ROYAL INSTITUTE OF TECHNOLOGY

A GIS-Model to Estimate the Sustainable Potential of Forest Fuel in Växjö, Sweden

MSc thesis project in Geoinformatics

Gunnar Wohletz

NORTH SEA SUSTAINABLE ENERGY PLANNING

The Interreg IVB North Sea Region Programme
Investing in the future by working together for a sustainable and competitive region

European Community
European Regional Development Fund

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July 14, 2011

Outline

- Introduction
- Objectives and Study Area
- Literature Review and Data Description
- Methodology and Intermediate Results
- Results & Conclusion
- Outlook

Växjö: “The Greenest City of Europe”

- Title awarded by the BBC in 2007
- Early efforts towards sustainable future since 1970s
- 2015 goal: reduce carbon dioxide emissions per inhabitant by 55% (compared to 1993)
- 2030 goal: fossil fuel free city
- City: district heating system supplied by combined heat and power (CHP) plant
- Municipality: 4 local heating stations
- All almost only run on wood

North Sea SEP Project

- "North Sea Sustainable Energy Planning"
- Part of North Sea Region Program (Interreg IV B)
- Supported by European Regional Development Fund (ERDF)
- Running period: 2009-2012
- Over €5 million budget
- Jade University has lead beneficiary role
- 26 project partners in 6 countries
- Partner: Energikontor Sydost in Växjö
- Goal: to develop and promote models for regional sustainable energy planning

Biomasses as Renewable Energy Source

- Renewable energy: water, wind, **biomass**, solar, geothermal
- Biomasses: all substances generated by plants or animals (live or dead)
- Exemplary study: “EnergieRegion Rhein-Sieg” by Research Studios Austria (RSA)
- Estimating potentials of wind, biomass, solar and geothermal
- Forest fuel potential: GIS-analysis on land use data with assumed annual forest fuel yield applied

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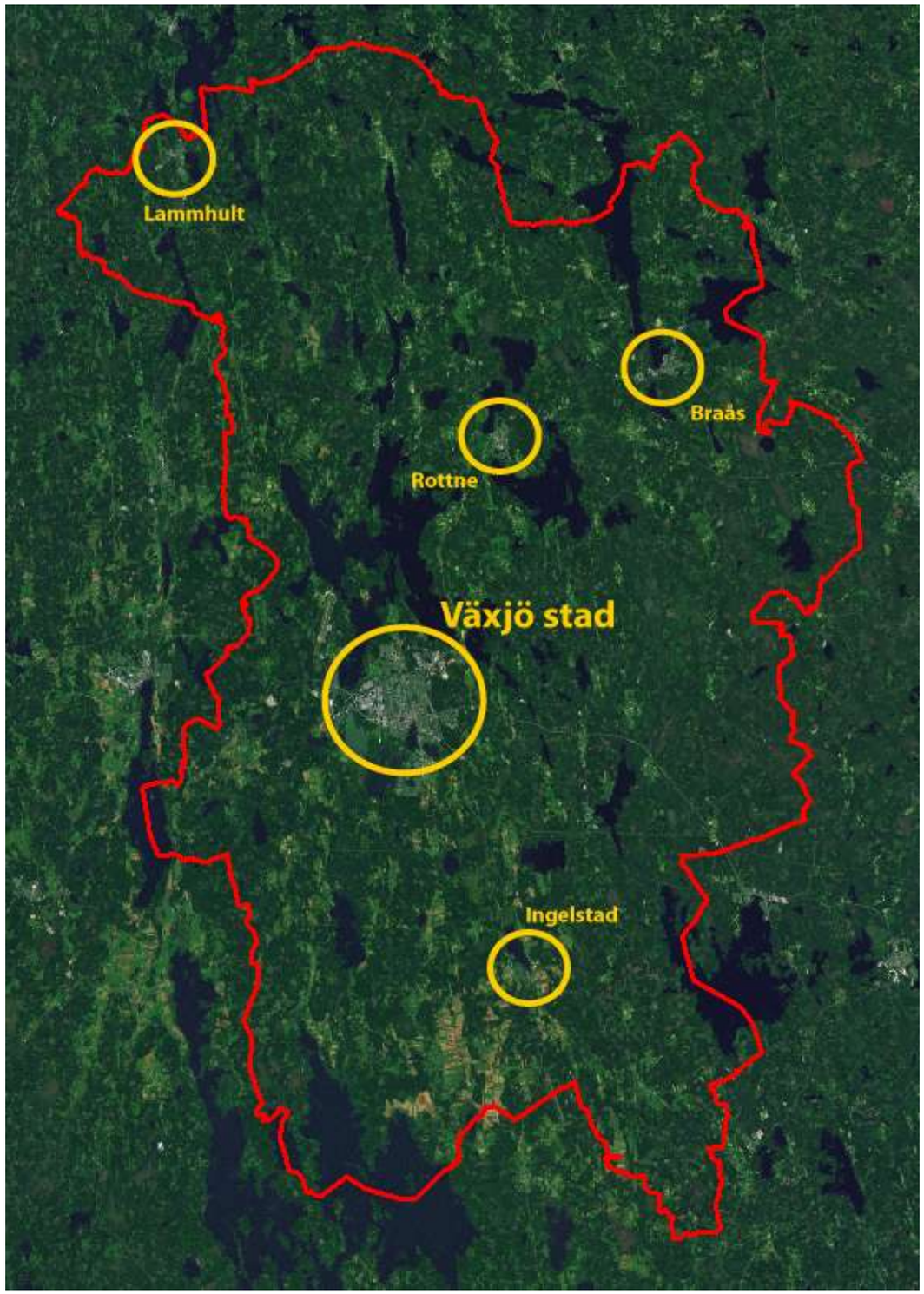
- Methodology and Intermediate Results
- Final Result & Discussion
- Conclusion

Objectives

- Create a GIS-model to model the sustainable forest fuel potential until 2050
  - Model outline
  - Forest growth
  - Annual forest fuel outtake
- Put results into perspective with real data
- Make conclusions about future of forest fuel in the region

Study Area

- Municipality of Växjö, province of Kronoberg
- Approx. 83,000 inhabitants (55,600 in Växjö city)
- Area: 1,925 km^2 (N/S ≈ 69km; E/W ≈ 46km)
- 1 CHP-plant ‘Sandvik‘ in Växjö city
- 4 local heating stations in outskirt towns



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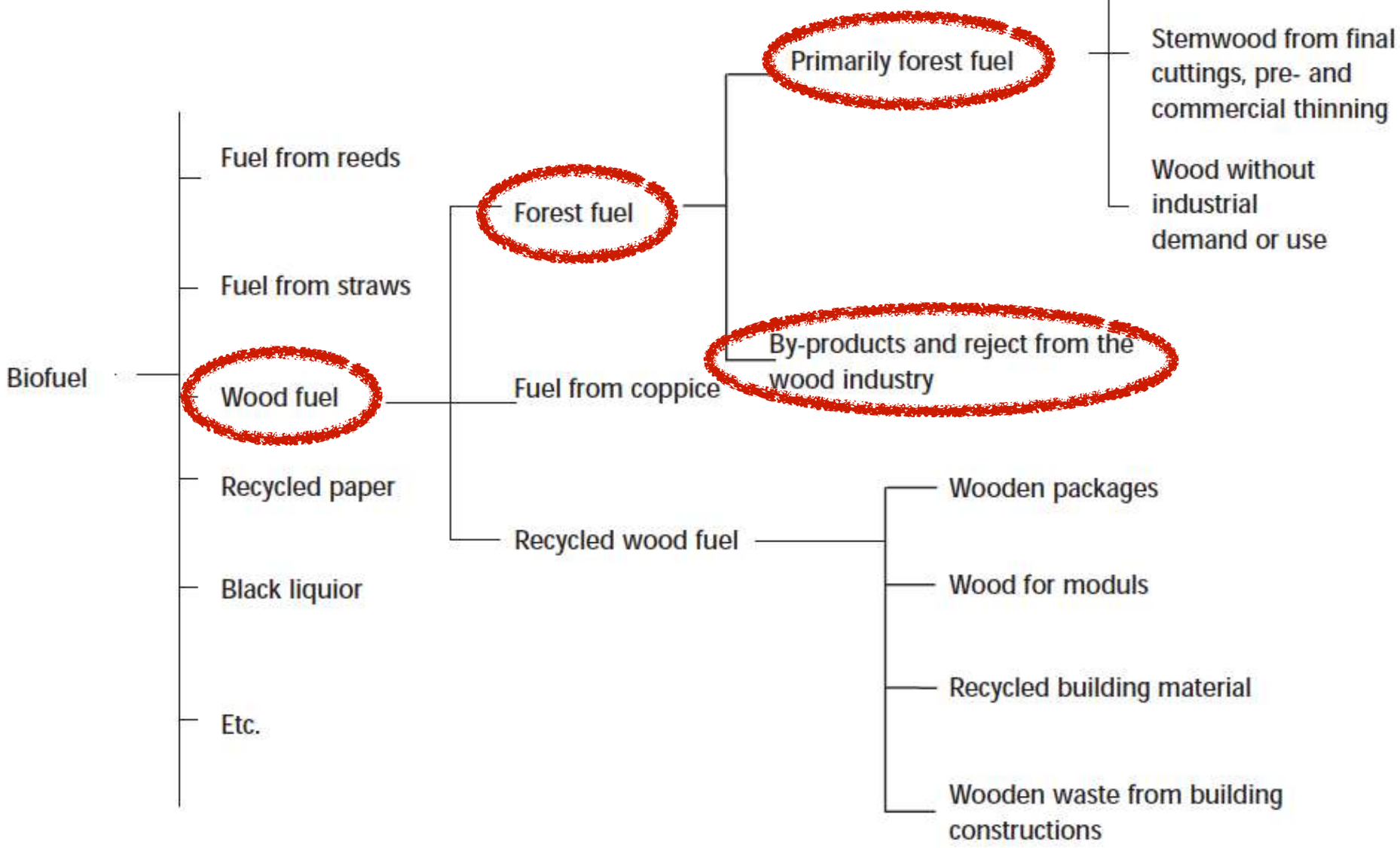
Forest Fuel

