Hybrid Life Cycle Assessment of Wood Based Heating

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Contents

Introduction

Method

System description

Results

Contents

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Method

System description

Results

Wood based heating- Environmentally friendly?

- Norway becoming a net electricity importer
- About half of stationary electricity demand is used for space heating.
- The government wants to increase energy flexibility.
- Wood stoves are present in 2/3 of Norwegian households
- Great potential for increased use of wood
- CO_2-neutral
- Transportation
- Local air pollutants
- Evaluate environmental performance using LCA.

Contents

Introduction

Method

System description

Results

Methodology

- We want to include the emissions from all the value chains connected to our system
- Hybrid life cycle assessment combines LCA and input-output data.
- The Norwegian input-output tables for 2000
  - Transactions between the sectors of the economy.
  - Capital
  - Imports
  - Emission tables

Inventory compilation

- Use specific process data combined with IO-data in hybrid LCA
- Estimate remaining purchases using input structure from a chosen sector in the economy
- Scale purchases so that prices balance

- This is further explained in our other presentation at NorLCA symposium

LCA on Matrix form using Leontief's Notation

Beregning av miljøbelastningsindikatorer:

Functional Unit Vector
Requirements Matrix
Stressor Matrix
Characterization Matrix
Category Indicator Vector

$$d = CF(I - A)^{-1} y$$

$$\begin{pmatrix} 7.12 \\ 4.57 \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 0.5 \end{pmatrix} \begin{pmatrix} 1.4 & 0 & 0.9 \\ 2.1 & 1.8 & 0 \end{pmatrix} \left[\begin{pmatrix} 1 & & \\ & 1 & \\ & & 1 \end{pmatrix} - \begin{pmatrix} 0 & 0.1 & 0.5 \\ 0.2 & 0 & 0.1 \\ 0.6 & 0.4 & 0 \end{pmatrix} \right]^{-1} \begin{pmatrix} 2 \\ 0 \\ 0 \end{pmatrix}$$

