Genetic Improvement of Shrub Willow as a Bioenergy Crop

Larry Smart, Associate Professor

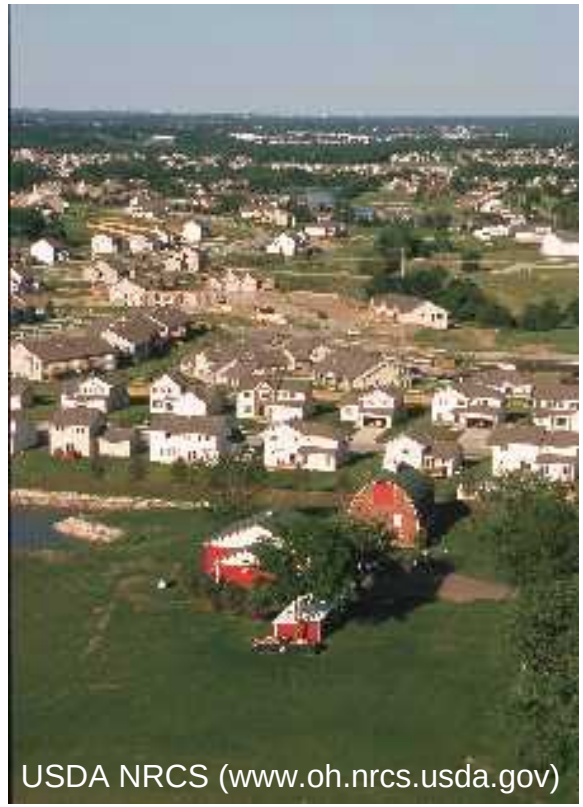
SUNY College of Environmental Science & Forestry

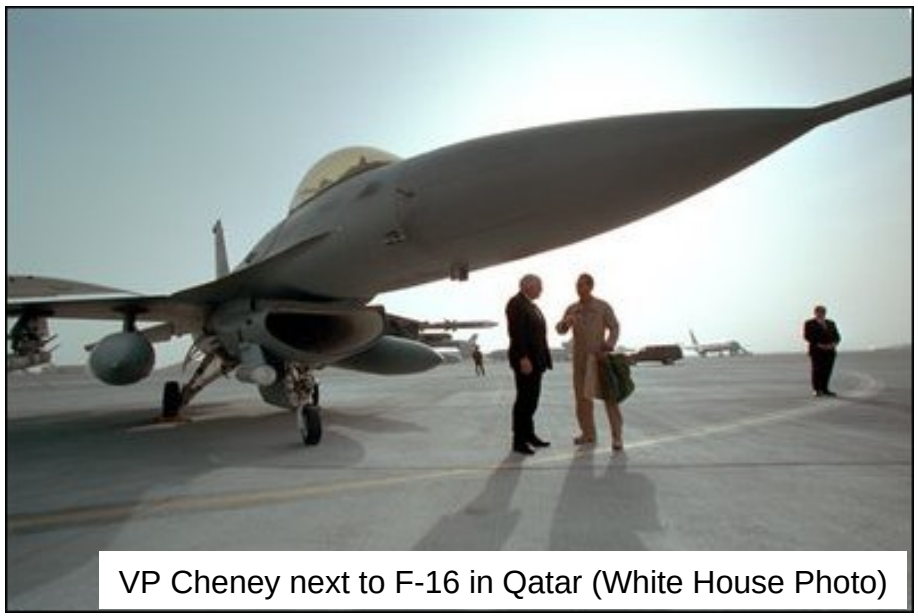
Syracuse, New York

lbsmart@esf.edu

www.esf.edu/efb/smart/

Paramount Pictures (www.climatecrisis.net)


USDA NRCS (www.oh.nrcs.usda.gov)


VP Cheney next to F-16 in Qatar (White House Photo)

New York State Energy Facts - 2005

- Of New York's primary energy consumption by Btu:
  - 77% petroleum, natural gas, coal
  - 10% nuclear power
  - 5% hydro
  - 3% bioenergy (wood residues and municipal waste)
  - 5% imported electricity

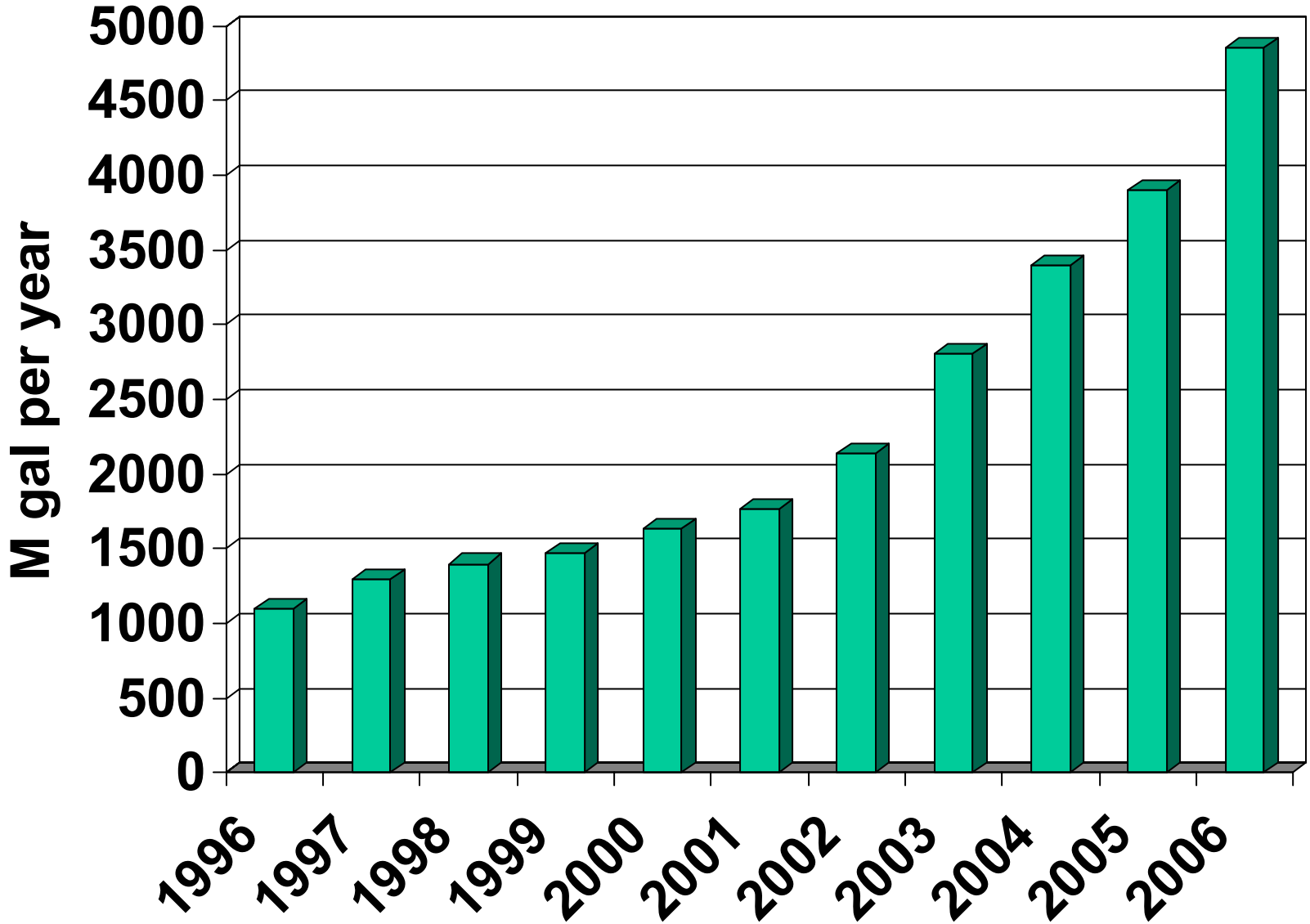
. . . costing $2,984 and releasing 12.5 tons of CO_2 *per person*