- Forest wood that is used for energy purposes



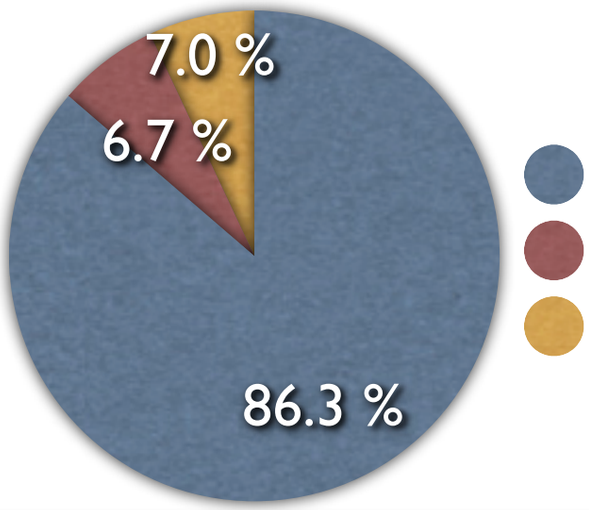
Source: L. Andersson and R. Budrys. Integration of forest fuel handling in the ordinary forestry. 2002

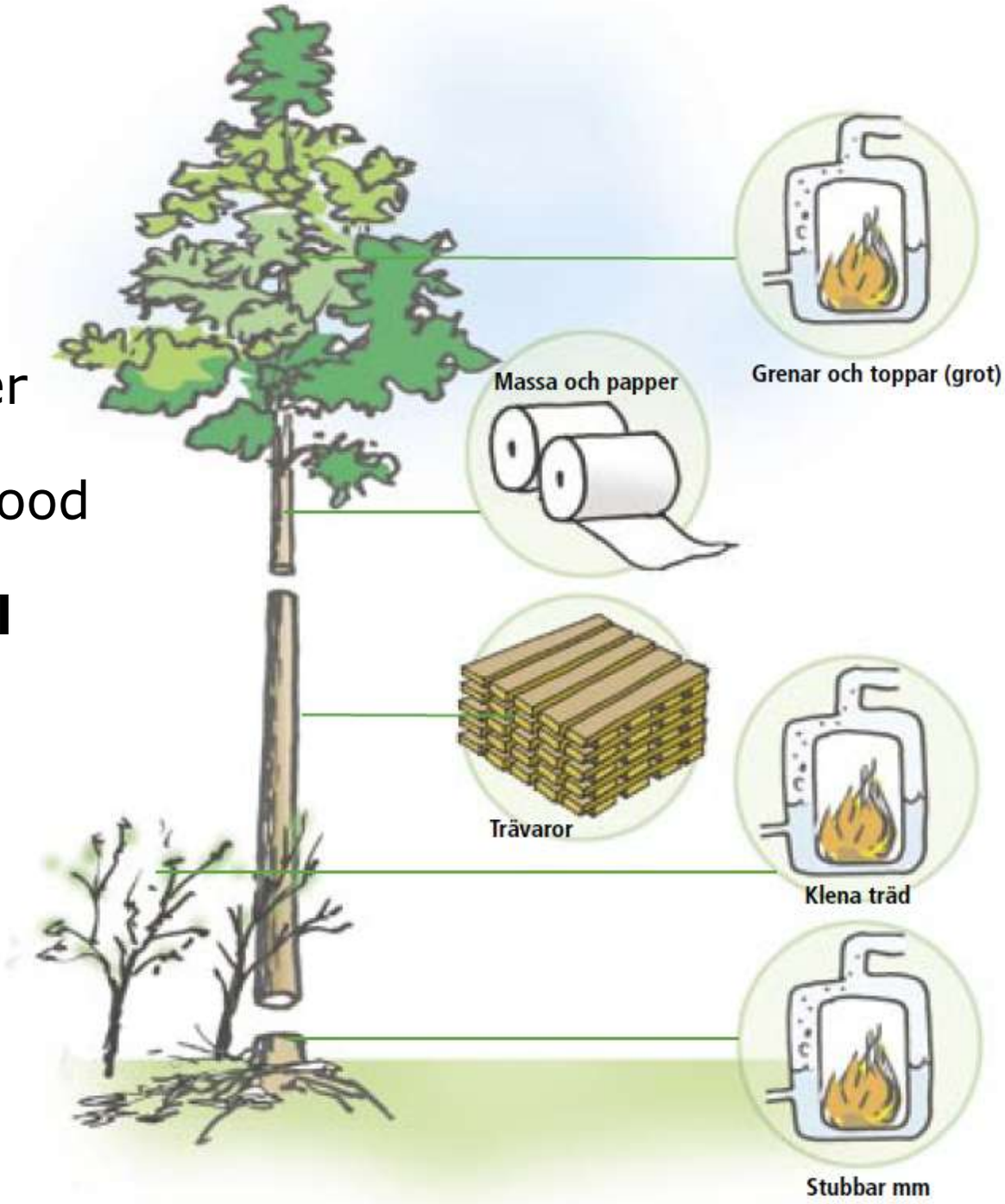
Forest Fuel in Växjö

- Forest coverage around 63%
- Large timber industry

- High-quality stem wood: timber
- Low-quality stem wood: pulpwood
- 'Logging residues': **forest fuel**

Wood fuel usage in 2009

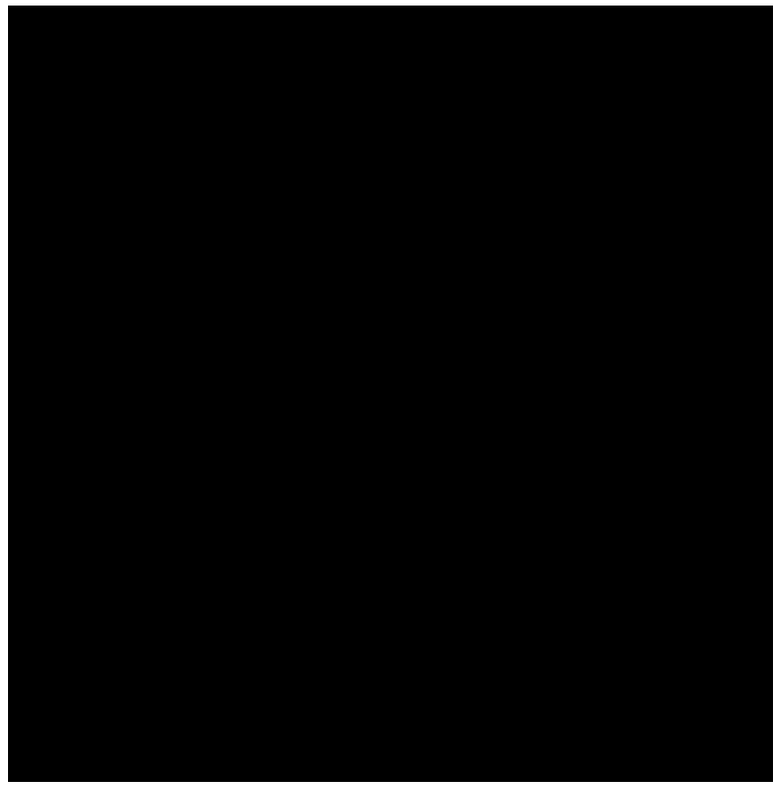




Source: *Biobränsle från Skogen - Tillgang och efterfragan (Biofuel from Wood - Supply and demand)*. Skogsindustrierna

Biomass Potential Model

- Methodology developed RSA
- Top-down strategy to delimit potential
- Theoretical potential
  - Sustainability criteria
  - No limitations
  - Primary energy
- Technical potential
  - Technical limitations (topography, competition)
  - Primary energy
- Reduced technical potential
  - Losses during energy conversion
  - Final energy