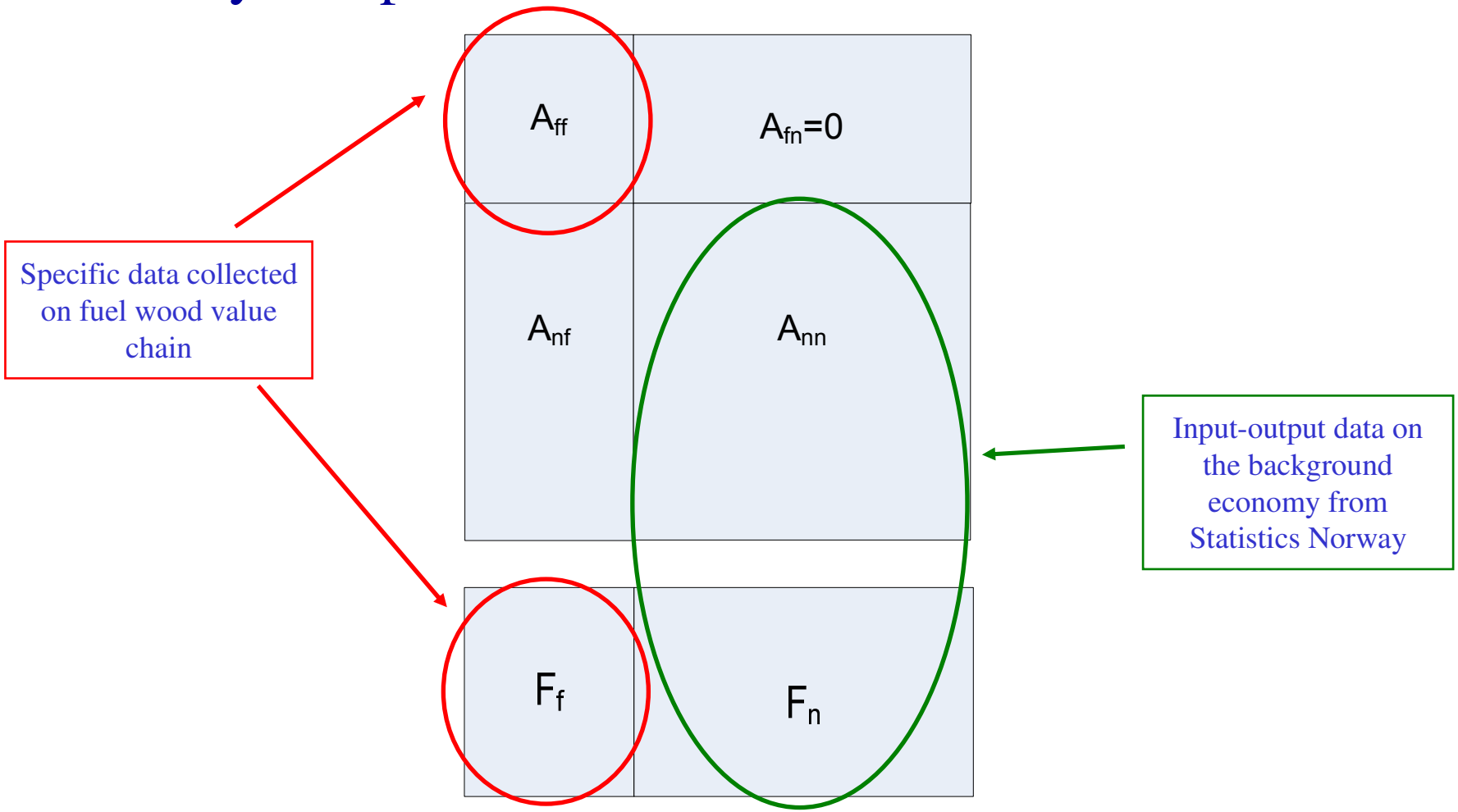
Inventory compilation

Specific data collected on fuel wood value chain

A_{ff}	$A_{fn}=0$
A_{nf}	A_{nn}

F_f	F_n

