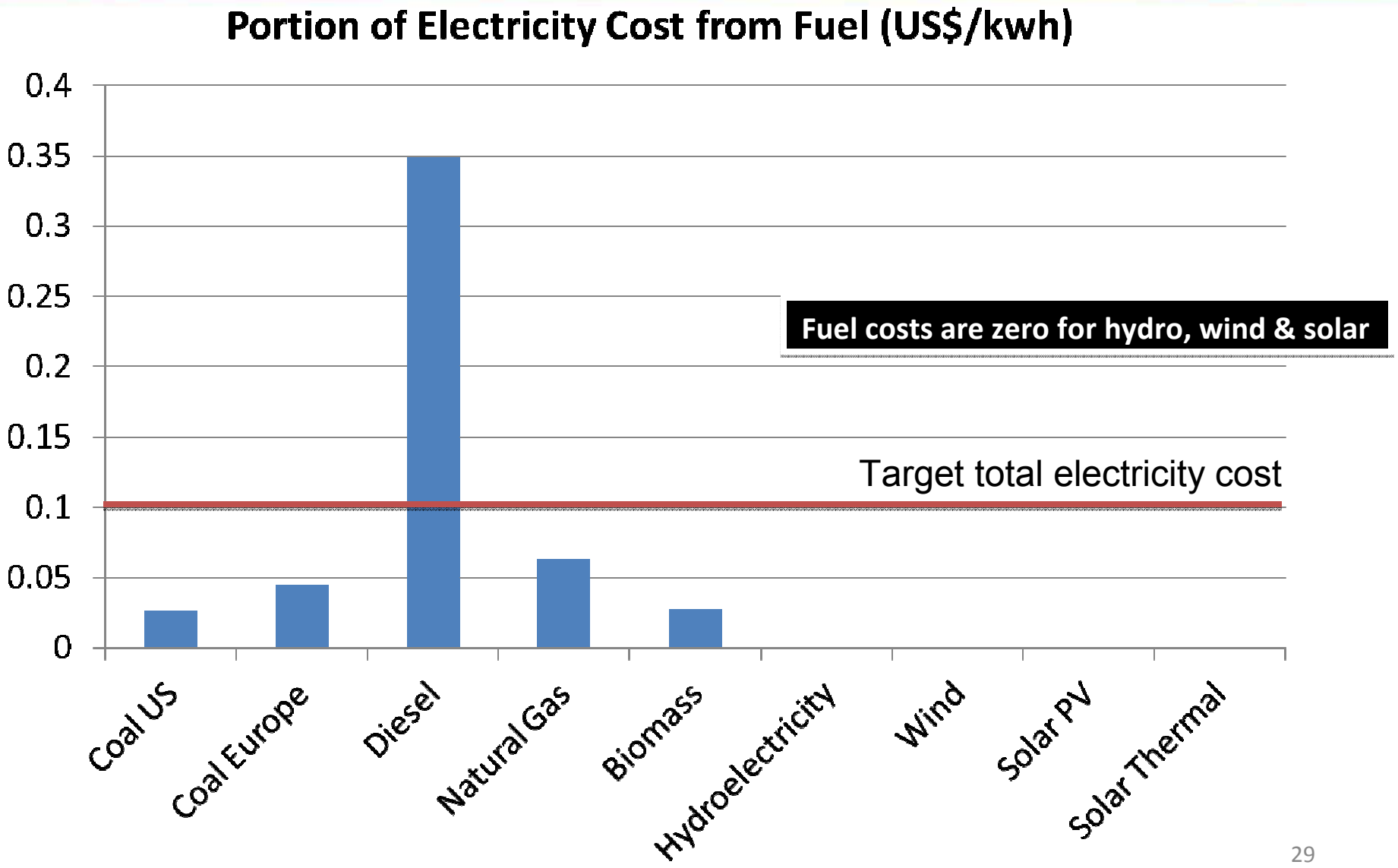

Portion of Electricity Cost From Capital Expense

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