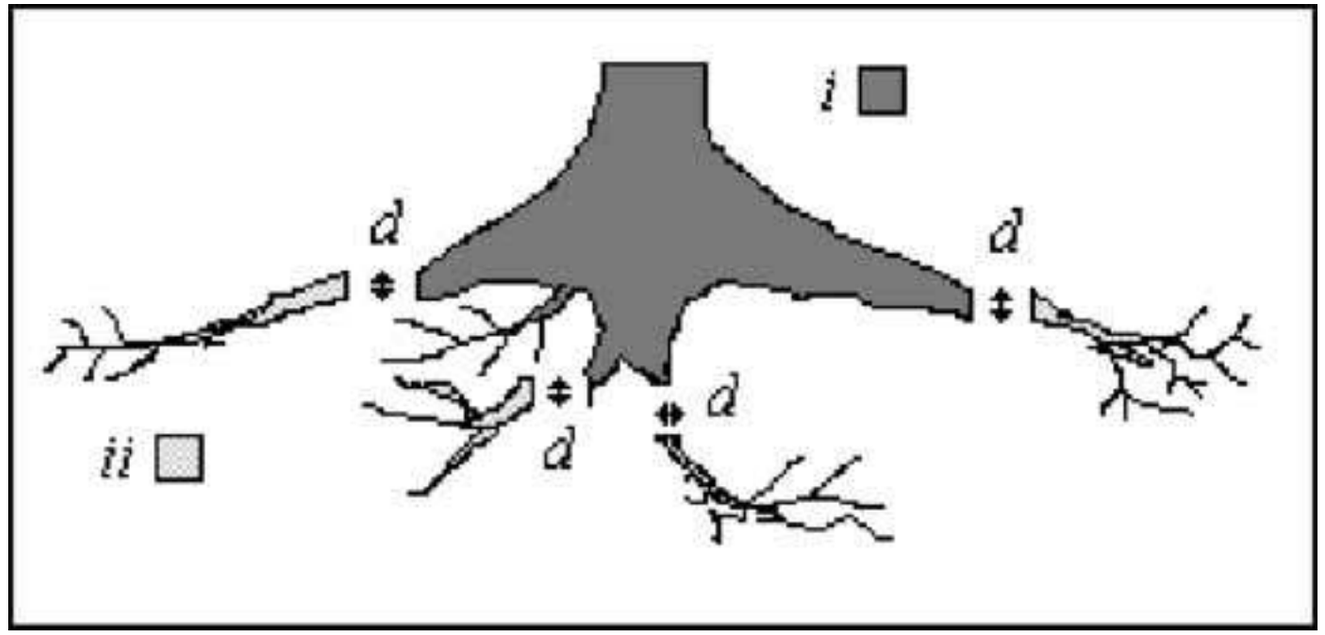
Source: M. Biberacher et al. *EnergieRegion Rhein-Sieg (Final report)*. 2008

Marklund's Biomass Functions

- Study from 1981-1988 at Swedish University of Agricultural Sciences, Umeå
- Dry-weight biomass functions for three main species in Sweden (spruce, pine and birch), divided in components
  - stem over bark (further divided)
  - living branches (further divided)
  - dead branches
  - stump-root-system (further divided)
- Largest correlation between tree biomass and *diameter at breast height (DBH)*
- List of biomass functions with different accuracy and simplicity

Additions/Revisions from Petersson/Ståhl

- New field measurements from Petersson & Ståhl in 2006
- Hypothesis: below-stump biomass underestimated
- Calibrate new data against Marklund‘s data
- Measure roots up to 2mm diameter



Source: H. Petersson and G. Ståhl. Functions for below-ground biomass of pinus sylvestris, picea abies, betula pendula and betula pubescens in Sweden. 2006

Managed Forest Life Cyle

- Year 0-10: Regeneration
- Year 10-25: Pre-commerial thinning / Cleaning
- Year 25+: Commercial thinning
- Final felling

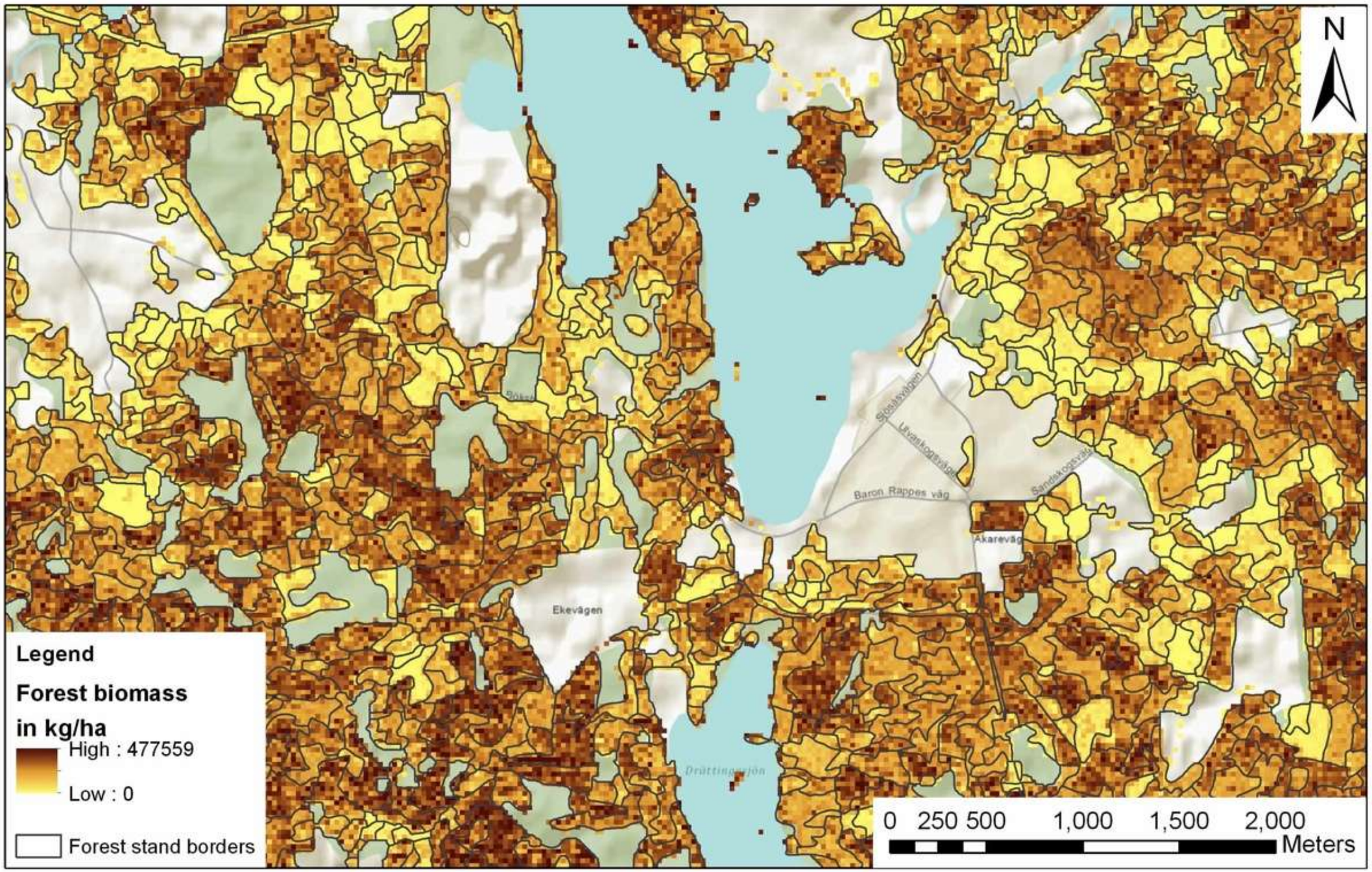
Geographic Sweden Data (GSD)

- Download from Lantmäteriet‘s Digital Map Library
  - Topographic map, scale 1:50,000, ESRI Shapefile format
  - Height data, 50x50m meter resolution, ESRI GRID format
- SWEREF 99 geographic reference system
- English documentations can be requested

SLU Skogskarta (kNN-Sweden) (1)

- Forest dataset with continuous estimates of forest parameters
- Method developed by the Remote Sensing Laboratory at SLU
- Use k- Nearest Neighbor algorithm
- Multiple data sources
  - Swedish National Forest Inventory (NFI) plot data
  - Satellite images (LANDSAT & SPOT)
  - Lantmäteriet topographic data („forest mask“)
- Datasets for 2000 and 2005 (planned for 2010)
- Raster datasets: 25x25 meter resolution
- RT 90 geographic reference system
- Free to download and use

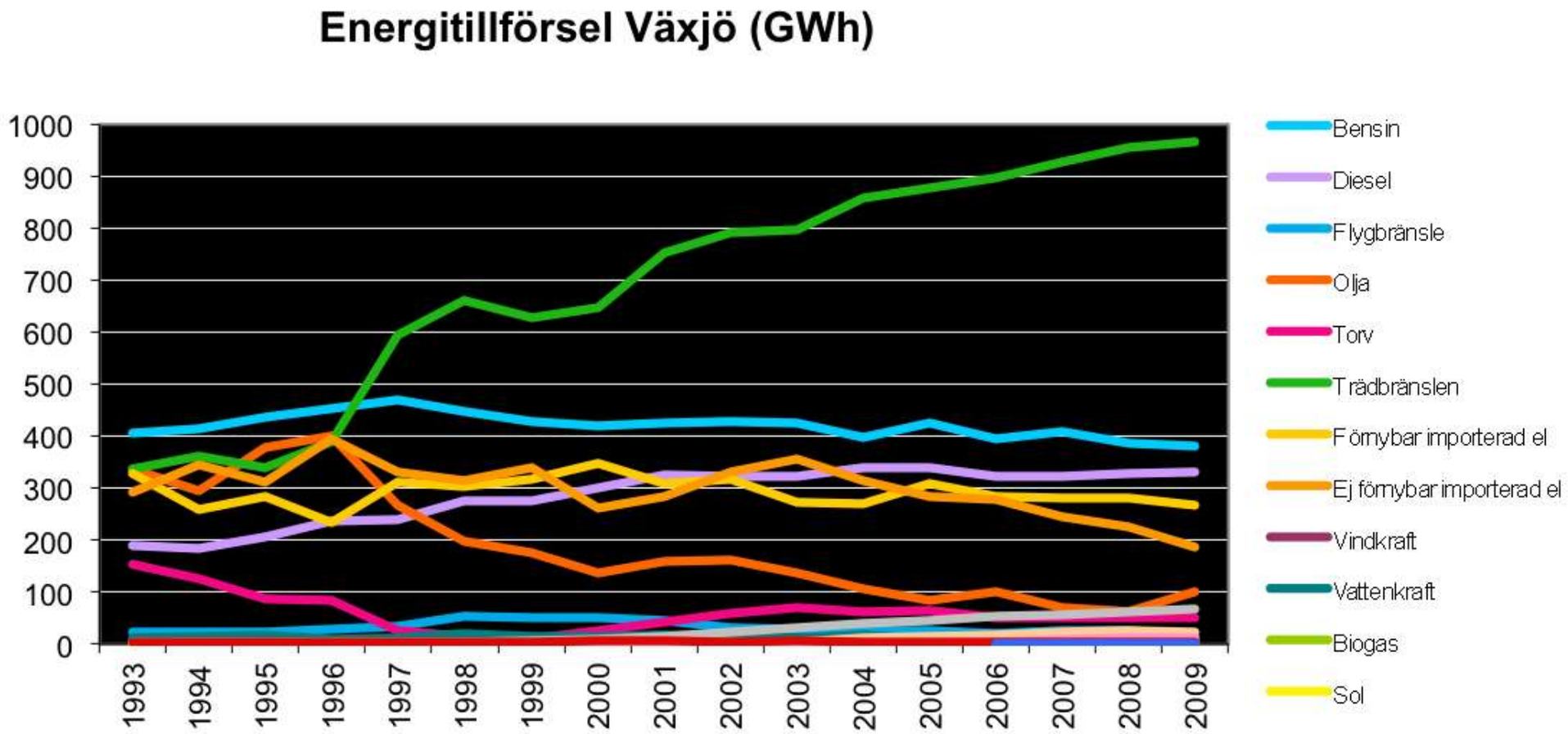
SLU Skogskarta (kNN-Sweden) (2)