- Only 10% of that was supplied by *in-state* sources

- 90% of petroleum used in NY is from *foreign* sources

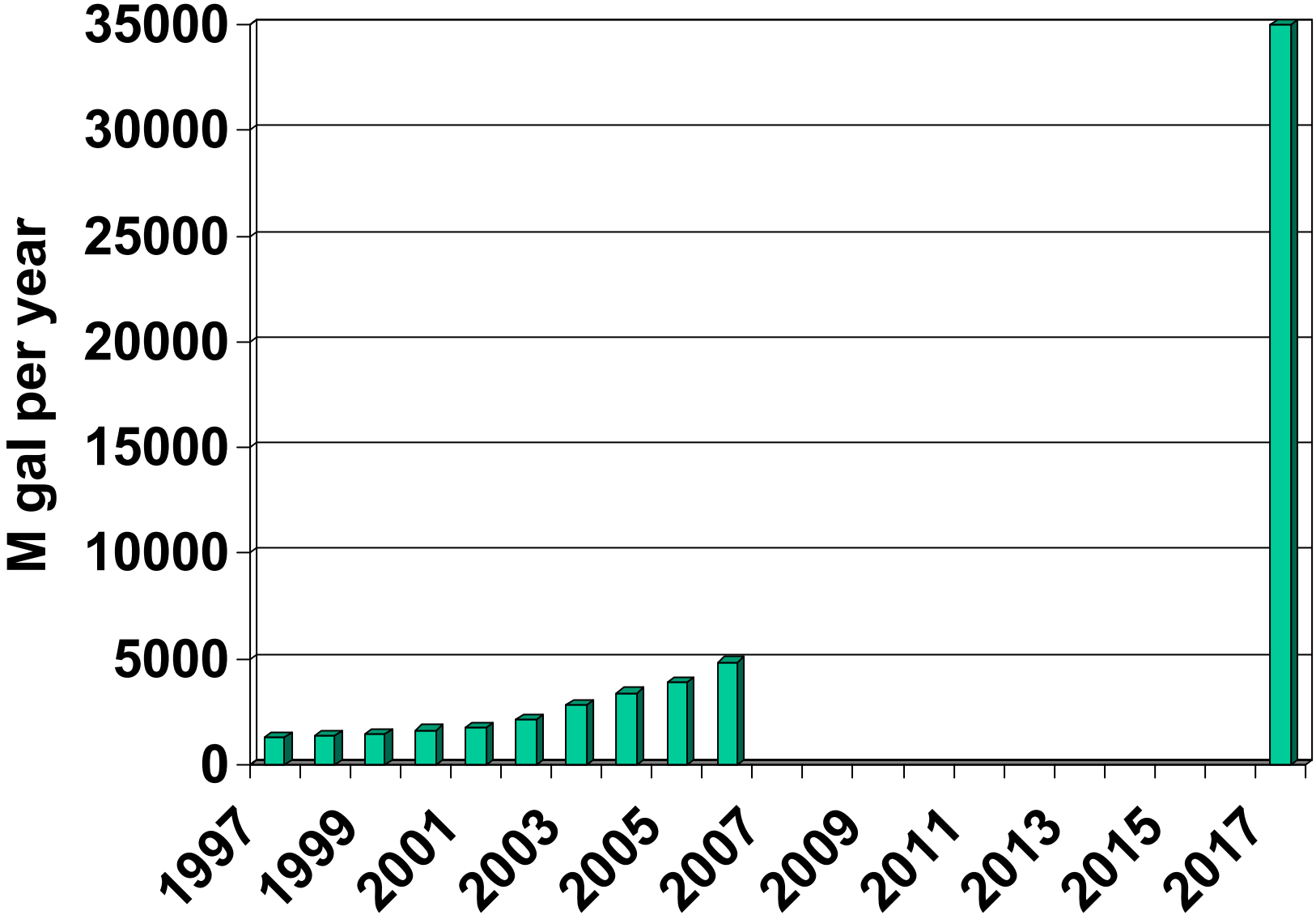
Patterns and Trends: NYS Energy Profiles: 1991-2005 (Jan. 2007) NYSERDA

Annual Ethanol Production in the U.S.



