Assessment of Feasibility of Biomass Fuel Conversion in Interior Villages

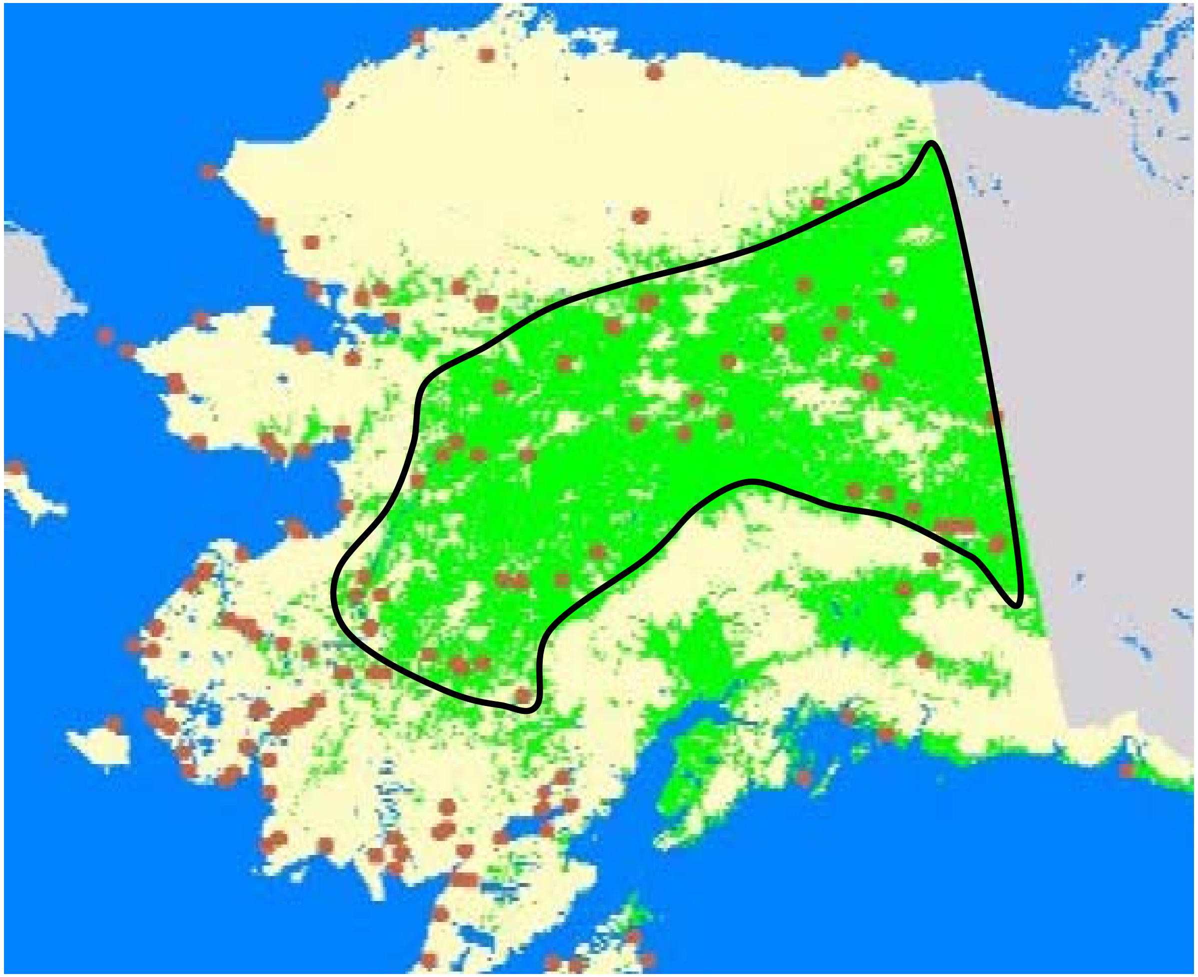
Is it ecologically, economically, and socially feasible to convert diesel electrical systems in Interior Alaska villages to wood biomass systems?