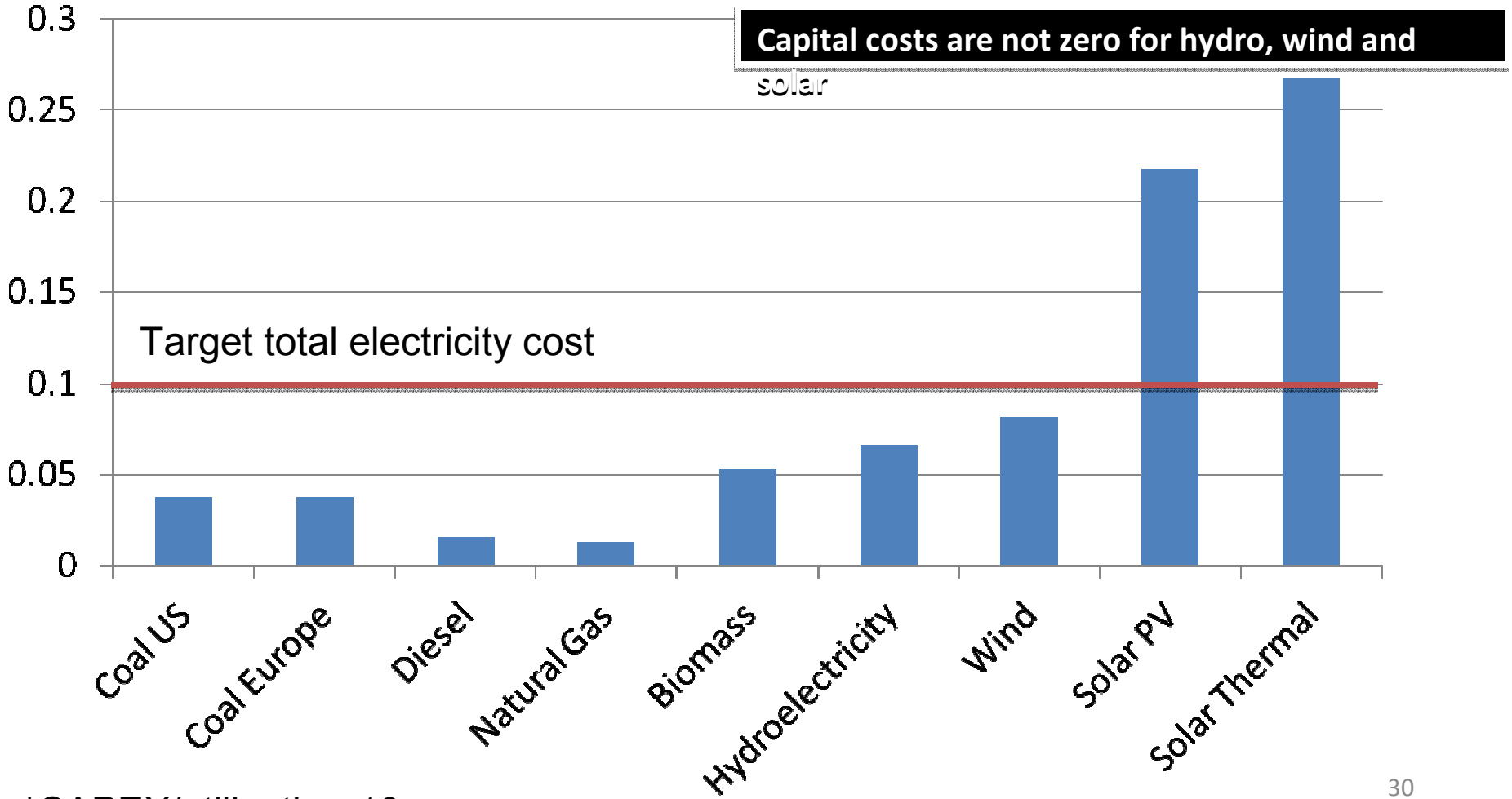
Crude Estimate* of Portion of Electricity Cost from CAPEX (US$/kwh)