Inventory compilation



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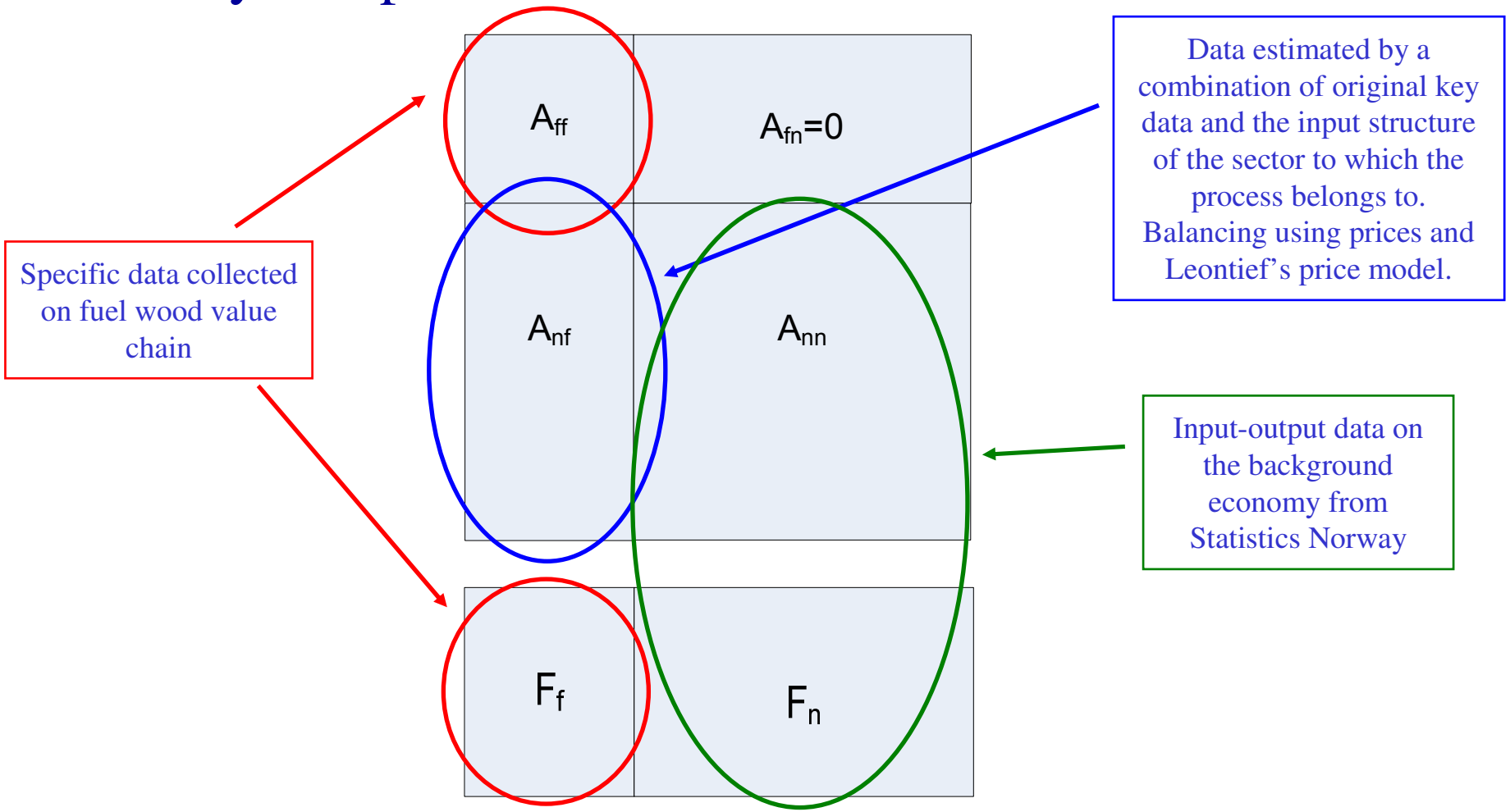
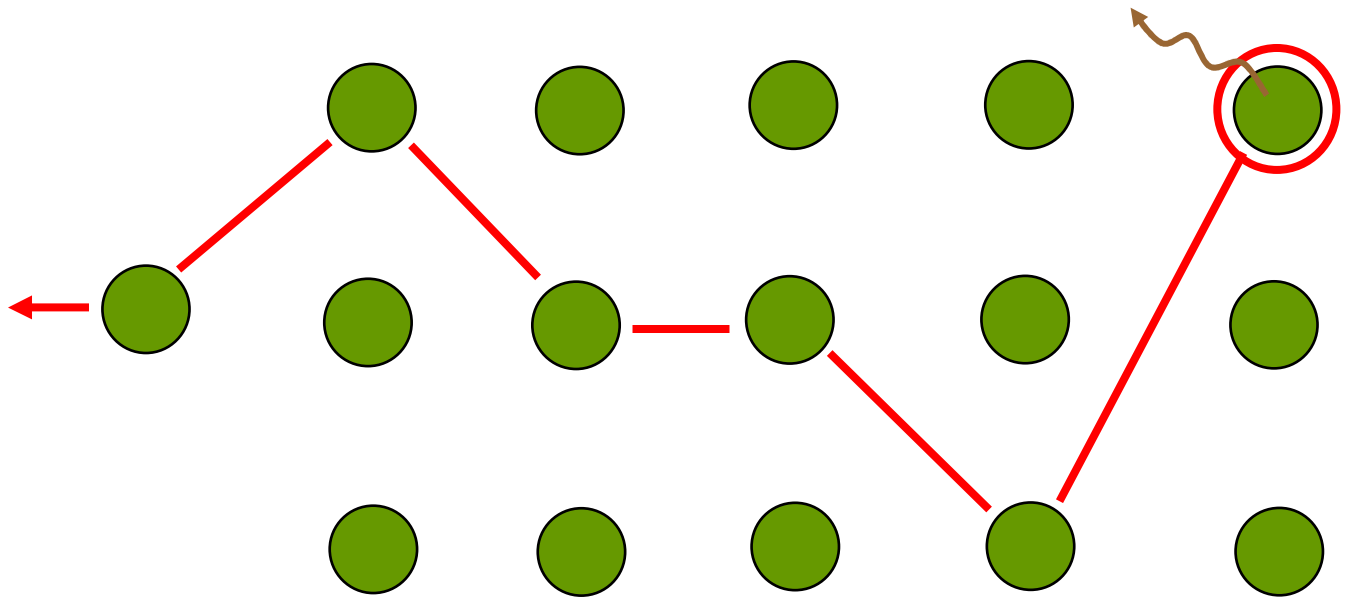