An Opportunity to Solve Multiple Problems?

Interior Alaska communities maintain strong cultural traditions with mixed economies

- Economic viability threatened by high fuel costs
- Physical viability threatened by matrix of flammable fuels near villages
- Social viability threatened by lack of local employment

Interior Alaska Communities



Rural Alaska Villages as Ideal Case Studies

- – Relatively small and self-contained
- – High current cost of power and/or heat
- – Proximity to biomass supplies
- – Lack of social opposition to use of wood fuel
- – Strong social impetus to mitigate global climate change
- – Interest in obtaining carbon credits.

Energy Systems in Rural Alaska

- 200 off-grid villages use diesel generators
- High fuel prices and storage prices
- Large state subsidies for diesel power

http://www.uaf.edu/aetdl/avecbulkfueltankfarmproject-petrie.pdf

Old tank farm, Anvik

Biomass Investment and Technology

Boilers, wood gasification, or pyrolysis

Existing combined heat and power systems

http://www.indiamart.com/nsyenergy/

http://www.fao.org/docrep/005/y4450e/y4450e02.htm

Federal and state grant money available

Forest Ecology and Ecosystem Services

Fire is a crucial component of ecological succession but poses an unacceptable risk to communities

http://www.fs.fed.us/r2/arnf/fire/hotshot/2004photos/alaska.shtml

CCX™ Chicago Climate Exchange

Carbon is now a tradable commodity

System Sub-models

1) **Ecological:**

   What is the maximum travel distance needed to sustainably harvest black spruce to meet village electrical energy needs?

2) **Economic:**

   How many years would it take, based on annual savings, to pay back infrastructure costs?

3) **Social:**

   What social factors are crucial to the success of a biomass conversion project?

Ecological Sub-model

Maximum travel distance to obtain wood fuel =

$$\sqrt{\frac{P \times Epc \times Eo \times R \times 0.01}{Bd \times Ad \times Ew \times Ee \times Fc \times \pi}}$$

Where:

***P** = Village population*

***Epc** = Per capita energy use*

***Eo** = Energy offset*

***R** = Rotation length for forest harvest*

***Bd** = Biomass density for black spruce*

***Ad** = Correction factor for converting green to air-dried wood*

***Ew** = Energy available from air-dried wood*

***Ee** = Electrical efficiency*

***Fc** = Forest cover*

Ecological Sub-model

Nominal values and ranges

- ***Village population = 21 to 1439***
- ***Per capita energy use = 3758 kWh/yr***
- ***Rotation length = 110 years (80-200)***
- ***Biomass density = 28 t/ha***
- ***Energy available = 5480 kW/t***
- ***Electrical efficiency = 28%***
- ***Forest cover = 44% (10%-75%)***

Technical Issues

- **Multiple technologies are available**

- **Combined heat and power would double the efficiency**

Type of process	**Electrical efficiency**	**Combined heat and power efficiency**	**Source**
Hot gasification/fuel cell	0.23	0.6	*Osmosun et al.*
Downdraft gasification	0.4	0.9	*Zerbin*
gasification		0.7	*Wu et al.*
gasification	0.35		*Willeboer*
gasification/fuel cell	0.24	0.6	*Wright et al.*
combustion	0.25		*USDA*
biomass integrated gasification	0.33		*Haq*
gasfication	0.21		*Somashekhar et al.*
combustion	0.2	0.6	*Bain et al 2003*
mean	**0.28**	**0.68**	

Economic Sub-model

Years to pay back investment in biomass system =

$$\frac{CapitalCosts}{AnnualSavings} = \frac{Ic \times El}{[(Ao \times De \times Dp) + (NFo \times NFc)] - (Bg \times Bc) + (De \times Ao \times Cc)}$$

Where:

Ic = installed cost of a biomass power system, per kW
El = electrical load
Ao = actual offset
De = diesel efficiency
Dp = diesel price
NFo = non-fuel offset
NFc = non-fuel costs
Bg = Biomass energy generated
Bc = Biomass energy costs
Cc = carbon credits available due to fuel offset

Economic Sub-model

Nominal values and ranges

- **Installation cost = $1849/kW**
- **Biomass energy costs = $.16/kWh**
- **Compares with current residential rates of $.17-$.56/kWh ($.23-$.80 unsubsidized)**

Firebreak project at Tanacross – work done by hand by local residents

Harvest Costs = Local Benefits

Fuels treatment project site	Type of treatment	Overhead and equipment cost per acre	Wages per acre	Total cost per acre	Cost per metric ton[1]	Operating cost per kWh[2]
Healy Lake[3]	Fire break	$640	$2,560	$3,200	$282	$0.22
Tanacross[3]	Parklike clearing to spacing of ~12'	$800	$3,200	$4,000	$353	$0.27
Delta Junction[4]	Fire break	N/A	N/A	$1,100	$97	$0.07
Stevens Village[3]	Light thinning of spruce understory	$100	$400	$500	$44	$0.03
Fairbanks[5]	Fire break	N/A	N/A	$2,700	$238	$0.18
mean		**$513**	**$2,053**	**$2,300**	**$203**	**$0.16**

1 Assuming 28t/ha, .405ha/acre

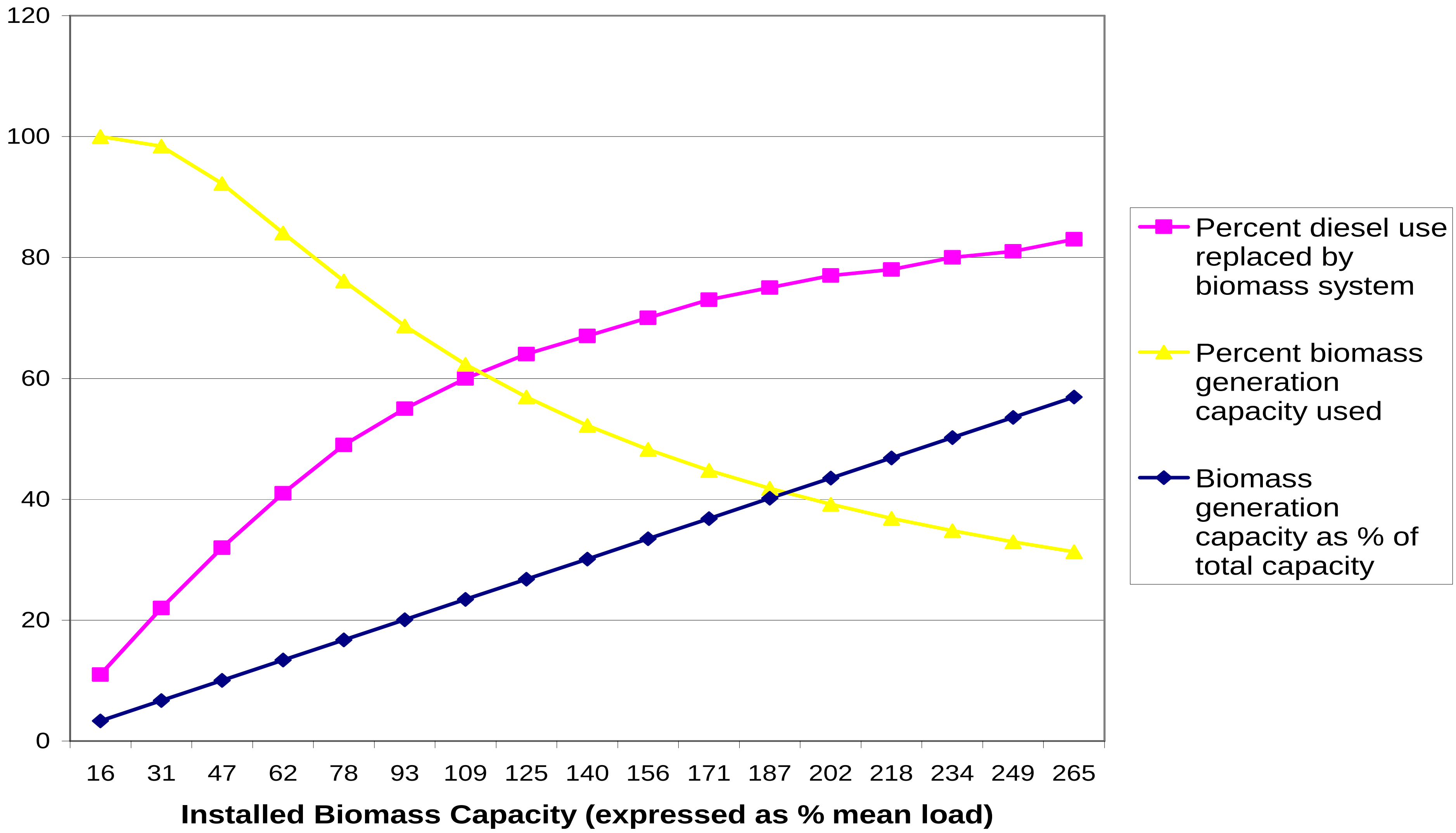
2 Assuming 5480*0.85= 4658 kWh/t (green weight)