*CAPEX/utilization-10 years

Compare Electricity Costs & CO2 Emissions

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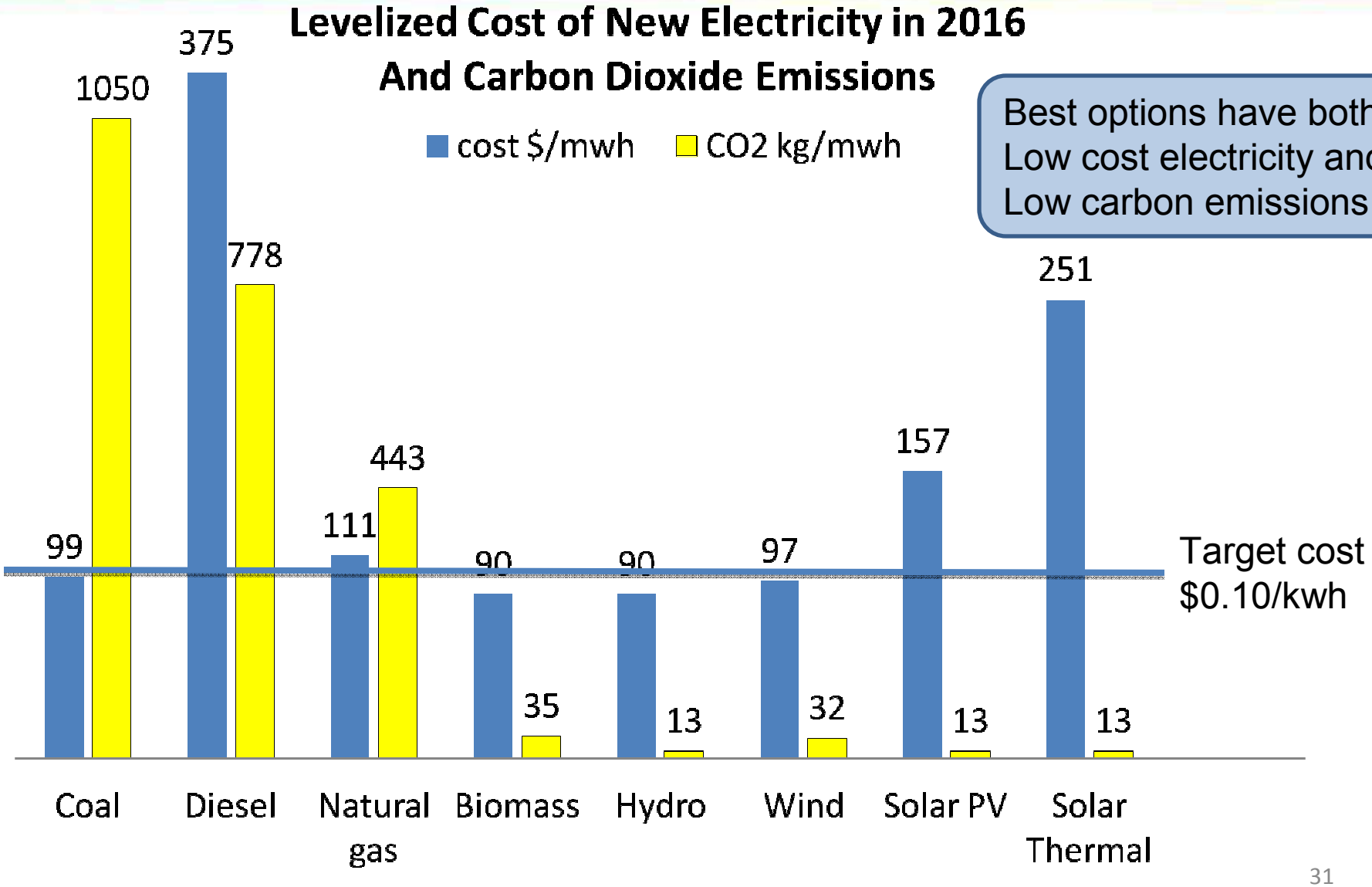

Project Finance

Who Will Provide the Funds

For the Project?

The Fundamental Issue!!!

Who Will Fund a New Power Plant?

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- Often the government will build and operate a power plant
  - But the Myanmar government is short of money
- Alternately the government will often guarantee to buy the clean electricity for the national grid at a certain price that guarantees outside investors a profit
  - But will the Myanmar government do that?
  - Can investors depend on the Myanmar government guarantee?

Who Will Fund a New Power Plant?

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- A new mine, factory, industrial park, resort or other business may be forced to build a power plant to support its business
  - This will help economic development, but how will it help provide electricity to the population?
- Development banks such as World Bank, Asian Development Bank fund infrastructure projects that are a national priority
- Export credit agencies (Export-Import Bank) fund imported equipment
- Foreign aid may be available
- A combination of local and foreign investors

Summary and Recommendations

VIASPACE Giant King Grass

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Giant King Grass Power Plant Scalable and Sustainable

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- Giant King Grass plantation co-located with a power plant, pellet mill, or biorefinery
  - Together, a scalable, clean energy module that can be replicated throughout Myanmar
- Provides local employment for farmers and power plant operators
- Provides clean electricity for residents and economic development
- Provides energy security & independence
- Money stays in country rather than sent overseas to purchase fuel

Direct Combustion Concept Proposal

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- 30 MW biomass plant co-located on 1600 ha (4000 acre) Giant King Grass plantation
  - Produces 200,000 MWh annually to the grid
  - 2% of current electricity in Myanmar, enough for 400,000 rural households of five people
  - Can be scaled down or up from 10 to 35 MW
  - Requires warm weather with sufficient rain or irrigation. Will not compete with food supply.
- Turnkey power plant and plantation delivered in 24 months