Data source: Renewable Fuels Association (http://www.ethanolrfa.org/)

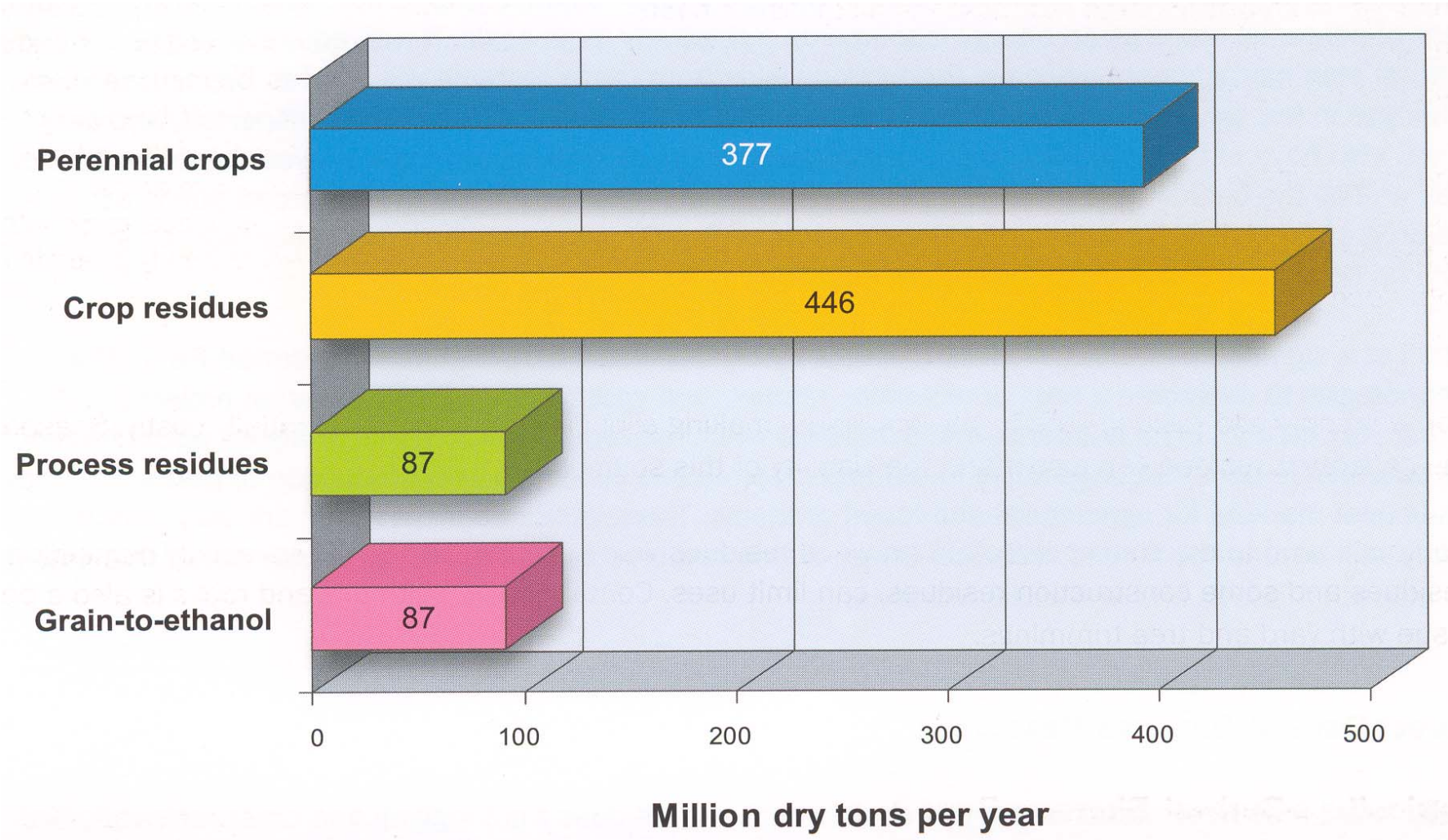
Annual Ethanol Production in the U.S.
"20 in 10" = 20% of petroleum replaced by 2017



Data source: Renewable Fuels Association (http://www.ethanolrfa.org/)

Perennial Energy Crops Will be Grown on 55 M acres by 2030

- to replace 30% of U.S. petroleum consumption



Perlack et al. (2005) U.S. D.O.E./U.S.D.A.

Regional Perennial Energy Crops

Hybrid Poplar

Willow Shrubs

The center of the basket willow industry (ca. 1892) is now a center for growth of shrub willow energy crops

Harvest of willow stems for basketry
Photo: Liverpool Willow Museum

Harvesting wood chips using a New Holland forage harvester and specialized head.

Genetic Improvement of Shrub Willow as a Bioenergy Crop

Intro to short-rotation willow culture

Breeding and selection for high yield

- ***Establish a diverse willow collection***
- ***Controlled pollination & hybridization***
- ***Selection and field testing for yield***
- ***Tech transfer and commercialization***