3 Data from Hanson 2005 Pers. comm.

4 Data from BLM 2005

5 Data from Lee 2005, hand-felling method only

Biomass Generation Capacity and Diesel Fuel Savings



Potential Income from Carbon Credits

Highly sensitive to market value and U.S. emissions policy

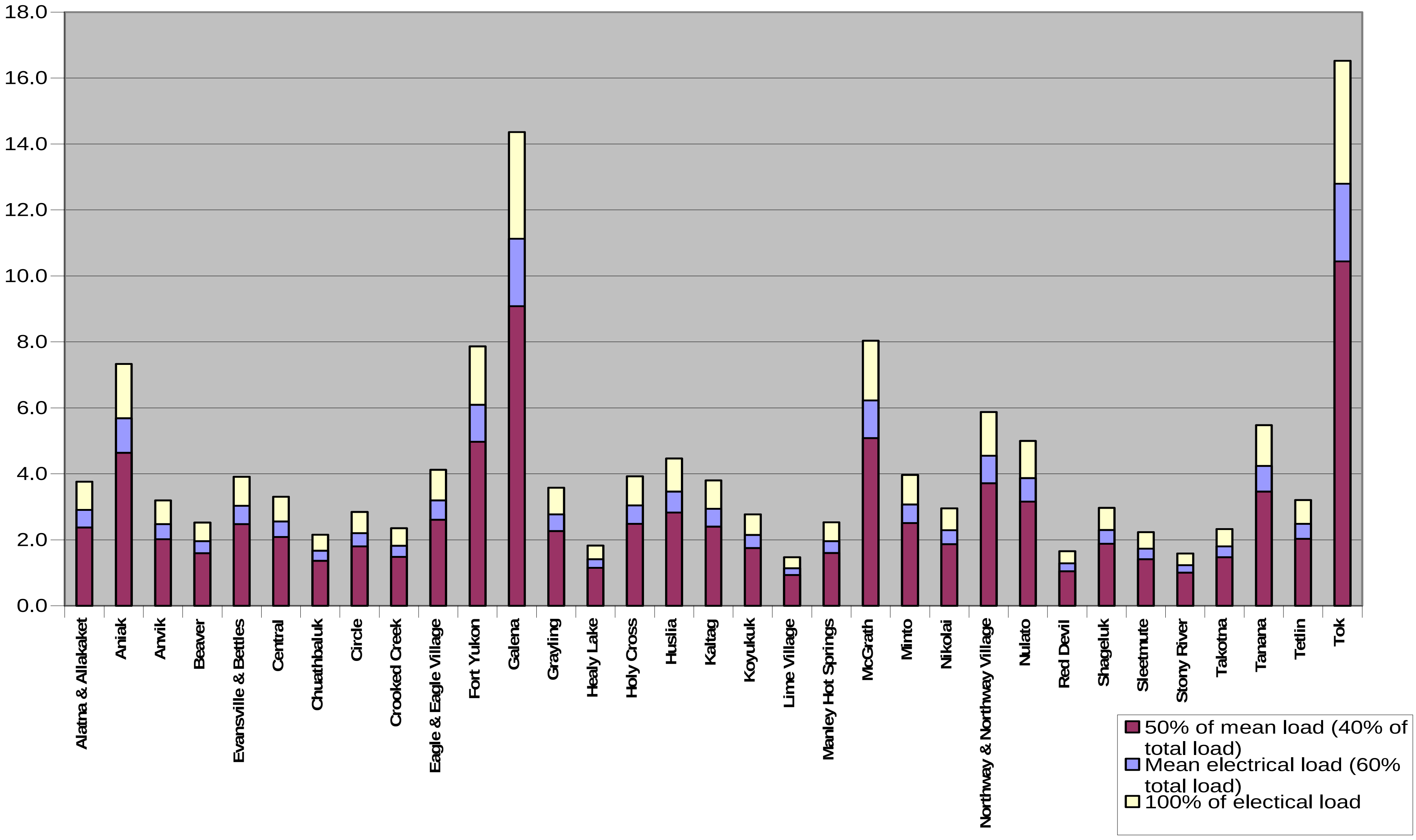
	Total liters of diesel fuel (AEA 2004)	CO2 emissions (t)	Value of credits at current CCX prices	Value of credits at current ECX prices
All PCE communities	107,796,786	263,700	$501,031	$6,328,807
Forested PCE communities in Interior AK	13,329,974	32,609	$61,957	$782,610
Per 1,000 gallons of diesel	3785	9	$18	$222