Inventory compilation

- Use structural path analysis (SPA) to operationalize the iterative structure of LCA
- Perform SPA for preliminary inventory
- Identify parts of inventory that need refinement
- Avoid spending time refining negligible data



Contents

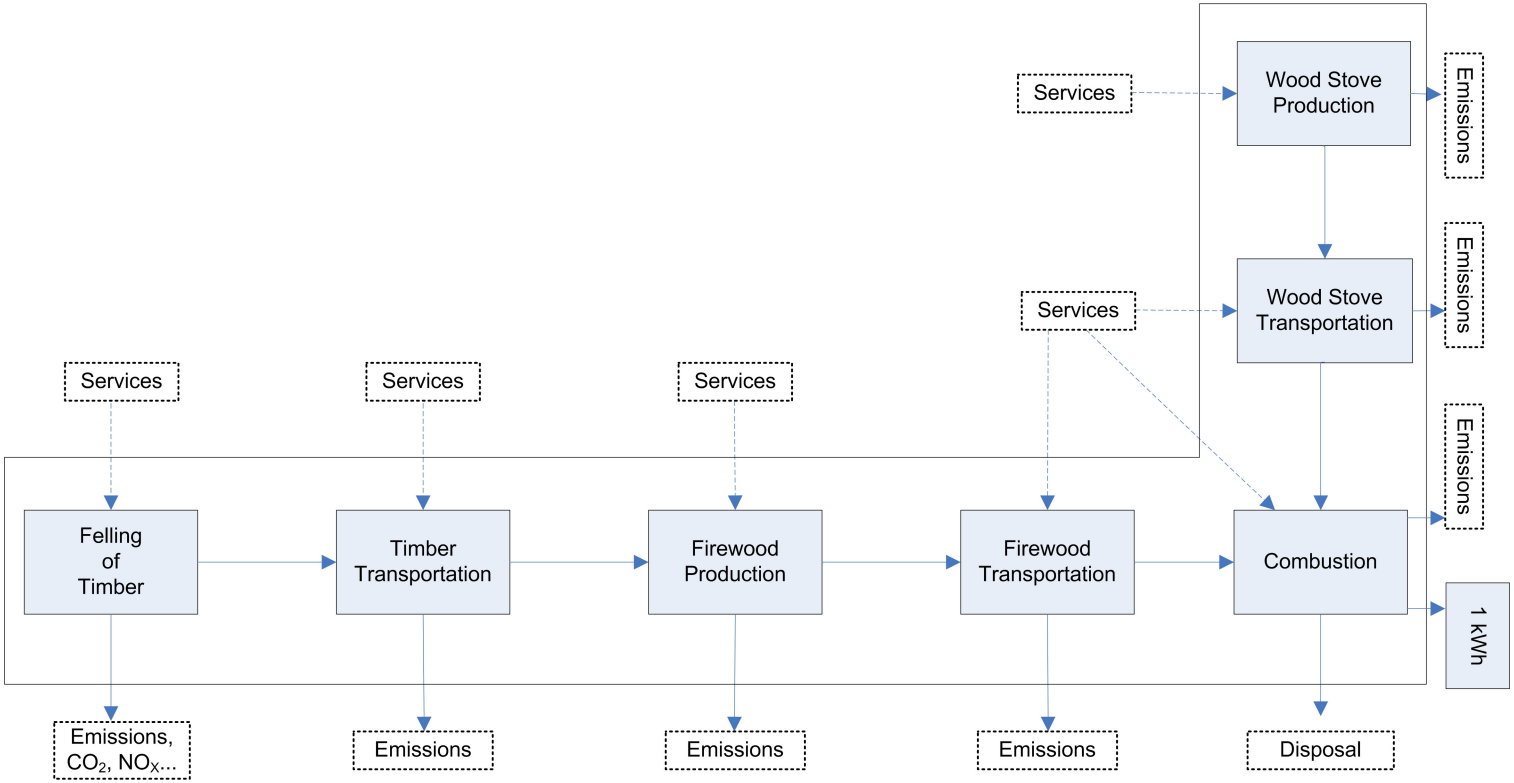
Introduction

Method

System description

Results

The wood based heating value chain



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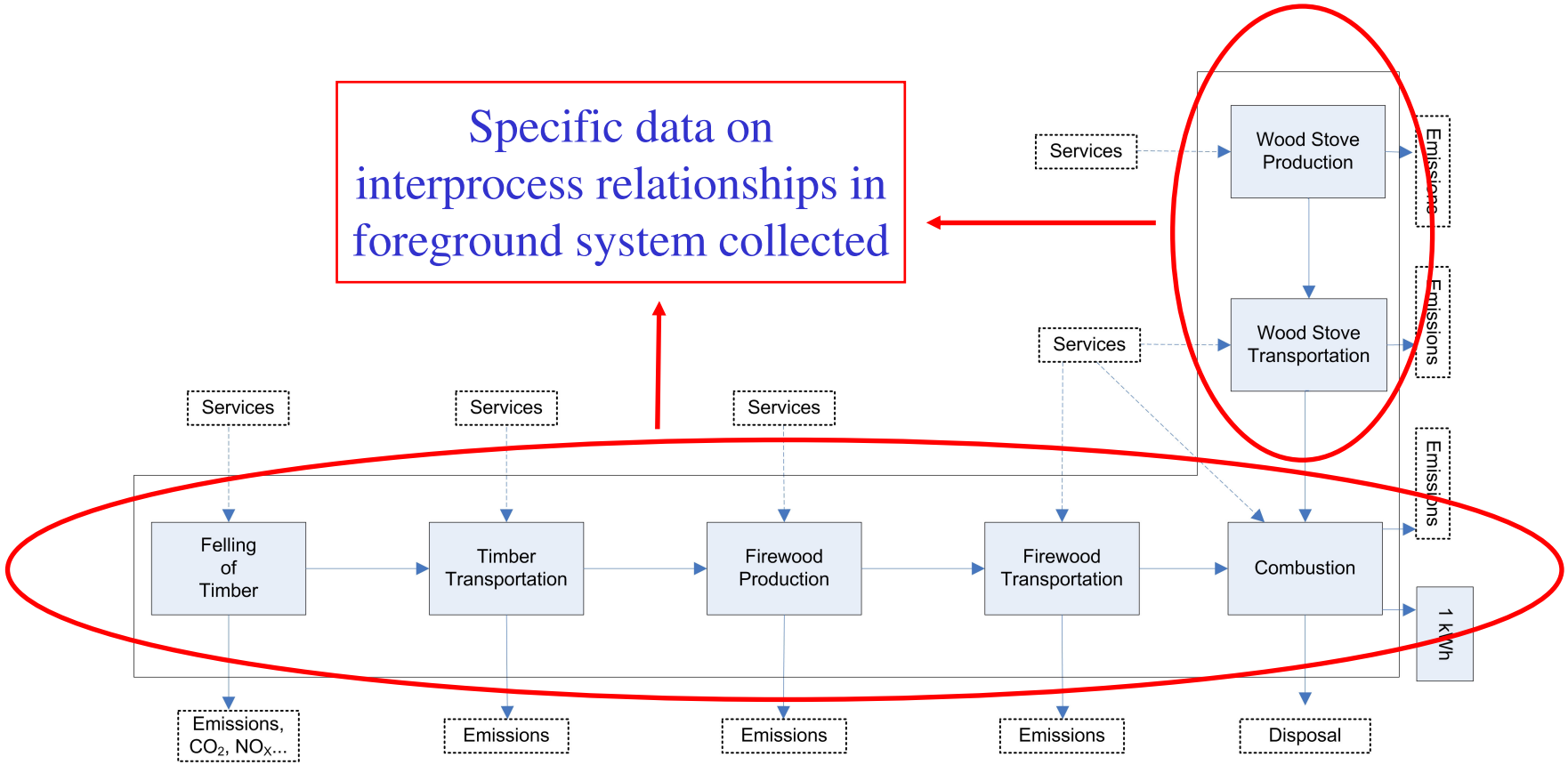