Sample kNN-Sweden forest biomass data with forest stands near Braås, municipality of Växjö.

Energy Balance for Växjö

- Data for 1993-2009
- Renewable energy, fossil energy (no nuclear energy)



Source: *Energibalans 1993- 2009 i Växjö kommun (Energy balance 1993-2009 for the municipality of Växjö)*. Energikontor Sydost, 2010.

- wood fuel energy conversion process

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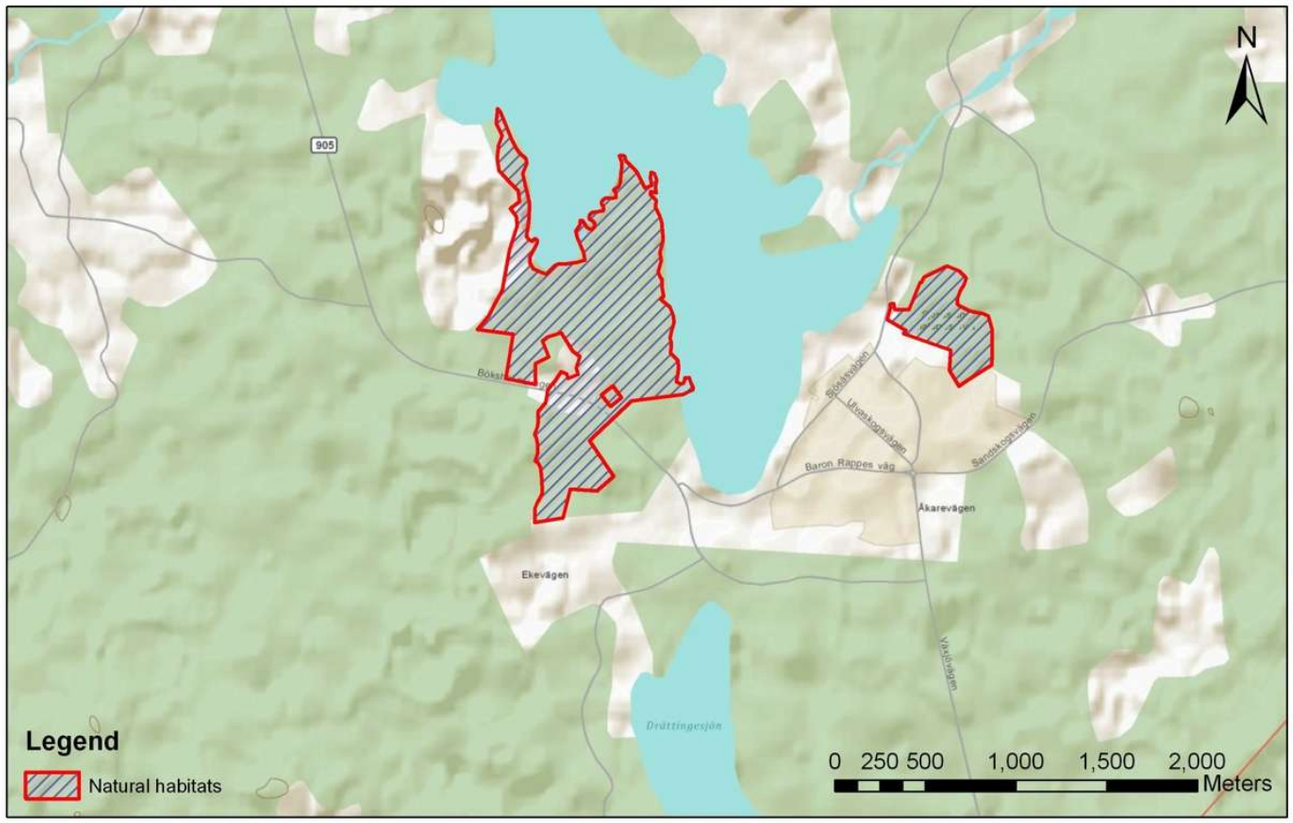
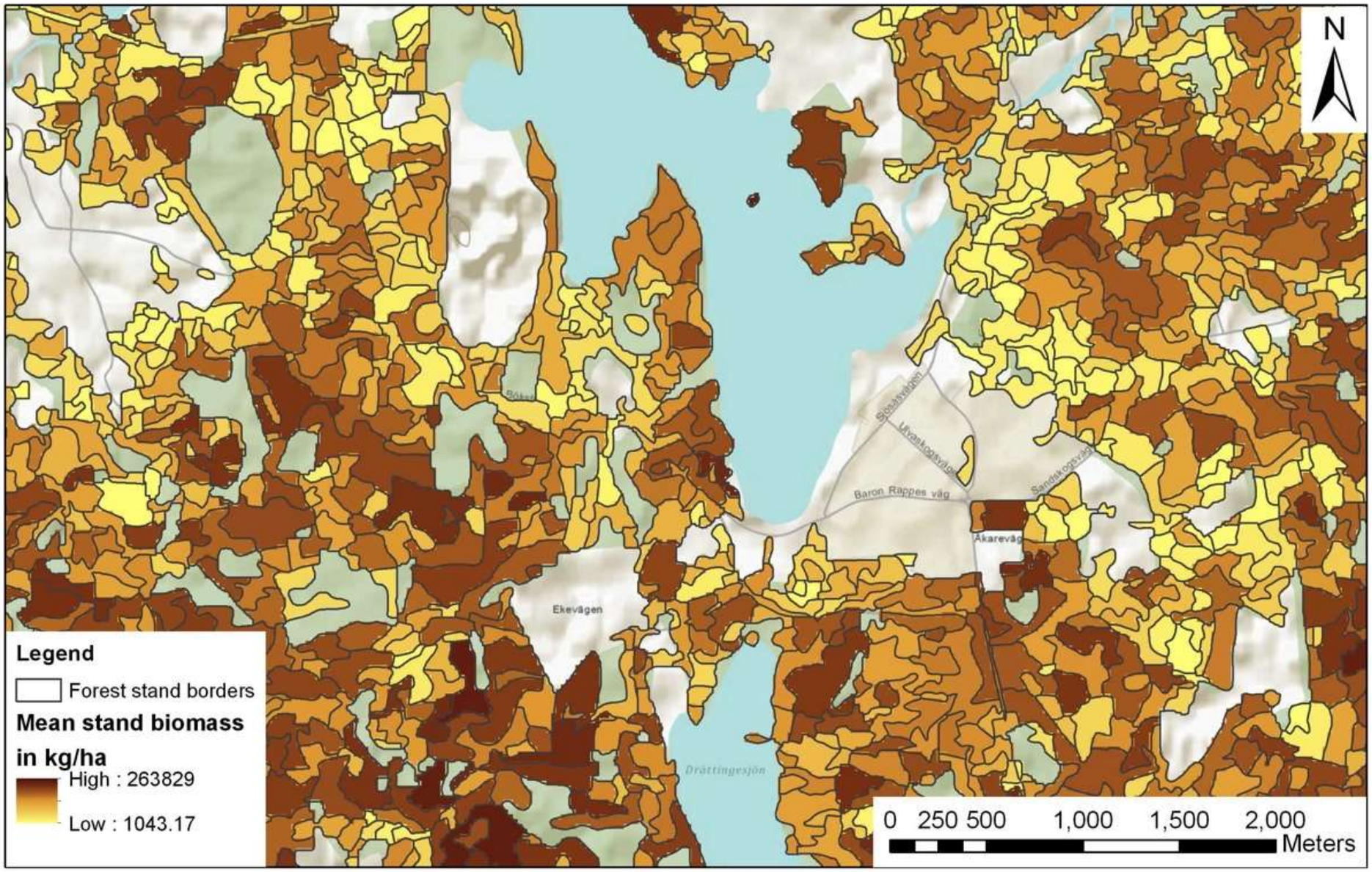
Topographic/Height data

- Municipal border of Växjö
- Define forest access roads
- Natural habitats
- Compute slopes