Social Sub-model

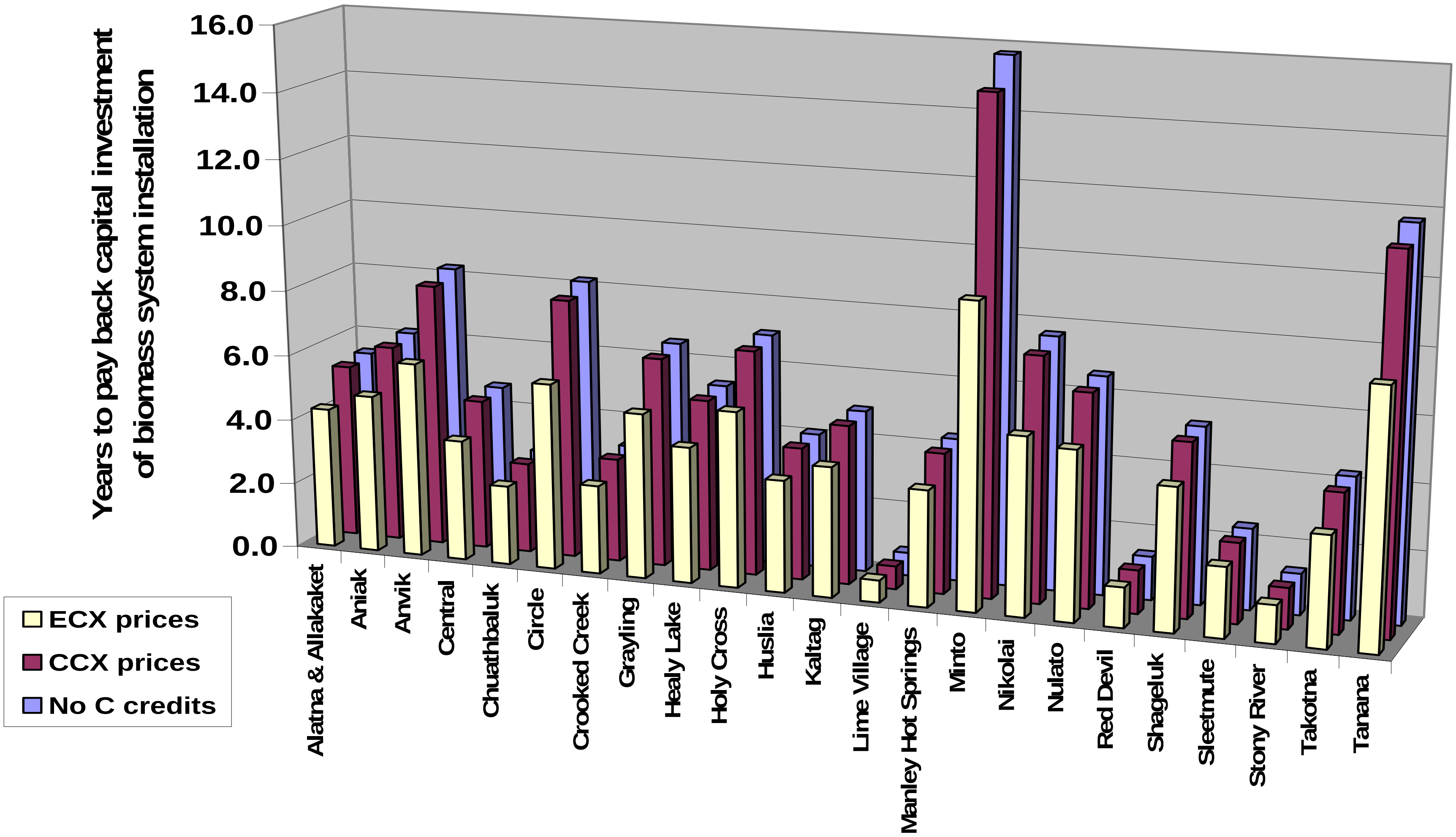
Factors Assessed:

- Existing social and technical capacity
- Threshold requirements
- Existing institutional barriers to change
- Potential positive and negative social feedback
- Lessons learned from existing biomass projects in rural Alaska