Willow Biomass Production Cycle

Site preparation

Planting

First-year growth

Willow Biomass Production Cycle

Site preparation

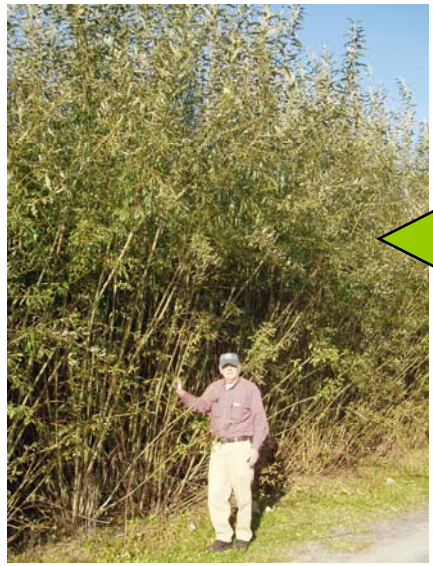
First-year growth

Winter Coppice

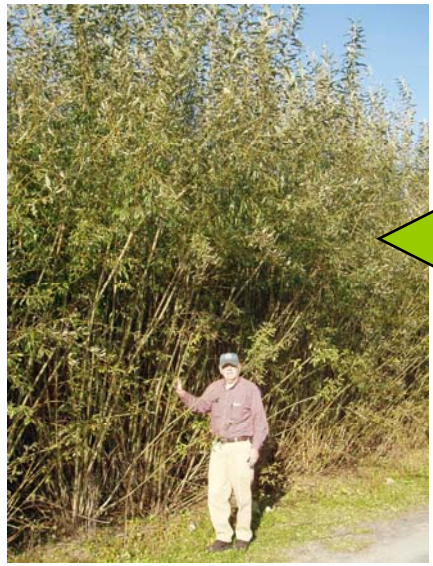
Regrowth after coppice

One year old after coppice

Three years old after coppice



Willow Biomass Production Cycle



Three years old after coppice

At least 7 harvests

One year old after coppice

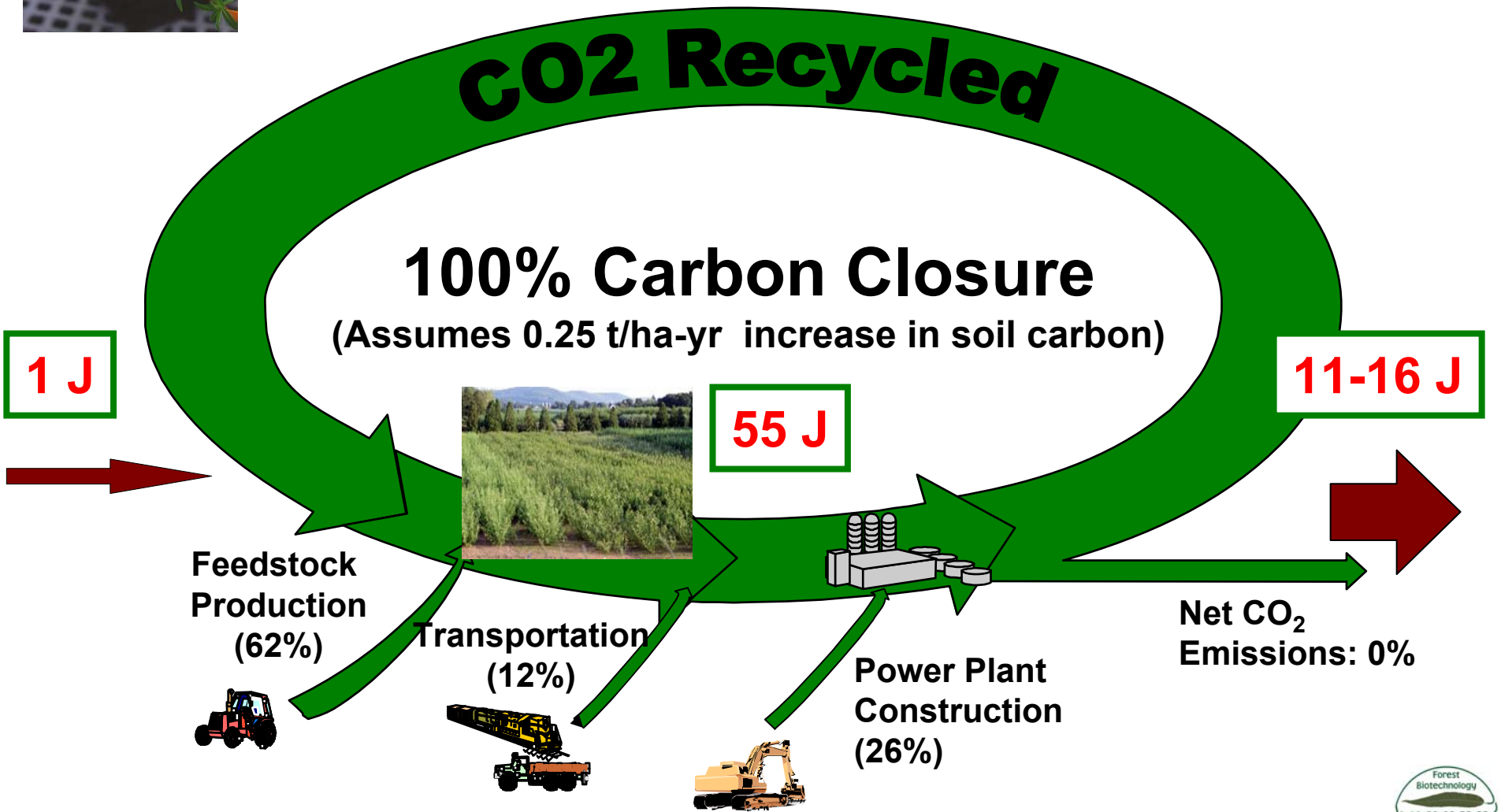
Regrowth after coppice

Heat/Power from Willow Wood Chips

- Burn in wood-fired heat/power plants
- Co-fire with coal in existing power plants
- Gasify to generate heat and power

Wood-fired boiler at Lyonsdale Biomass, Lyons Falls, NY

Willow Energy Crops Provide CO_2 Benefits



(Mann and Spath 1997, Heller et al. 2003, 2004)

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Breeding is Likely to Improve Productivity of Willows

A 20% increase in yield reduces cost by 13%

- High genetic diversity
- Little domestication
- Short generation time
- Clonal propagation
- Many species can hybridize