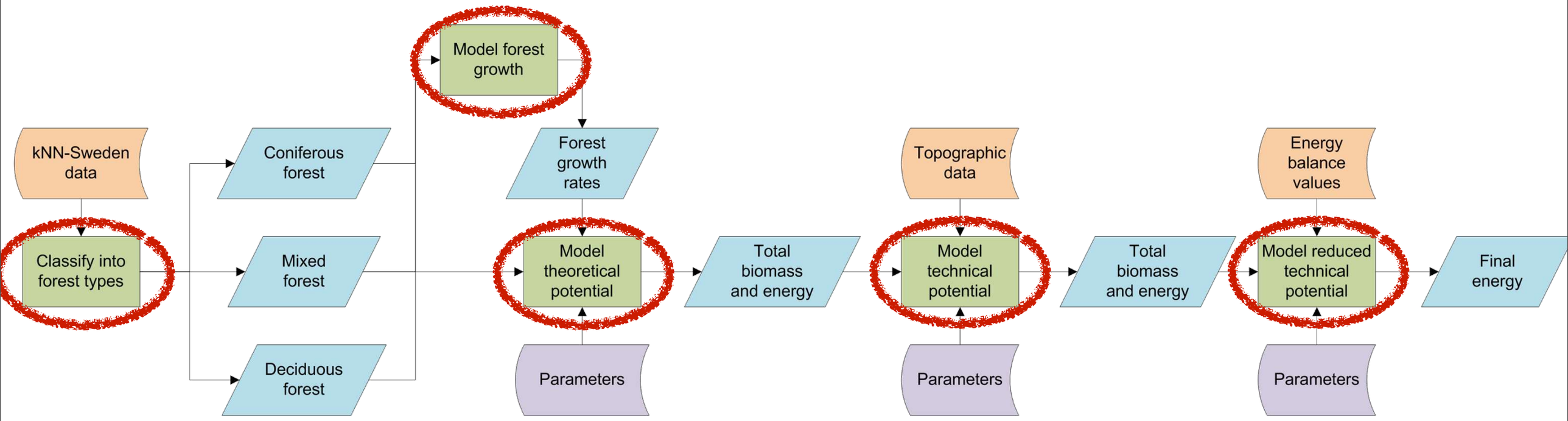


SLU Skogskarta (kNN-Sweden)

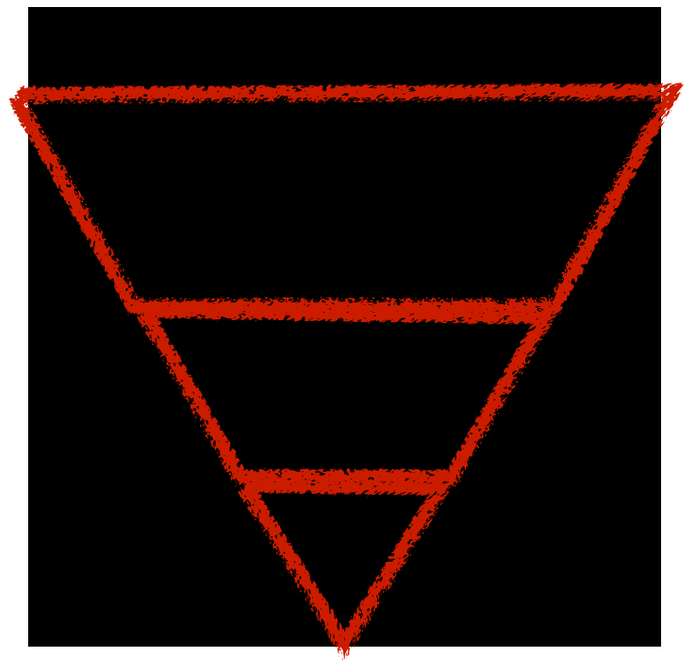
- Transform from RT 90 to SWEREF 99
- Compute average values for forest stands



Model Outline



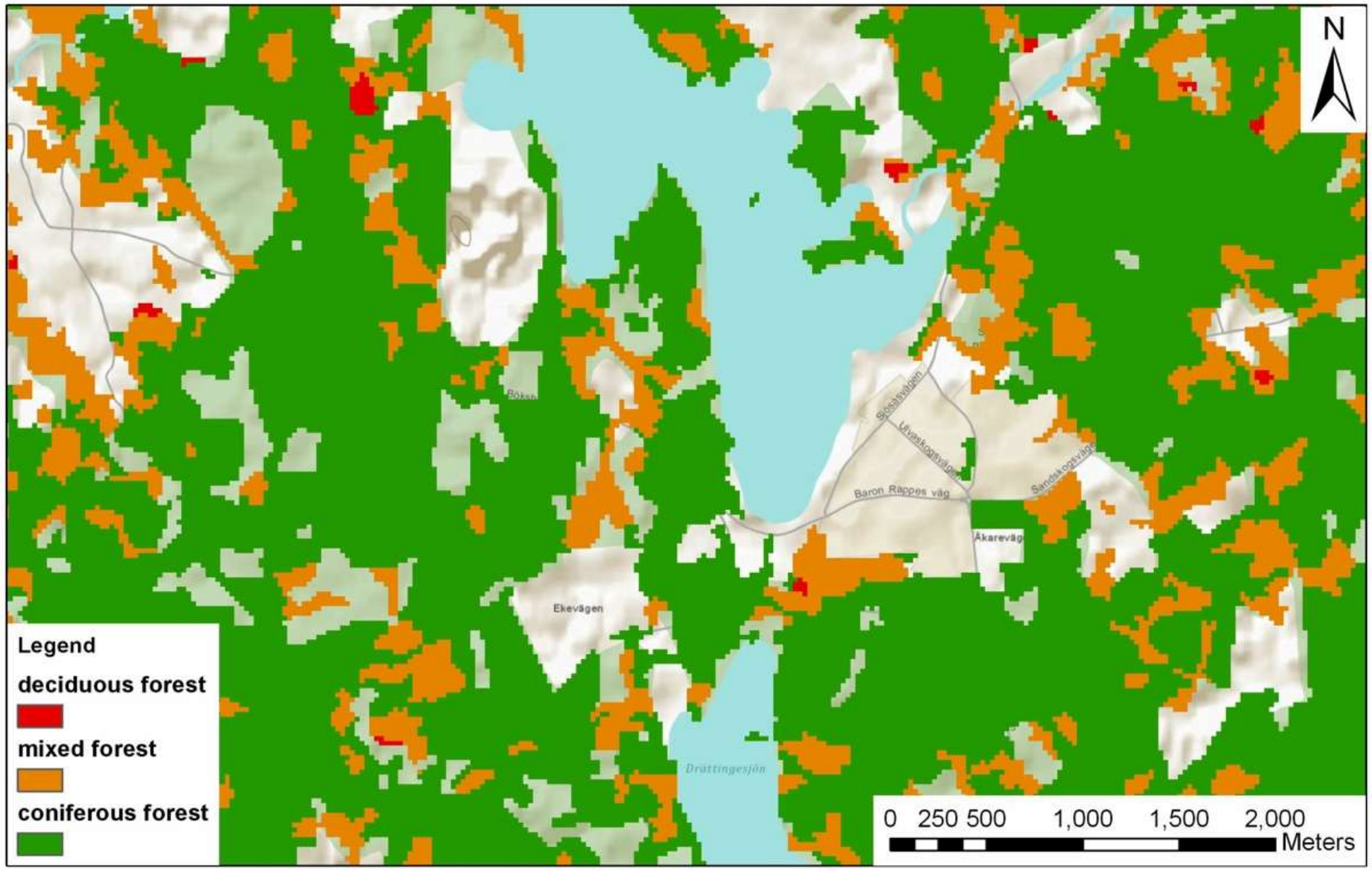
- Model with ArcGIS ModelBuilder



Step 1: Forest classification

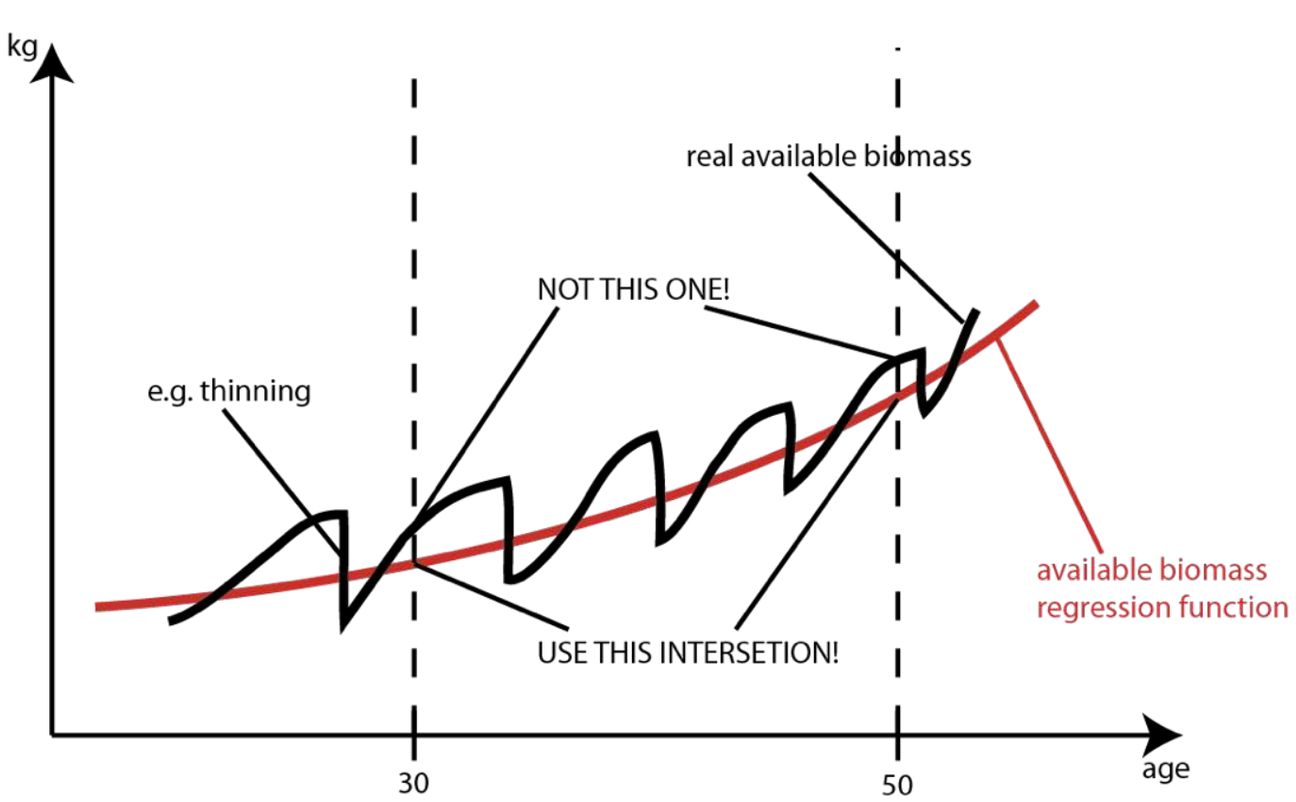
- 3 classes: coniferous, mixed and deciduous
- Default threshold value of 75%