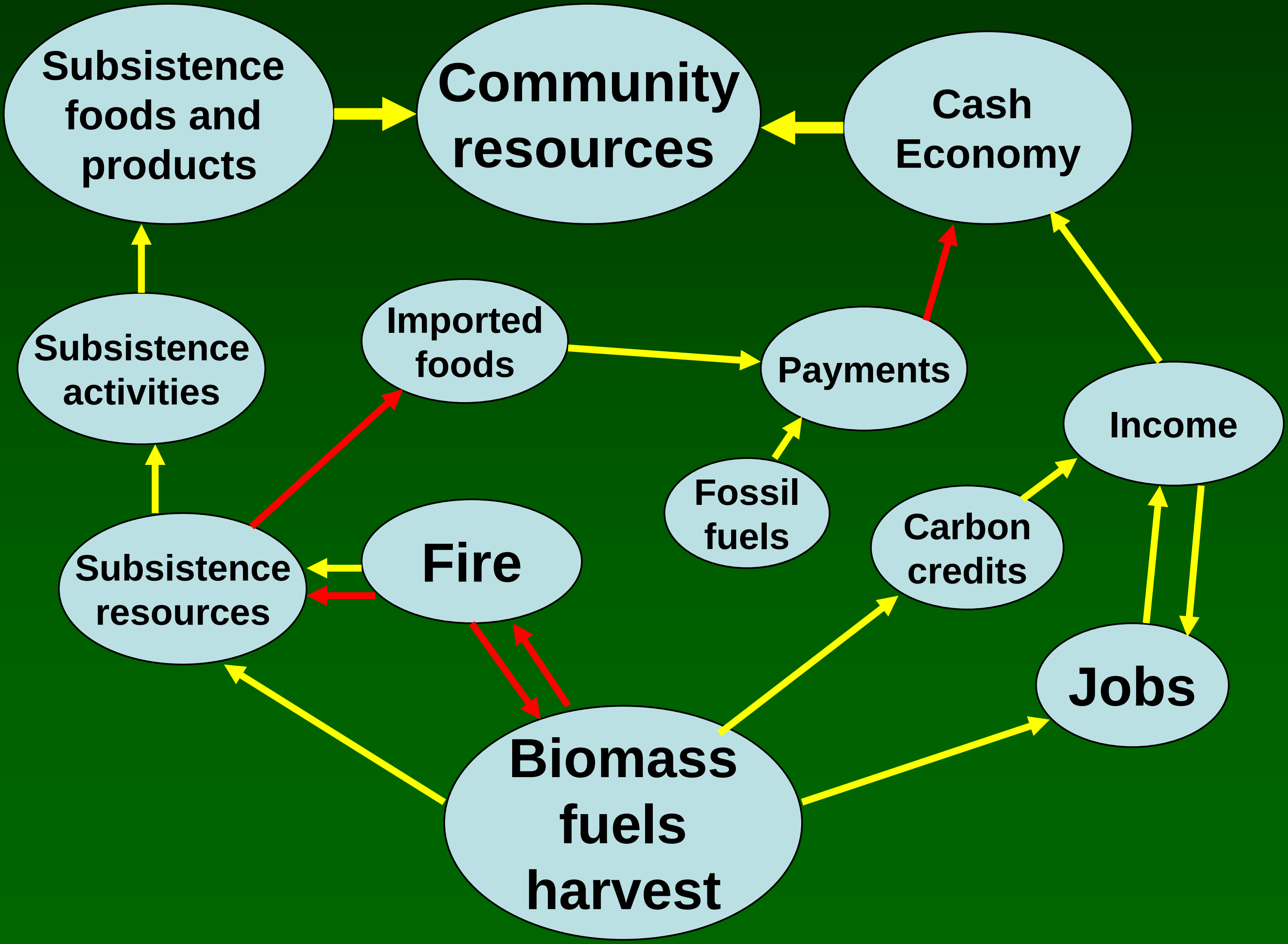
Maximum Travel Distance Required to Supply Fuels Sustainably