Generalized Willow Breeding Strategy

Molecular Techniques

Breeding Population
Many clones of 10-15 species

ongoing ↓ **Nursery screening**

↓ **Select parents for breeding**

Family Screening Trial
Many crosses; Single-plant plots

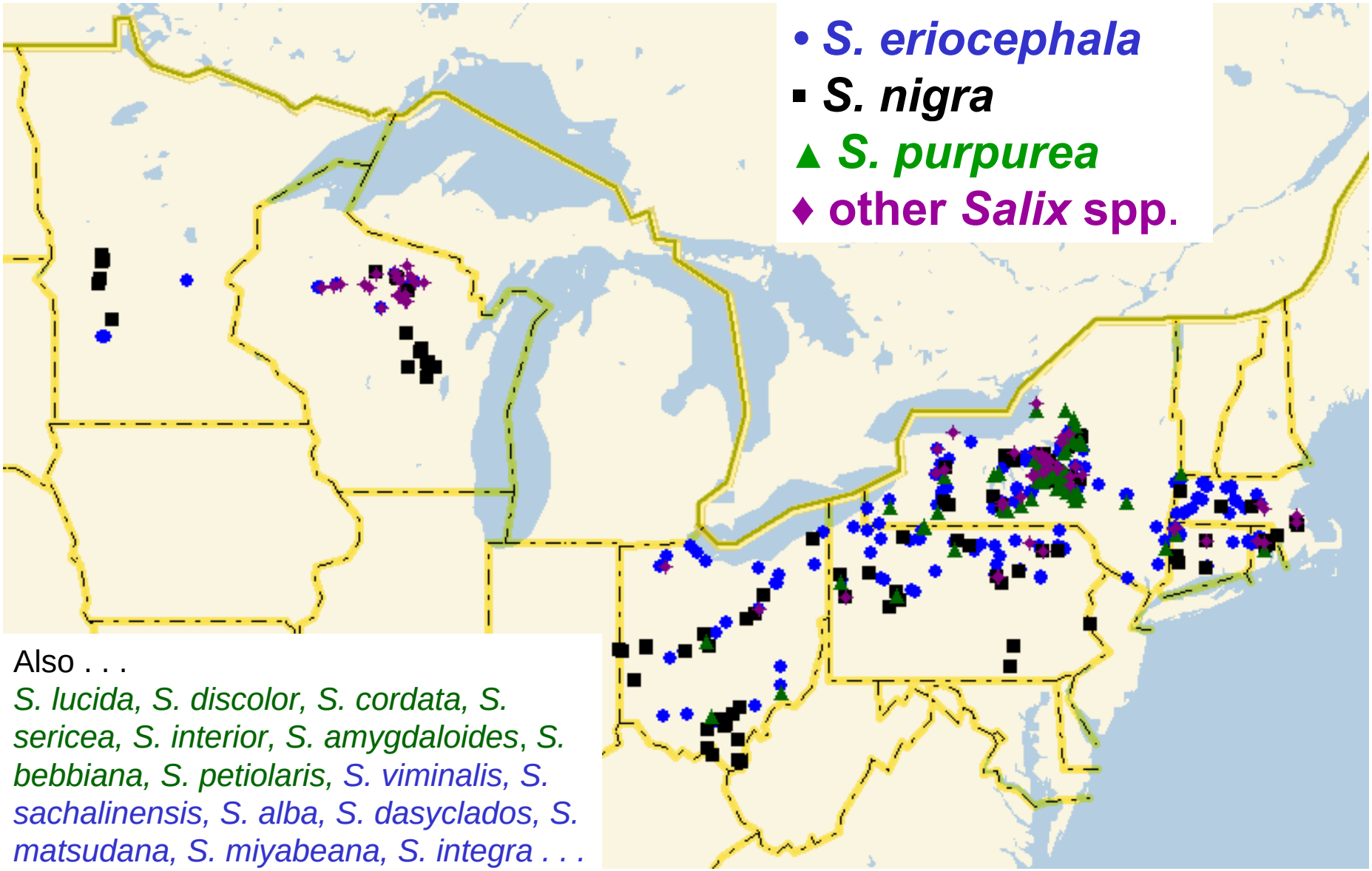
2-3 years ↓ **Select, propagate**

Selection Trial
Replicated, multi-plant plots

→ **Select** *2-4 years*

Yield Trials

More than 600 Accessions Collected: 1994 - 2006



Also . . .
S. lucida, S. discolor, S. cordata, S. sericea, S. interior, S. amygdaloides, S. bebbiana, S. petiolaris, S. viminalis, S. sachalinensis, S. alba, S. dasyclados, S. matsudana, S. miyabeana, S. integra . . .