- 73% coniferous
- 25% mixed
- 2% deciduous



Step 2: Forest Growth

- Remove natural habitats zones from forest datasets
- Create exactly overlapped age and biomass datasets
- Export as ASCII, import into SPSS
- Curve fitting

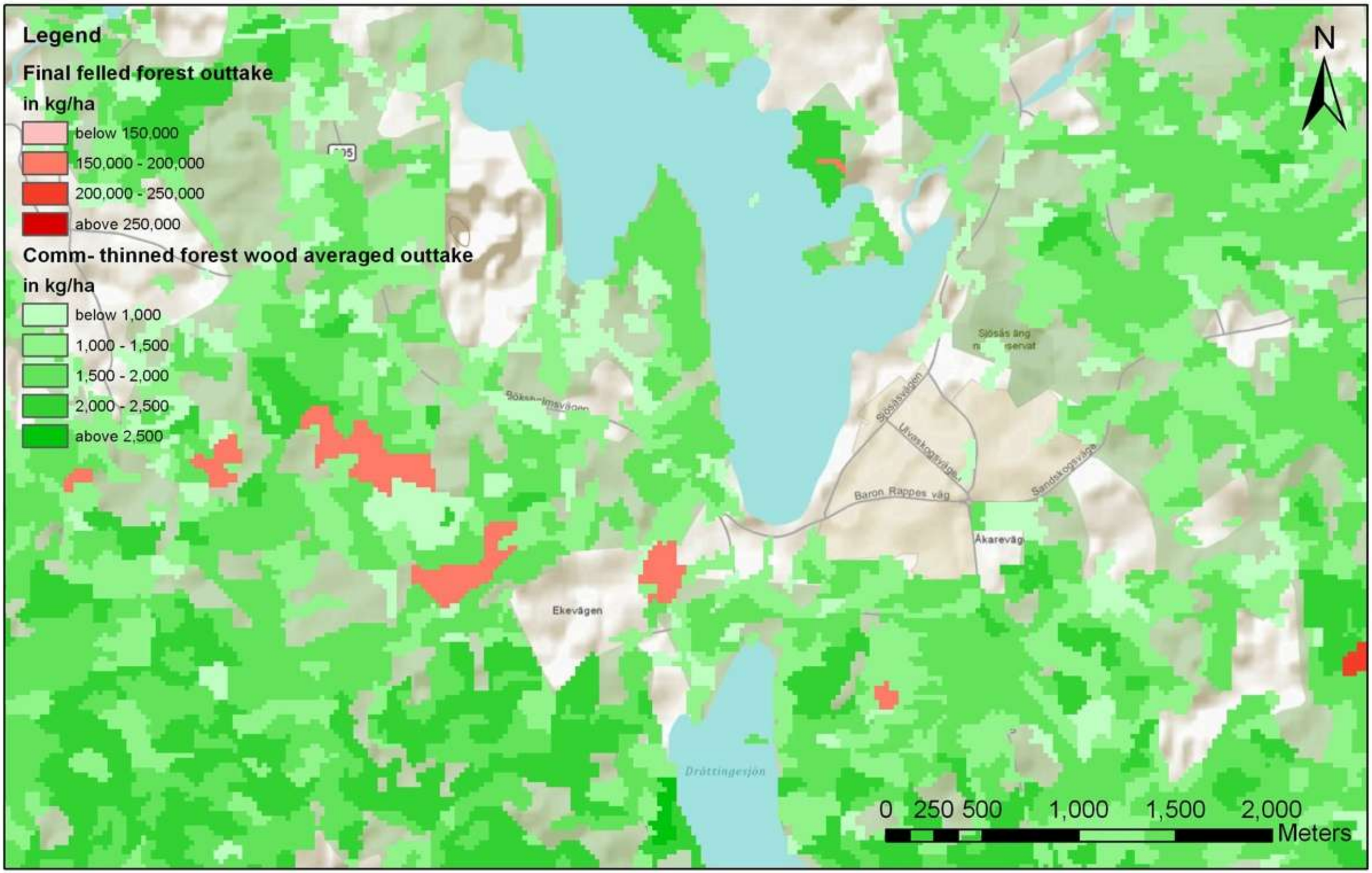


kg: available tree biomass as biofuel
age: mean age of the forest stand

Step 3: Theoretical Potential (1)

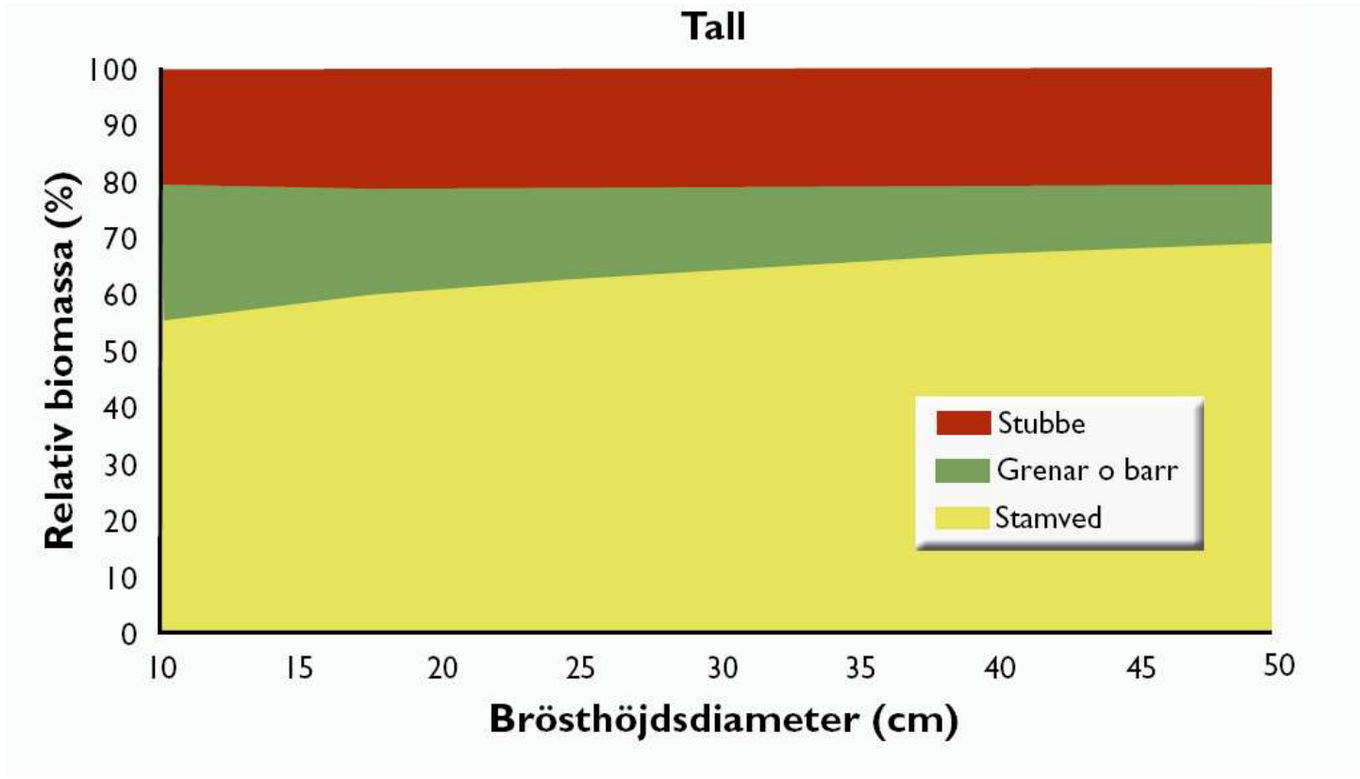
- Input: age and biomass datasets
- Output: theoretically harvestable forest fuel
- Main parameters
  - Modelled year (e.g. 2015)
  - Growth rates
  - Start of ‘commercial thinning’ period
  - Felling ages
  - Average percentual annual forest fuel outtake during thinning period

Step 3: Theoretical Potential (2)