1MW Biogas Power Plant

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- Requires only 200 acres of Giant King Grass
- Provides enough electricity for 13,000 rural households
- Can provide electricity for irrigation pumps, schools, hospitals and factories
- Can be built in 12 months
- Uses fresh grass not dried
- By-product is organic fertilizer
- Even smaller sizes may be available

Summary: Project Economics

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- A 4000 acre Giant King Grass plantation and 30 MW power plant can add 2% to Myanmar's electricity supply– sufficient for 400,000 rural households & factories
  - Electricity price at $.12-$.13 per kilowatt hour
- A 200 acre Giant King Grass plantation and 1 MW biogas power plant costs can supply electricity to 13,000 rural households
  - Electricity price at $.15 – $.17 per kilowatt hour
- Both are much cheaper than diesel electricity at $.375 per kilowatt hour

Policy Recommendation

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- Myanmar government should endorse and pursue biomass as an additional renewable resource (in addition to hydro) to produce clean and affordable electricity
  - Biomass uses Myanmar's favorable climate and land to produce electricity today– and for biofuels, biochemicals and bio materials in the future.
  - Biomass electricity generation technology is mature and affordable
  - There is plenty of land in Myanmar for both food and fuel

Implementation Recommendation

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- Myanmar government should encourage a combination of private industry, development banks and foreign aid to build a biomass power plant in Myanmar
  - A successful demonstration will lead to many other power plants developed without the need for foreign aid throughout Myanmar
  - Providing jobs for energy crop farmers and clean electricity for economic development
  - A feasibility study can be conducted immediately

Thank You

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Backup Slides

VIASPACE Business

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- VIASPACE works on integrated plantation and bioenergy, pellet or biorefinery projects
- VIASPACE is seeking quality project opportunities
- VIASPACE will work with partners, project developers or act as project developer
- Potential R&D collaborations
- Giant King Grass samples available

Fuel Costs & Portion of Electricity Cost From Fuel

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Coal US price	27GJ /mt	$60 /mt	**$2.22 /GJ**	**$7.99 /mwh thermal**	**$26.63 /mwh electric**
Coal Europe	27GJ /mt	$100 /mt	**$3.70**	**$13.31**	**$44.37**
Diesel	36.4 MJ/l	$1.06/l =$4/gal	**$29.07**	**$104.57**	**$348.57**
Natural Gas		$5.00 /Mbtu	**$5.27**	**$18.96**	**$63.20**
Bio-mass	18.4 GJ/mt	$42 /mt China	**$2.28**	**$8.20**	**$27.33**

GJ= 0.278 mwh; metric ton=2204 lb; thermal to electric efficiency= 0.30

Total Electricity Costs Fuel+ Capital+ Operating

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	Capital Cost * $/MW	Avail-bility %	Fuel cost $/mwh	Electricity Cost 2017 $/mwh**	CO2 kg/mwh lifecycle	Comments
Diesel	1.24	90	348	375 (2012)	778	24/7
Natural gas US Myanmar	0.98 0.98	87 87	48 63-100	69 84-111	443 443	24/7, also for transportation
Coal	2.84	85	29	99	1050	24/7
Hydro	3.08	53	0	90	13	seasonal
Solar PV Thermal	4.76 4.69	25 20	0 0	157 251	32 13	Transient -storage or backup needed
Wind	2.44	34	0	97	10	transient
Biomass US Asia >10 MW Asia 1-3 MW	3.86 2.00 3.50	83 83 80	48 27 27	120 90 (2012) 110 (2012)	14-35	24/7

Sources: private communications and
Benjamin K. Sovacool., *Energy Policy*, Vol. 36, 2008, p. 2950
http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

*Costs in US in 2017 but current dollars except where indicated
** Price is 20% higher