Since 1998, more than 600 crosses attempted

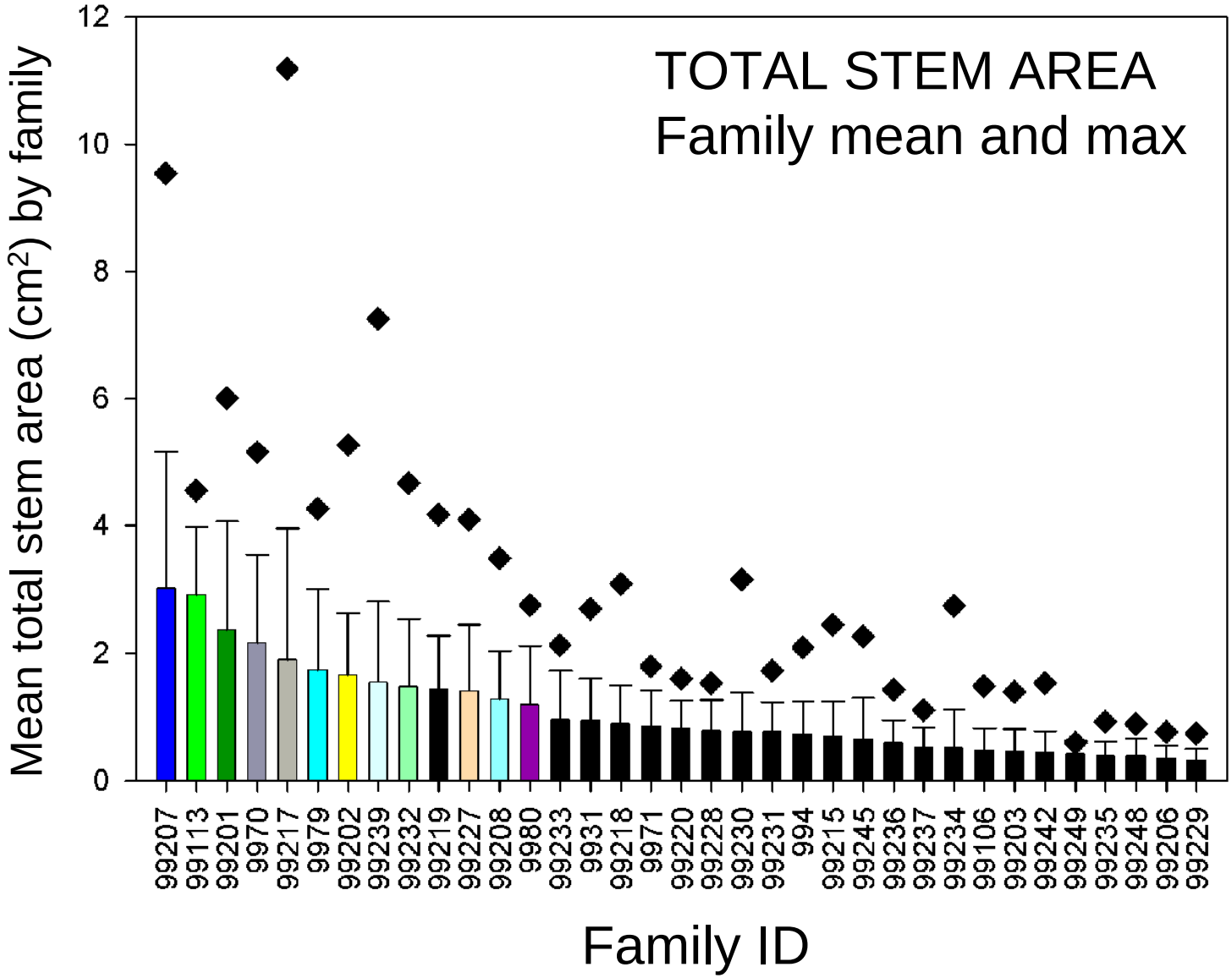
26 families of
S. purpurea

101 families of
S. eriocephala

91 other families, mainly *S. sachalinensis, S. miyabeana*

1999 Family Screening Trial - Syracuse

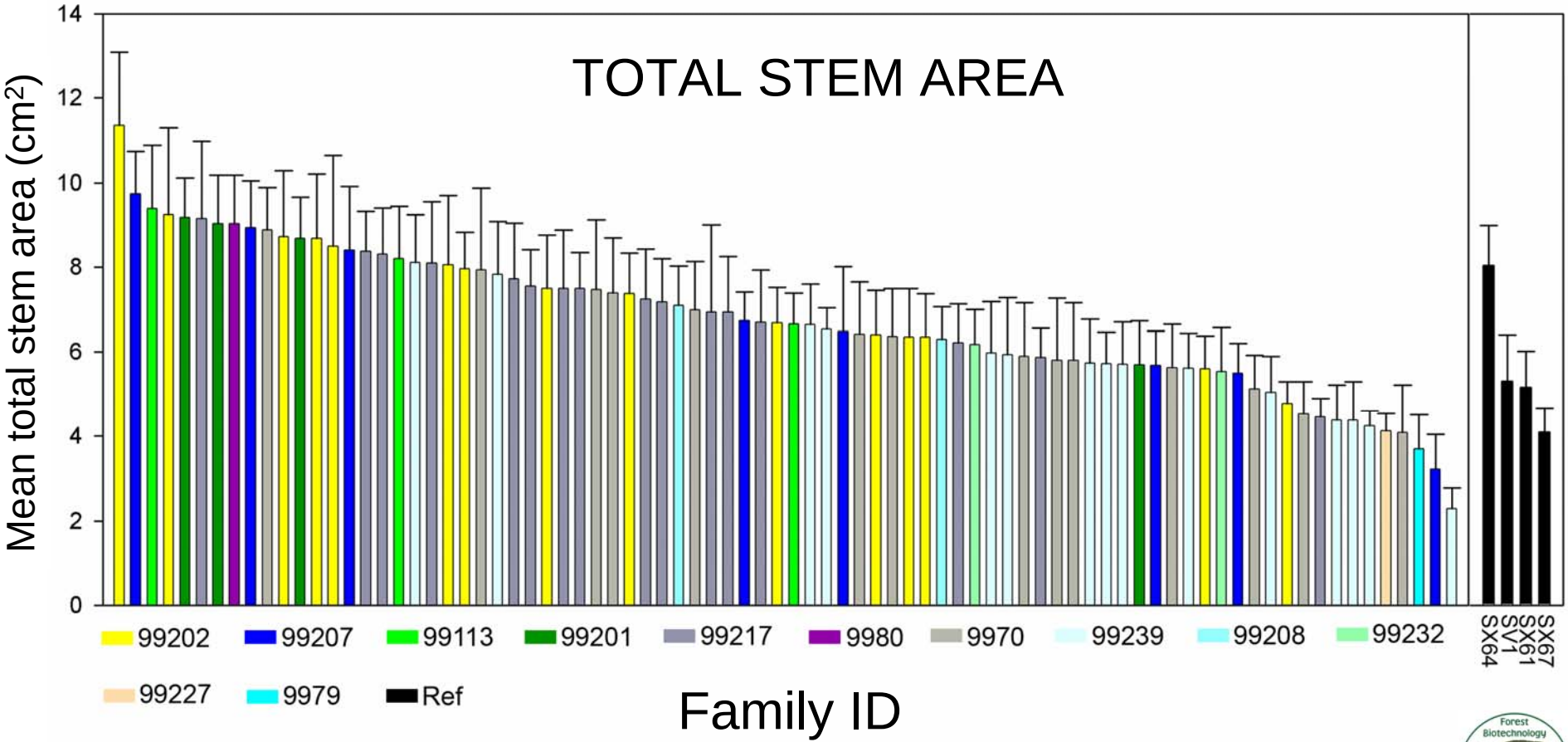
Two years post-coppice measurements



2002 Genetic Selection Trial