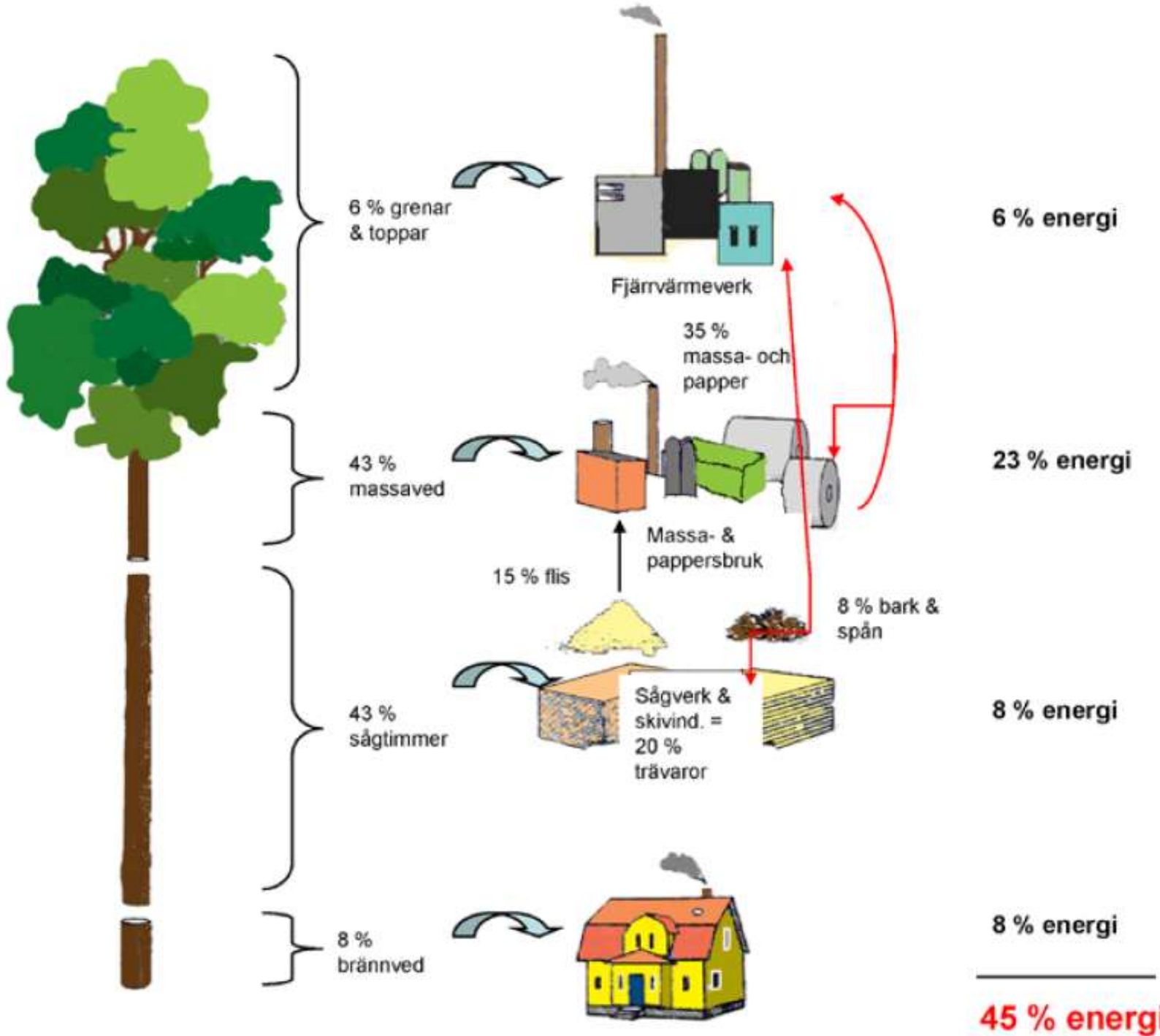
Step 4: Technical Potential (1)

- Input: theoretical potential dataset
- Output: technically harvestable forest fuel
- Main parameters
  - Maximum slope
  - Maximum hauling distance
  - Natural habitat areas
  - Harvest of stumps and roots
  - Wood competition



Source: G. Egnell. *Skogsbränsle (Forest fuel)*. Skogsstyrelsen, 2009.

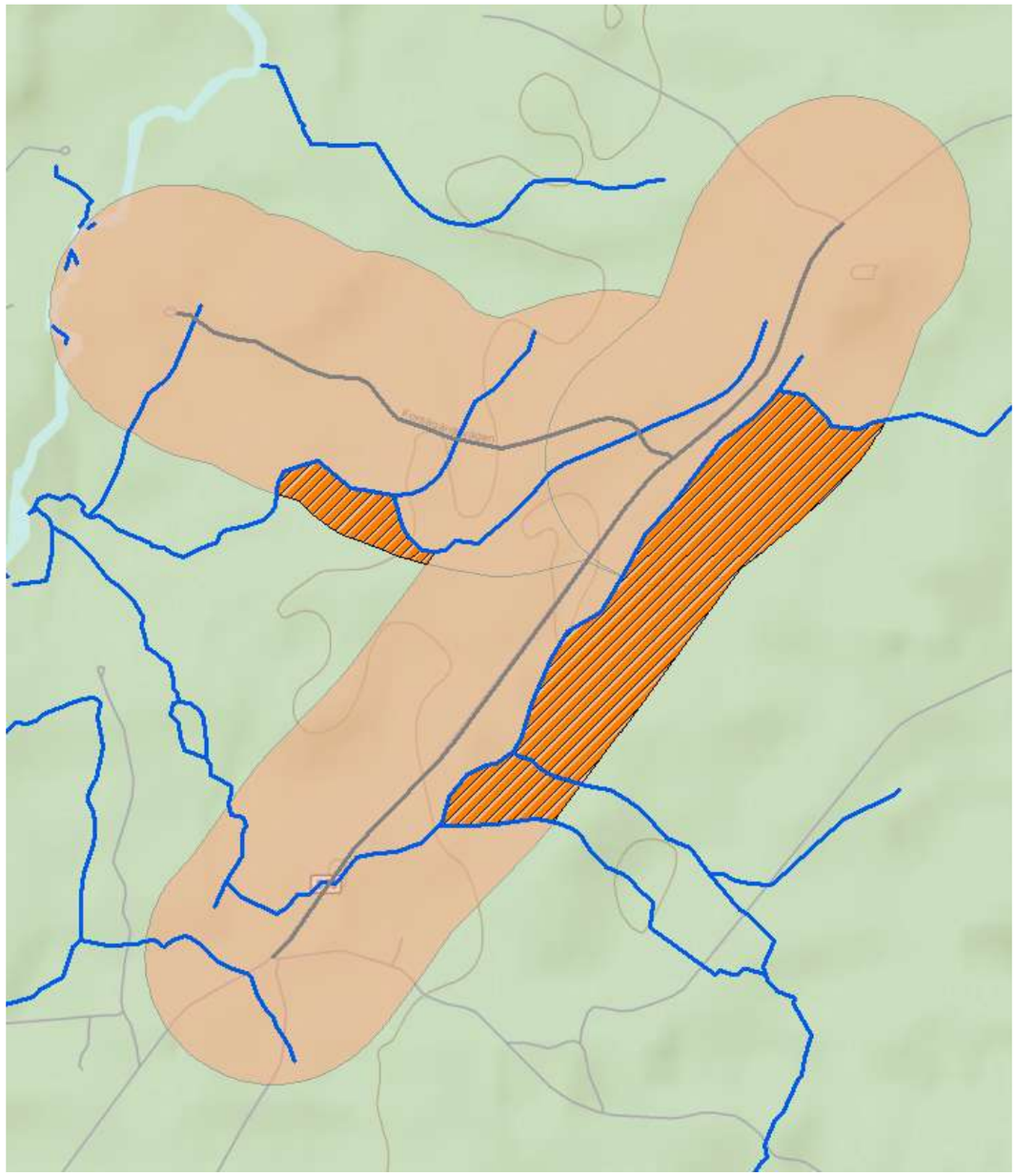
Step 4: Technical Potential (2)



Source: Biobränsle från Skogen - Tillgång och efterfrågan (Biofuel from Wood - Supply and demand). Skogsindustrierna.

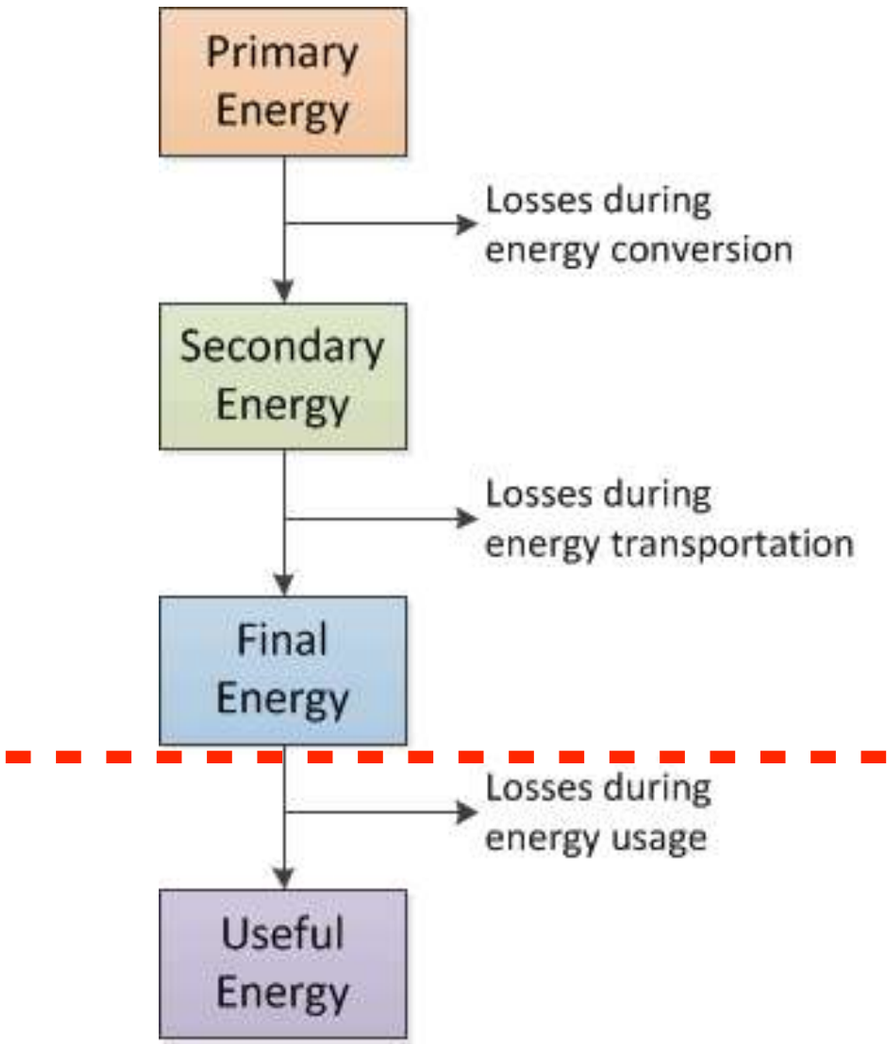
Insertion: “Forest Blocked by Water”