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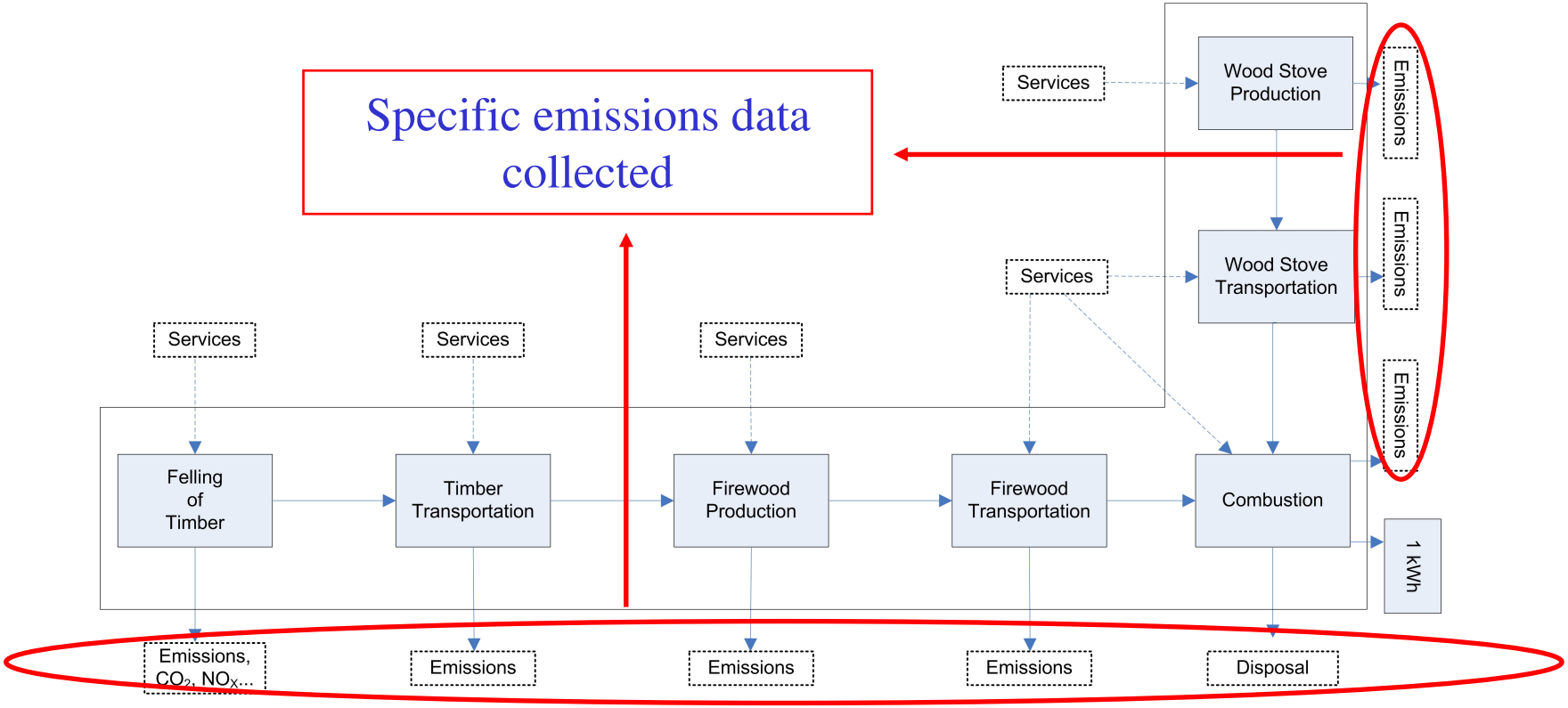