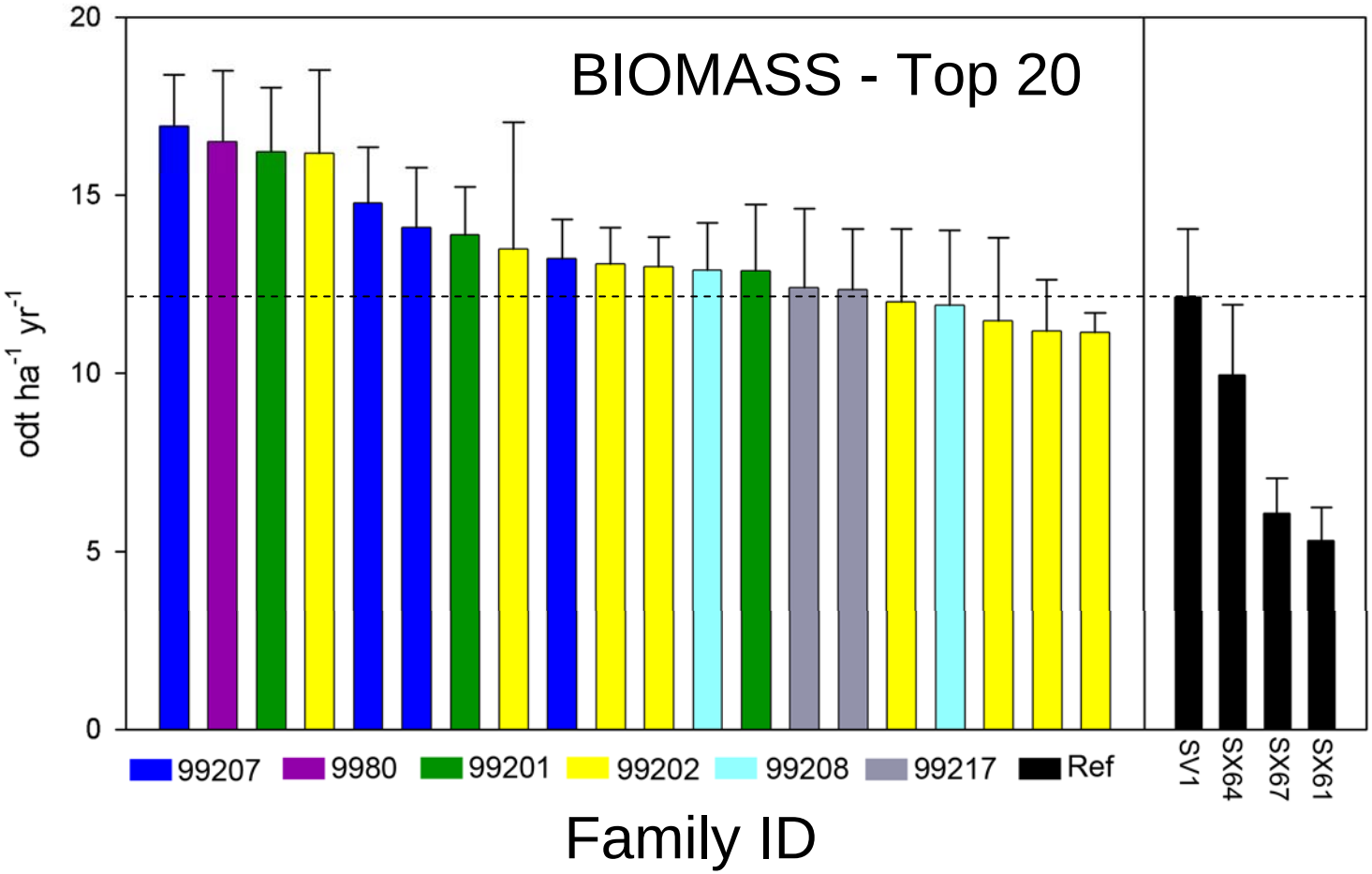
First year post-coppice measurements

Four-plant plots; eight reps; Tully, NY



2002 Genetic Selection Trial

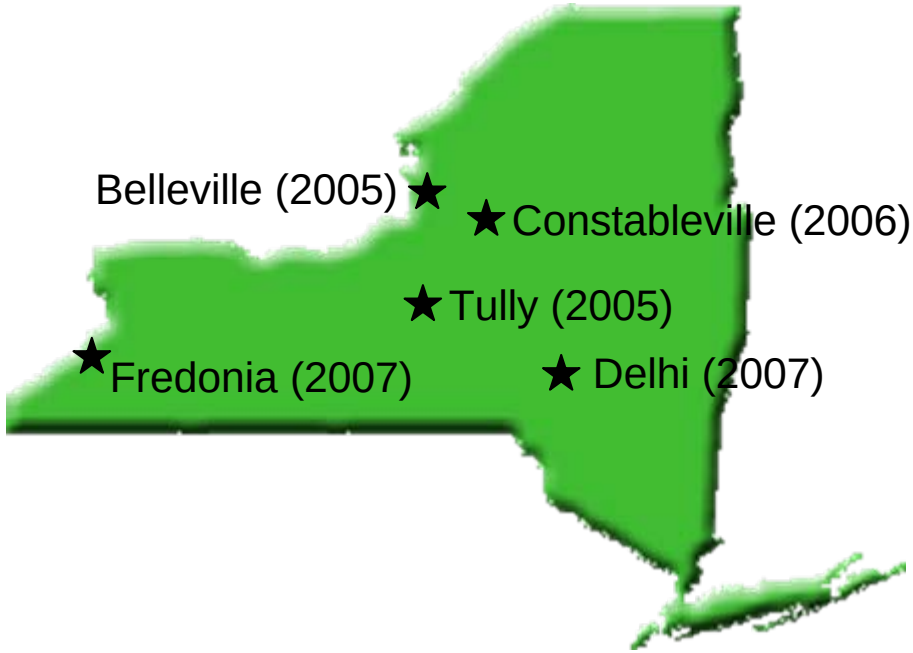
Biomass harvest - Two years post-coppice



- *15 varieties with greater yield than 'SV1'*
- *top variety had 40% greater yield than 'SV1'*