- Unfinished feature due to complexity and software limitations
- Scenario: water between forest and access road
- Forest expensive or impossible to reach

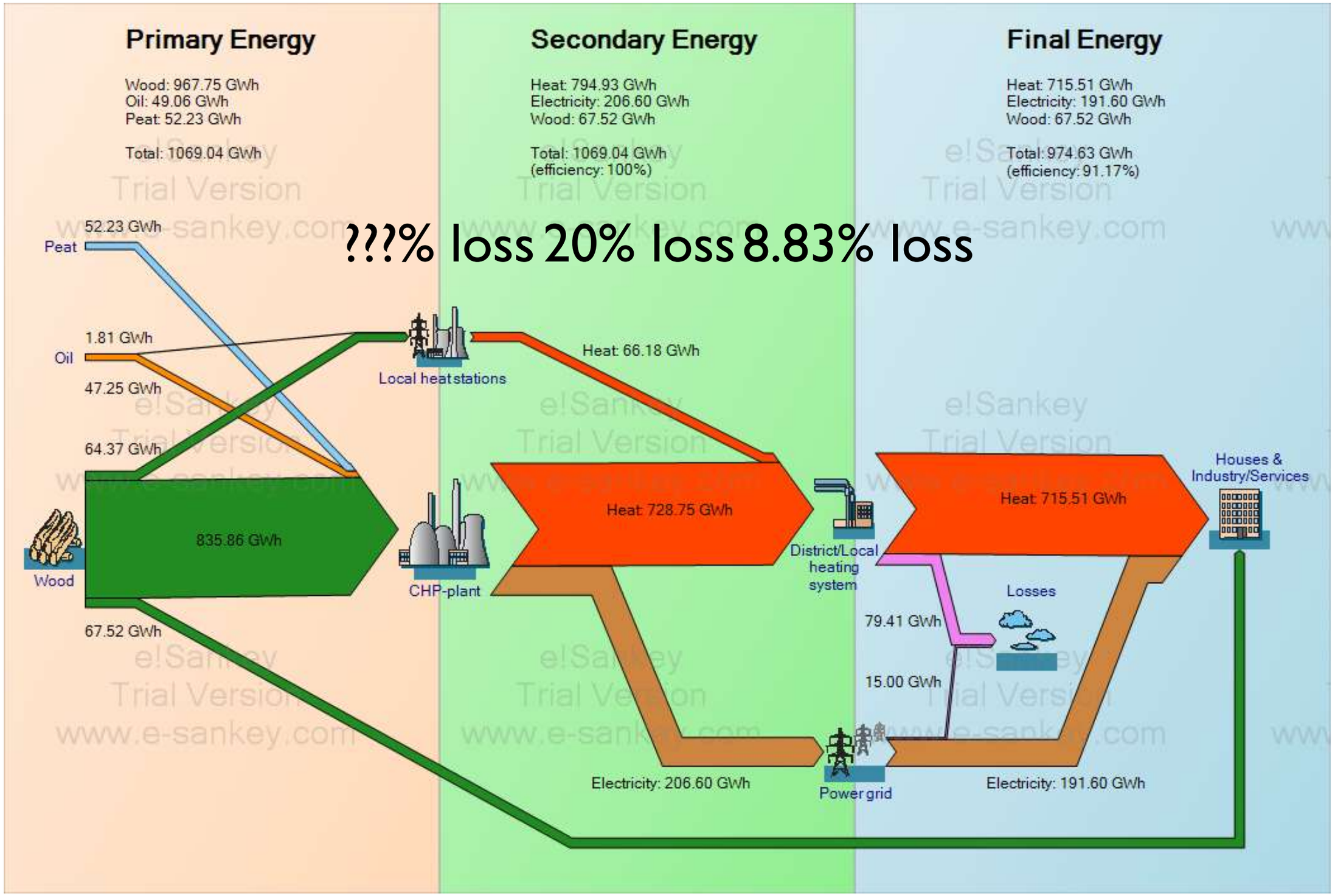


Step 5: Reduced Technical Potential (1)

- Final Energy
- Losses during energy conversion process



Step 5: Reduced Technical Potential (2)



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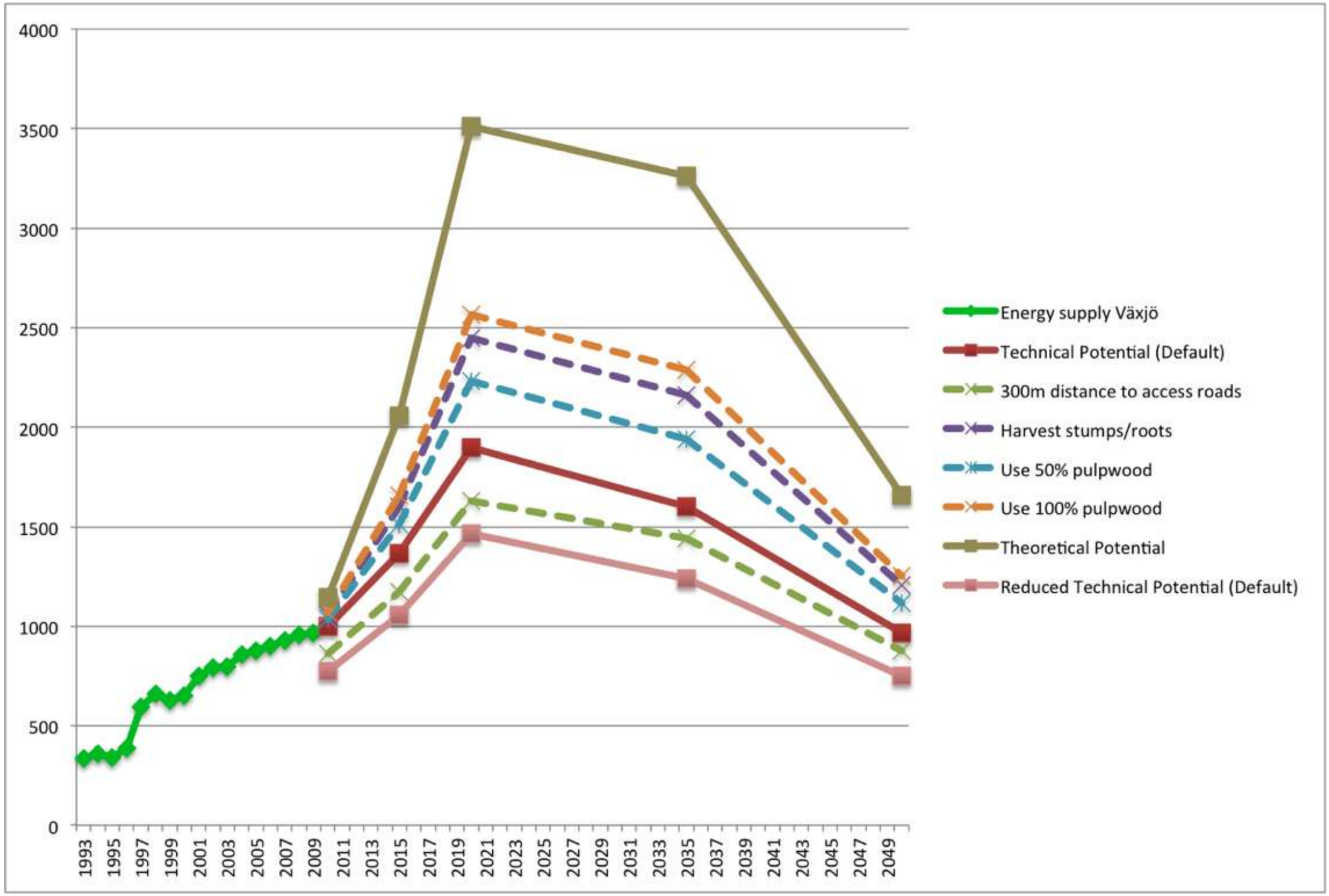
Final Model Results (2010-2050)



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Outlook

- Contribution
  - Detailed model considered many factors
  - Closely correspondent data to actual wood supply 1993-2009
- Further Improvements
  - Completeness of the road network
  - Higher accuracy of the forest data
  - Correlation between age and biomass of a tree
  - Growth of managed forest
  - Optimum management style of the forest
  - Forest classification

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Thank you very much for your attention!