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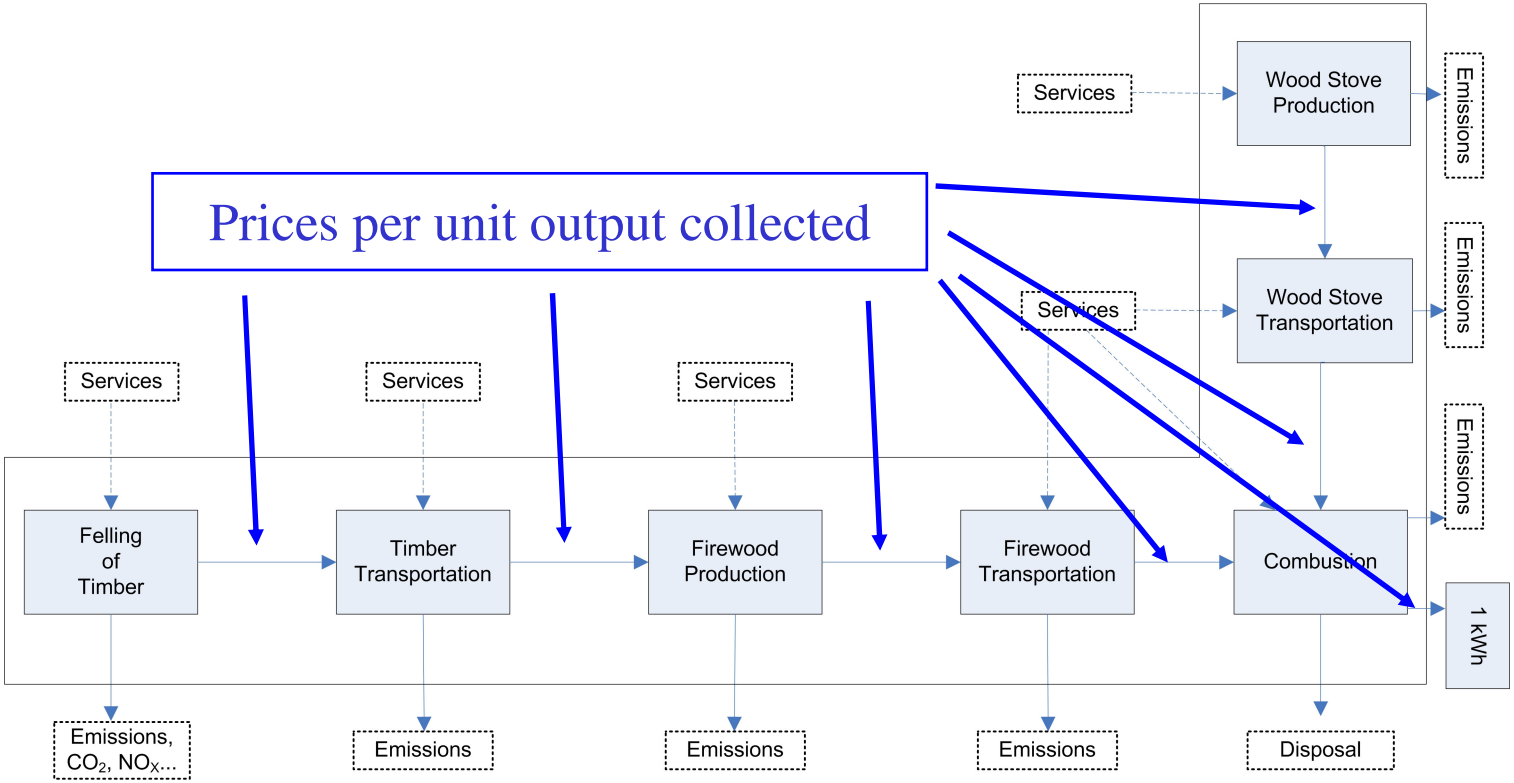

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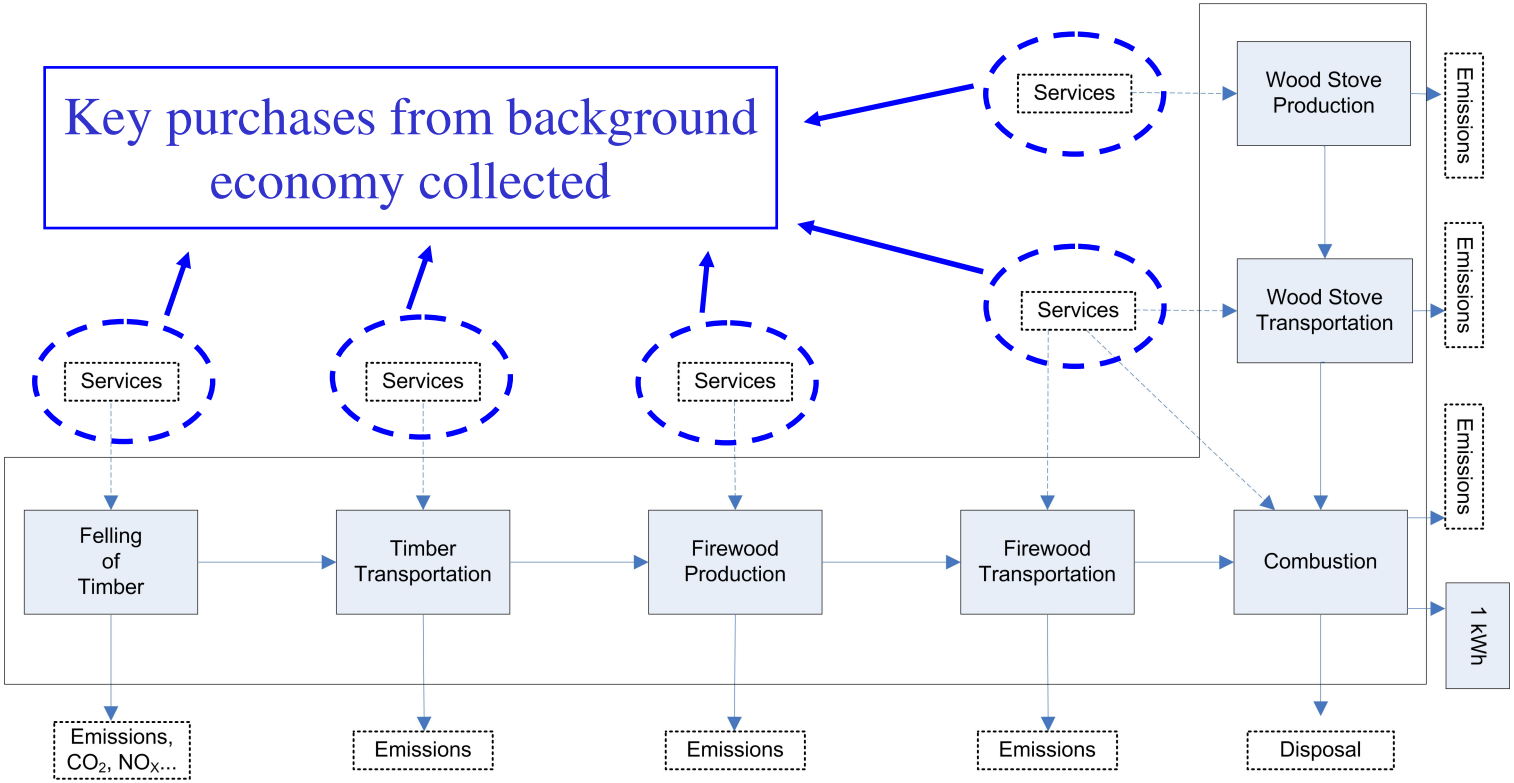