Compare Electricity Costs & CO2 Emissions

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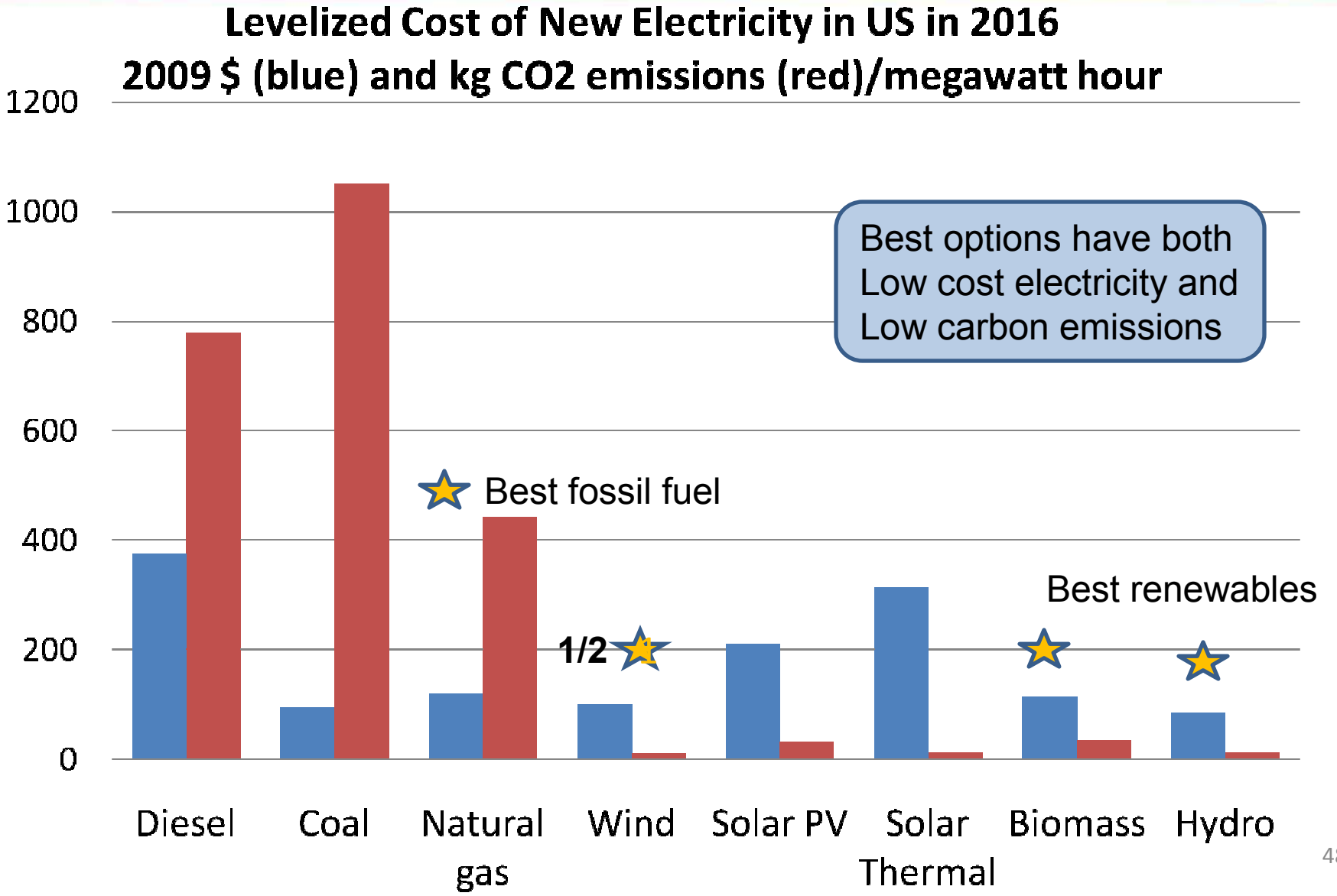

Yield Comparison of Perennial Grasses

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Perennial Grass (Genus-Species)	Dry Mass (US ton/acre/year, mt/ha/yr))	
Phalaris-- Reed Canary Grass	2.0 – 3.6	4.5-8.1
Panicum-- Switchgrass	5-9	11-20
Miscanthus--Miscanthus x Giganteus	13-21	29-47
Pennisetum-- Pennisetum Purpureum	24 –27	54-61
Giant King Grass	44	100

Notes: data taken from the literature. Sources are available upon request

- Reed Canary Grass data from US state of Michigan and Ontario Canada
- Switchgrass data from trials by the University of Illinois in the state of Illinois
- Miscanthus data from trials by the University of Illinois in the state of Illinois
- Pennisetum Purpureum data from trials at the University of Florida in the state of Florida

Important factors to consider in interpreting the data.