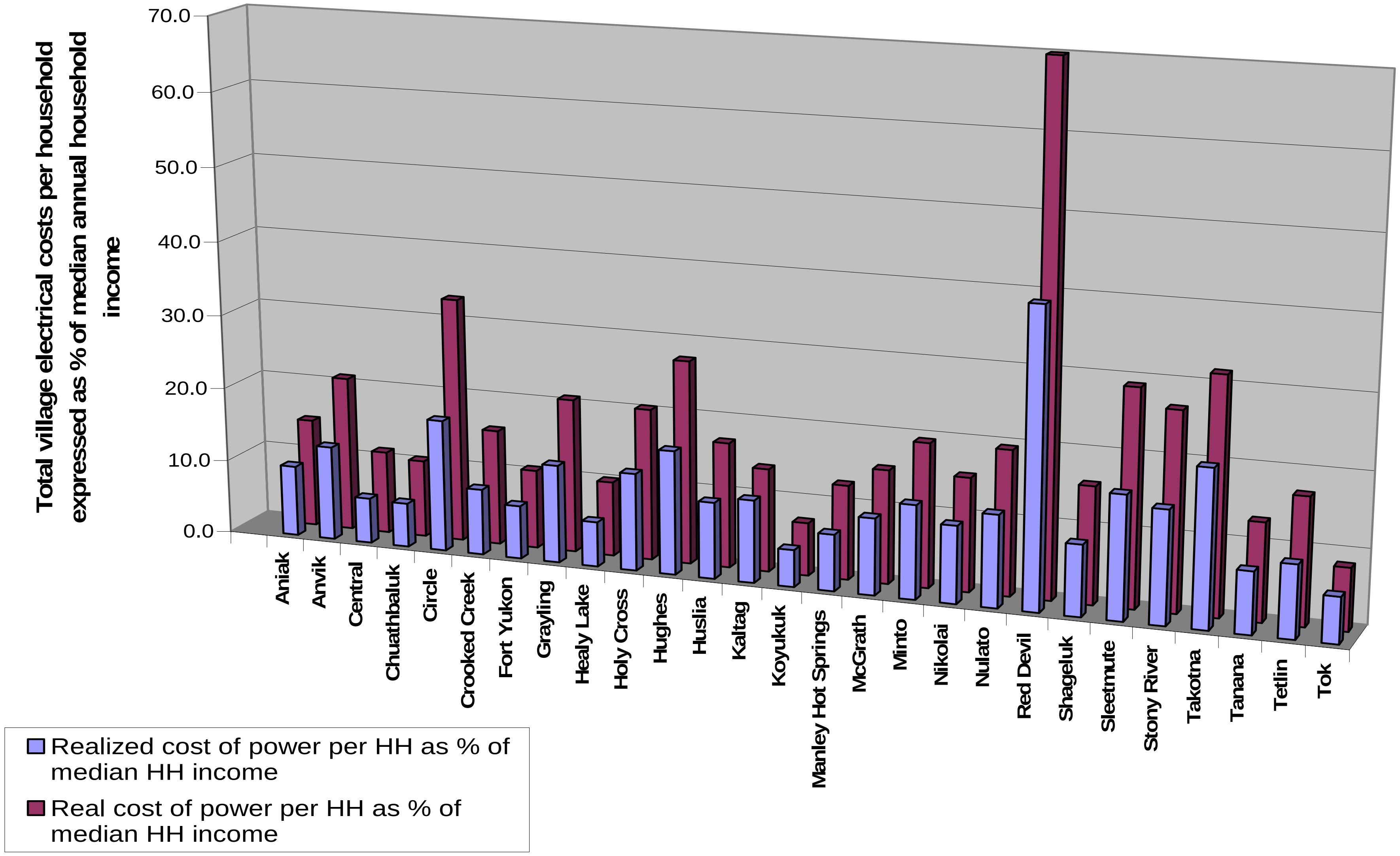
Years to Recoup Initial Investment



Social Feasibility



Cost of Electrical Power (% of household income)



Barriers to Implementation

- AEA funding allocated to diesel power
- State electrical subsidies favor status quo
- Many power cooperatives managed regionally
- No forest certification system
- Failure of U.S. to sign climate-change agreements keeps carbon credit prices low

Thresholds to Feasibility

- Development of necessary leadership and technical skills in villages
- Formation of effective collaboration between agencies, power industry, and villages

Potential Hurdles and Benefits

	Hurdles	**Benefits**
Economic	Cost of new infrastructure	Wages from fuel gathering
	Cost of biomass harvest	Reduced cost of diesel
	Certification for sustainable wood harvest	Reduced cost of subsidies
		Market value of carbon credits
Social/Political	Political buy-in from agencies and power companies	Health benefits from reduced pollution
	Ensuring local involvement and continuity	Greater autonomy of local communities
Technical/Ecological	Technical challenges of biomass energy generation	Reduced fire risk
		Greater landscape diversity
	Ensuring long-term sustainability of harvest	Creation of diverse wildlife habitat

Conclusions

- ***Fuel conversion is most viable in small remote villages, including 22 villages studied***

- ***Combined heat and power would increase potential benefits***

- ***Social feasibility requires case studies***

- ***Alaskan villages could provide global leadership in rural biomass power systems***