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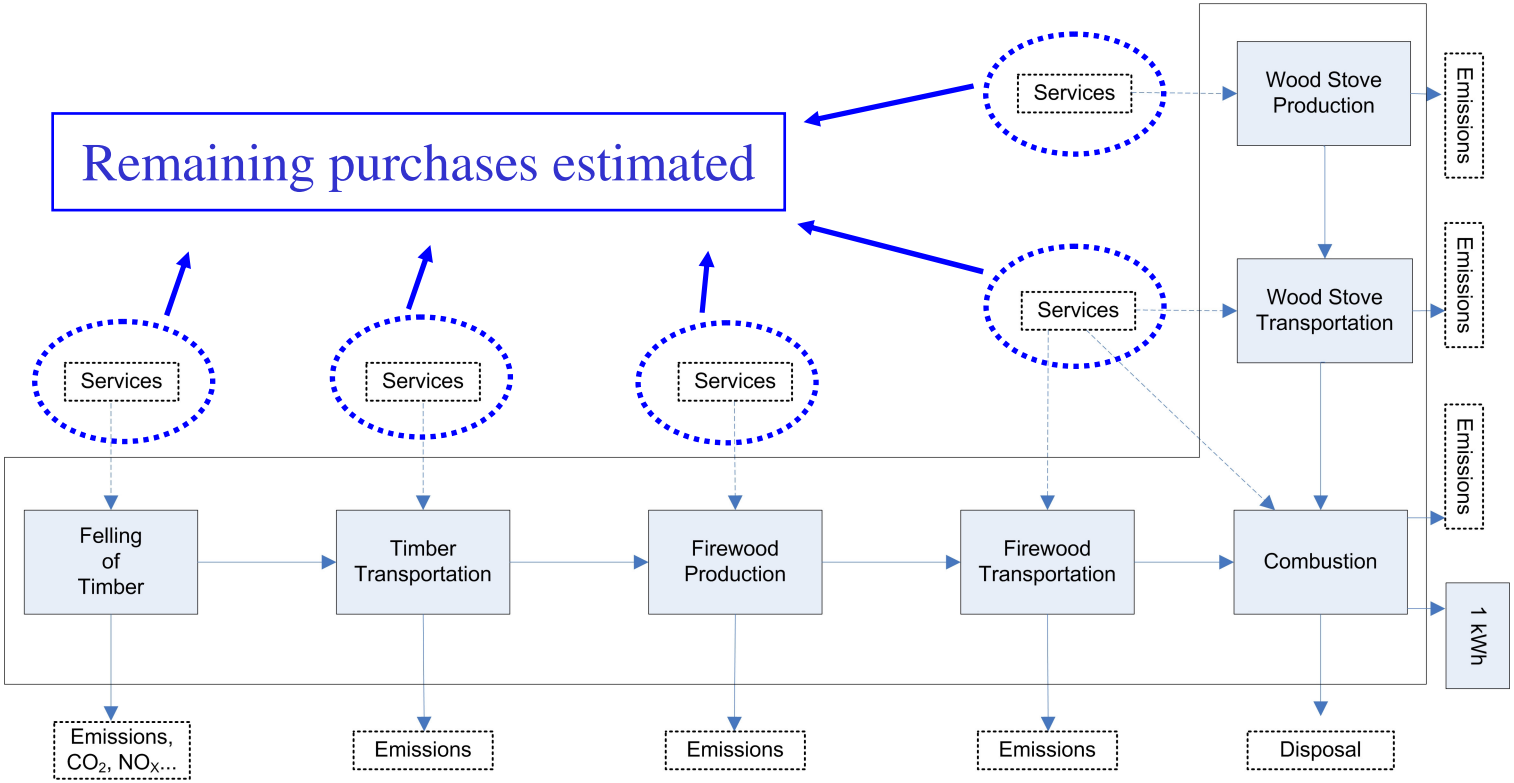