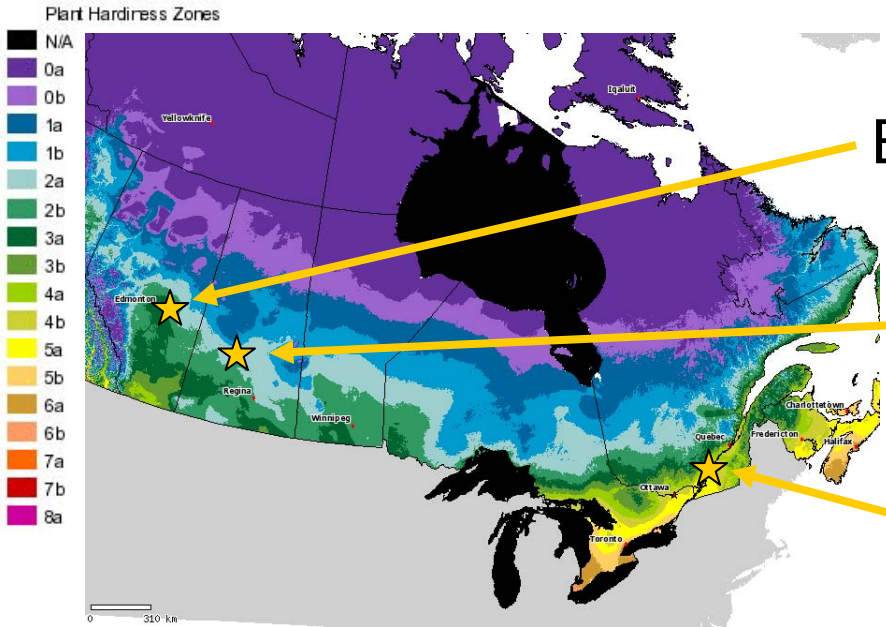
Yield Trials Planted in 2005, 2006, 2007

2006: 1 year post-coppice, Belleville, NY

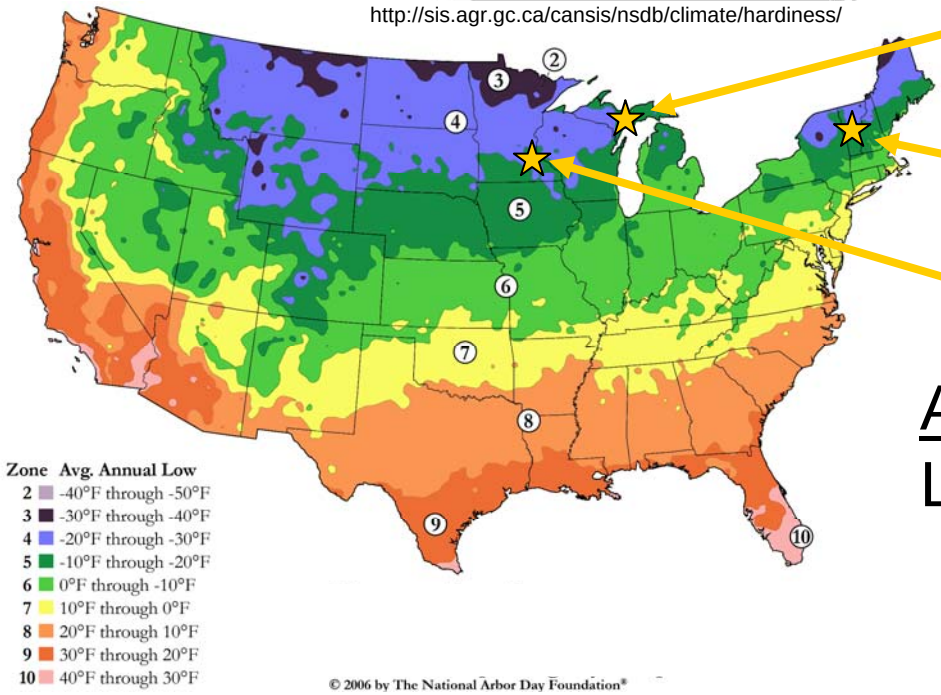


- 78 plants per plot
- 4 replicate blocks
- 18-30 varieties
- double-row spacing
- hand planted/harvested

Yield Trials Planted on 12 Sites



http://sis.agr.gc.ca/cansis/nsdb/climate/hardiness/



Edmonton, AB (2006)

Saskatoon, SK (2007)

Montréal, QC (2007)

Escanaba, MI (2007)

Middlebury, VT (2007)

Waseca, MN (2006)

<u>Also in 2007:</u>

Loughgall, N. Ireland (2007)

Establishing a Commercial Willow Nursery in New York

Double A Vineyards dba Double A Willow (Fredonia, NY) will produce and sell whips for commercial scale-up

Clone ID #	Variety epithet (PP, plant patent)
99207-018	'Owasco' (PP 17,845)
9980-005	'Oneida' (PP 17,682)
99201-007	'Otisco' (PP 17,997)
99113-012	'Onondaga'
99202-011	'Tully Champion' (PP 17,946)
9970-036	'Canastota' (PP 17,724)
9871-031	'Sherburne'
9882-034	'Fish Creek' (PP 17,710)
99239-015	'Allegany'
99217-015	'Millbrook' (PP 17,646)
SX61	
SX64	
SX67	
S25	
S365	
SV1	

Nursery beds doubled each of last three years to >300,000 plants in 2007

(www.doubleawillow.com)

Genetic Improvement of Shrub Willow as a Bioenergy Crop

Summary

- Shrub willow is a viable perennial bioenergy crop with established systems for planting, harvesting, transport, and use of willow biomass
- New varieties produced through traditional breeding generate higher yields than existing varieties
- Trials have been planted on 12 sites to estimate regional yield potentials
- New willow bioenergy crop varieties are being deployed commercially in the U.S.

Collaborators and Funding

Dr. Tim Volk
Research Associate

Dr. Larry Abrahamson
Sr. Research Associate

Dr. Kim Cameron
Research Scientist

Dennis Rak (Double A Willow) Ed Priepke (CNH America)

Rich Kopp, Juan Lin, Ingrid Phillips, Michelle Serapiglia, Jason Purdy, Ken Burns, Mark Appleby, many undergraduates...

USDA Rural Development CSREES NYSERDA New York State Energy Research and Development Authority CNH Case New Holland Forest Biotechnology