- Phalaris and Panicum are cold weather grasses that can tolerate a long freeze. The growing season is relatively short in the cold areas
- Miscanthus can tolerate moderate but not deep freezes. Cold weather induces senescence
- Pennisetum Purpureum and Giant King Grass are tropical and subtropical grasses. The do not survive a long freeze. The growing season can be 12 months and these crops can be harvested more than once a year

Biogas to Electricity

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- Sizes of Biogas power plants are 0.5 to 3 MW
- 70 hectare Giant King Grass per 1 MW power
- Provides 24/7 electricity for remote area, factory or to the grid
- Biogas power plant and plantation should be co-located to minimize fuel transportation costs
- Waste heat and organic fertilizer have value
- Thousands of biogas power plants in Europe

Giant King Grass has both higher biogas yield per kilogram and higher kilogram yield per hectare than competing biomass

- Lower cost feedstock and electricity & higher profit

1.5 MW biogas engine generator set

Anaerobic Digestion to Produce Biogas

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Left-1 MW Anaerobic Digester In Germany

Right Caterpillar Engine/ Generator

Left Feed system Anaerobic Digester

Right-Drying Organic Fertilizer Byproduct

Bio-Methane Yield/ Hectare of Land

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- Biogas production uses fresh Giant King Grass with yield of 375 mt/ha
- Measured biogas yields are 160-190 cubic meters of biogas/tonne of fresh grass
  - Methane content is 57% of biogas
- Bio-methane yield is 94 -111 m3/ha/day
- Giant King Grass bio-methane yield is 3.4 - 4.0 million BTU per hectare per day
- 1 MW of electricity requires 70 ha

Test Data on Giant King Grass

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Composition Determination

Parameter	Amount (a.r.)	Amount (o.d.)
Total Moisture	8,81	
Moisture Airdry		
Ash	4,66	5,11
Volatile matter incl. moisture.		
Volatile matter	70,34	77,14
Fixed Carbon	16,18	17,75
Gross Calorific Value	4055,2	4446,9
	16,978	18,618
Nett Calorific Value (cV)	3742,1	
	15,667	
	6735,7	
Nett Calorific Value (cP)	15,592	

TLR international laboratories

国家煤炭质量监督检验中心
China National Coal Quality Supervision and Testing Center

SGS

Biofuels, Biochemicals and Biomaterials

Cellulosic Biofuels, Biochemicals & Bio Plastics

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- 1st generation bio ethanol is made from sugar cane, corn or recently cassava
  - Making fuel from food is being restricted or prohibited
- 2nd generation is cellulosic ethanol made from
  - corn straw– not the corn grain
  - Sugar cane bagasse—after the sugar is removed
  - Dedicated energy crops such as Giant King Grass
- 2nd generation processes utilize the polymeric sugars trapped in the stalks and leaves
  - Requires pretreatment and enzymatic hydrolysis
  - Currently more expensive and not yet commercial

Giant King Grass for Fermentation-Based Biorefinery

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Composition Dry Weight %	Giant King Grass	Corn Stover	Miscanthus
Glucan	43.0	37.4	44
Xylan	22.3	21.1	22
Arabinan	2.9	2.9	2
Lignin	17.4	18.0	17
Ash	4.5	5.2	2.5-4

Notes and references:
Giant King Grass: average of samples cut at 4 m tall
Corn Stover: Aden et al. NREL/TP-510-32438, 2002
Miscanthus: Murnen et al. Biotechnology Progress 23, 4, 846-850, 2007 and other sources

Giant King Grass tests by 3 independent companies.
Giant King Grass has essentially the same composition as corn Stover and miscanthus per dry ton

Compare Giant King Grass Yield to Corn & Miscanthus

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Yield Dry Matter	Giant King Grass	Corn Stover	Miscanthus
US ton/acre	44	3.5-4.7	14-18
Metric ton/ha	100	8.6-11.6	30-40

Yield: The yield comparison amongst Giant King Grass, corn Stover and Miscanthus is not an exact apples-to-apples comparison.

- Corn will grow in cold areas, whereas Giant King Grass cannot tolerate freezing temperatures
- Corn is an annual crop and must be planted every year which causes additional expense. The annual planting also has issues for soil erosion, soil organic matter and some of the corn and wheat must be left on the field for nutrient recycling and to mitigate soil erosion, etc.
- Giant King Grass and Miscanthus are both perennial grasses. Giant King Grass requires tropical and subtropical regions and can be harvested several times a year for many years. Miscanthus will grow in cold areas.

Land-Use Efficiency

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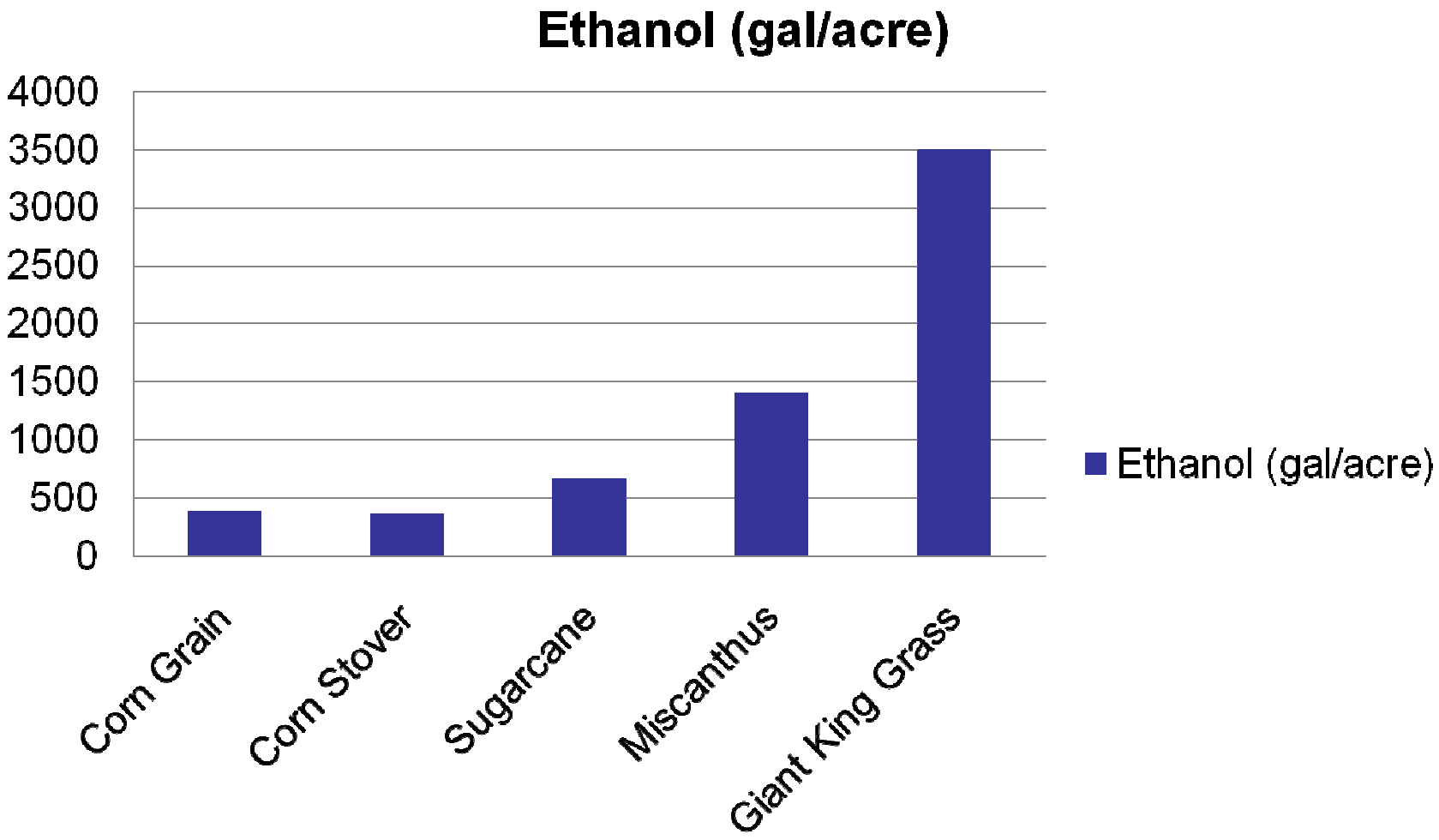

Feedstock is the Largest Cost of Cellulosic Ethanol

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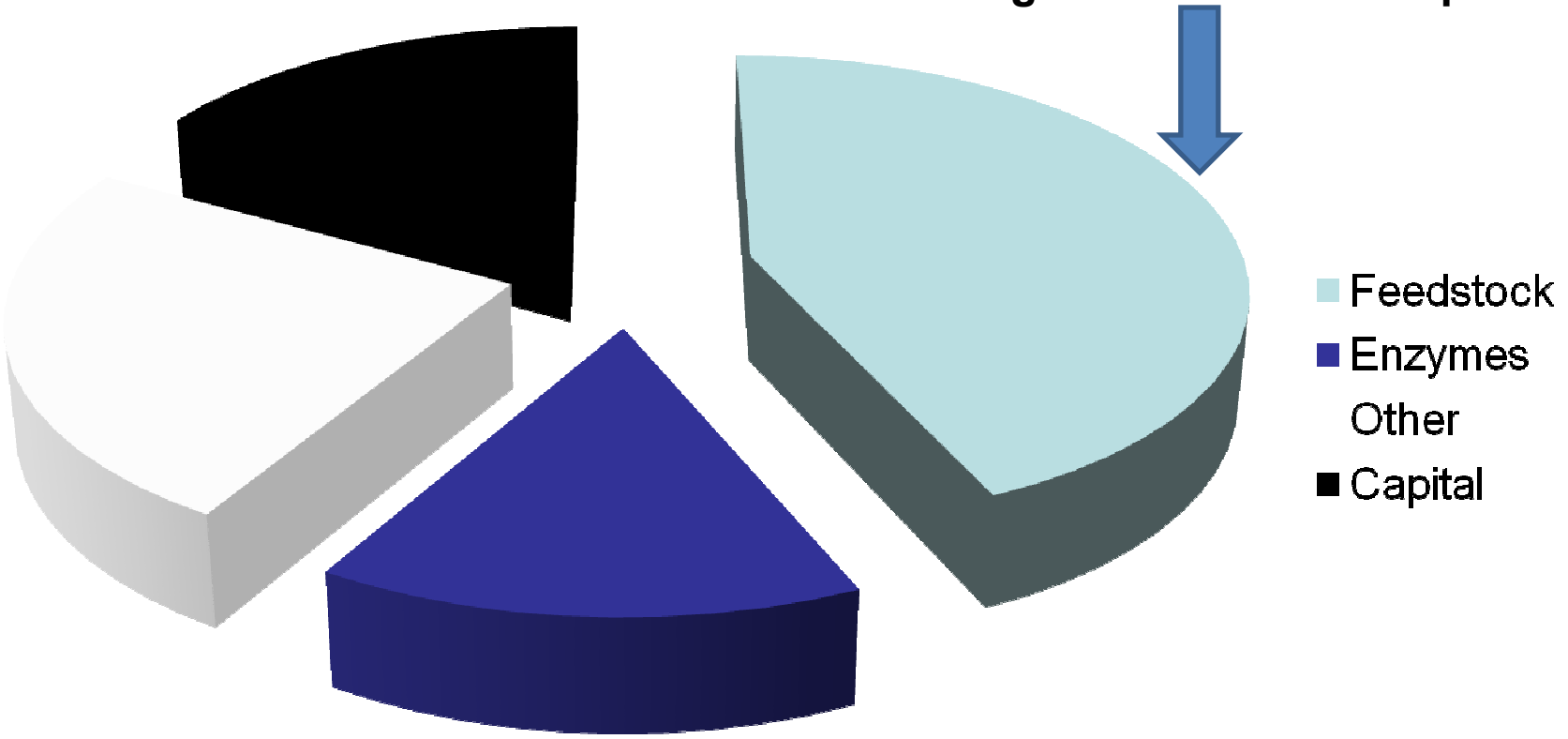
Giant King Grass and co-location can reduce feedstock cost by 40-50% making cellulosic ethanol profitable



Electricity Generation
No Perfect Option

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- Each option has its positives & negatives—for example
  - Diesel oil generators are quite inexpensive to purchase, but the fuel is very expensive and CO_2 emissions are high
  - A coal power plant is much more expensive, but the fuel is inexpensive. CO_2 emissions are highest. Coal mining has environmental issues.
  - Hydroelectricity is expensive to install, but fuel is free and there are no CO_2 emissions. There are environmental and social issues with damming rivers. Hydroelectricity is seasonal– high output during monsoon and low in dry season
  - Solar energy is expensive to purchase, but the fuel is free. Solar energy is transient– only available for about five hours per day on sunny days only. Not reliable, difficult manage on the grid. Need backup generation capability

Electricity Generation
No Perfect Option

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- It is important to understand the pluses and minuses of each option and then to make an informed decision
- A power plant decision today will likely be in place for the next 40 years at a minimum
  - The capital investment in the power plant will be large and you cannot afford to change direction
- Learn from experiences and mistakes of other countries
- A mix of fossil fuels and renewables is probably the right answer for Myanmar
  - Donor countries for foreign aid and development banks will push for use of low carbon and renewable electricity

Summary: Electricity Options for Myanmar

VIASPACE Clean Energy for a Cleaner Tomorrow

- Natural gas is best fossil fuel with reasonable cost and lowest carbon emissions
- Hydroelectricity is good large-scale, clean option
- Biomass could easily provide 10% of energy needs (several power plants) at reasonable cost. Extremely low carbon emissions & suitable for remote locations
- Coal has acceptable cost, but highest carbon emissions. Mining may be problem to environment. Avoid if possible
  - Today's technology can clean most emissions except carbon dioxide. Carbon capture may be possible in future
- Wind is a relatively low-cost option if grid can handle and unpredictable transient source
- Big solar is expensive and transient
  - Solar/Biomass hybrid could provide base and peak power
- Diesel or heavy fuel oil is extremely expensive with high carbon emissions