Stove technologies

- Difference in efficiency (LHV_{wood} to heat delivered to house)
- ~70% for new technology
- ~50% for old technology
- Hard to estimate for real life operation (ventilation effects etc.)
- Difference in emission factors
- Data from Statistics Norway

- Birch as fuel wood

Contents

Introduction

Method

System description

Results

Results – Comparing old and new stove technology

- 1 KWh of heat delivered to house

Impact category	Indicator	Old technology	"Clean burning" technology	Improvement
GWP	kg CO_2-eq.	1,03E-01	7,49E-02	27 %
Photochemical oxidation	kg C_2H_2-eq.	5,57E-03	3,11E-03	44 %
Acidification	kg SO_2-eq.	4,86E-04	3,54E-04	27 %
Eutrophication	kg PO_4-eq.	8,99E-05	6,53E-05	27 %
HTP air, cancer	kg benzene eq.	3,75E-03	6,94E-04	81 %
HTP air, noncancer	kg toluene eq.	1,16E+00	6,23E-01	46 %
Value added	NOK	7,43E-01	5,43E-01	27 %

Results – Comparing old and new stove technology

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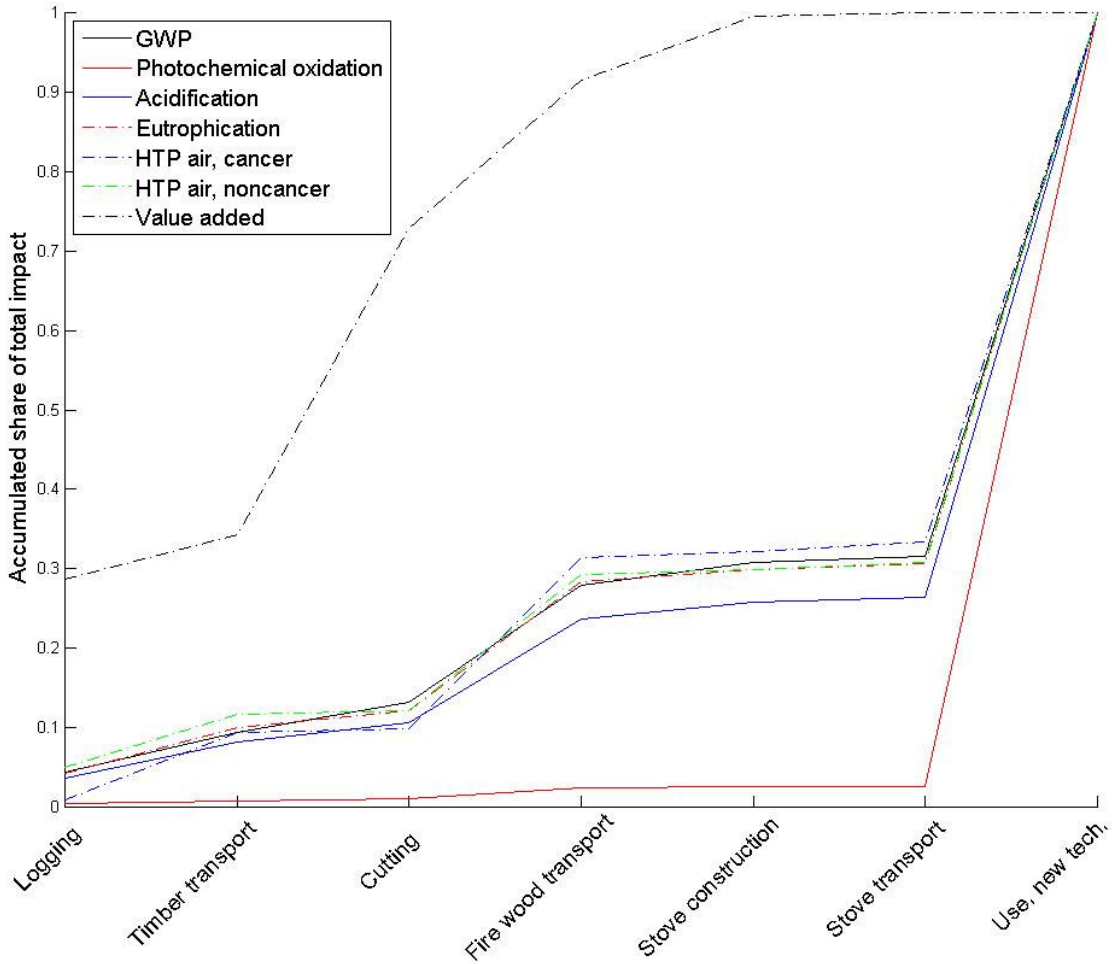
Large improvement for all impact categories

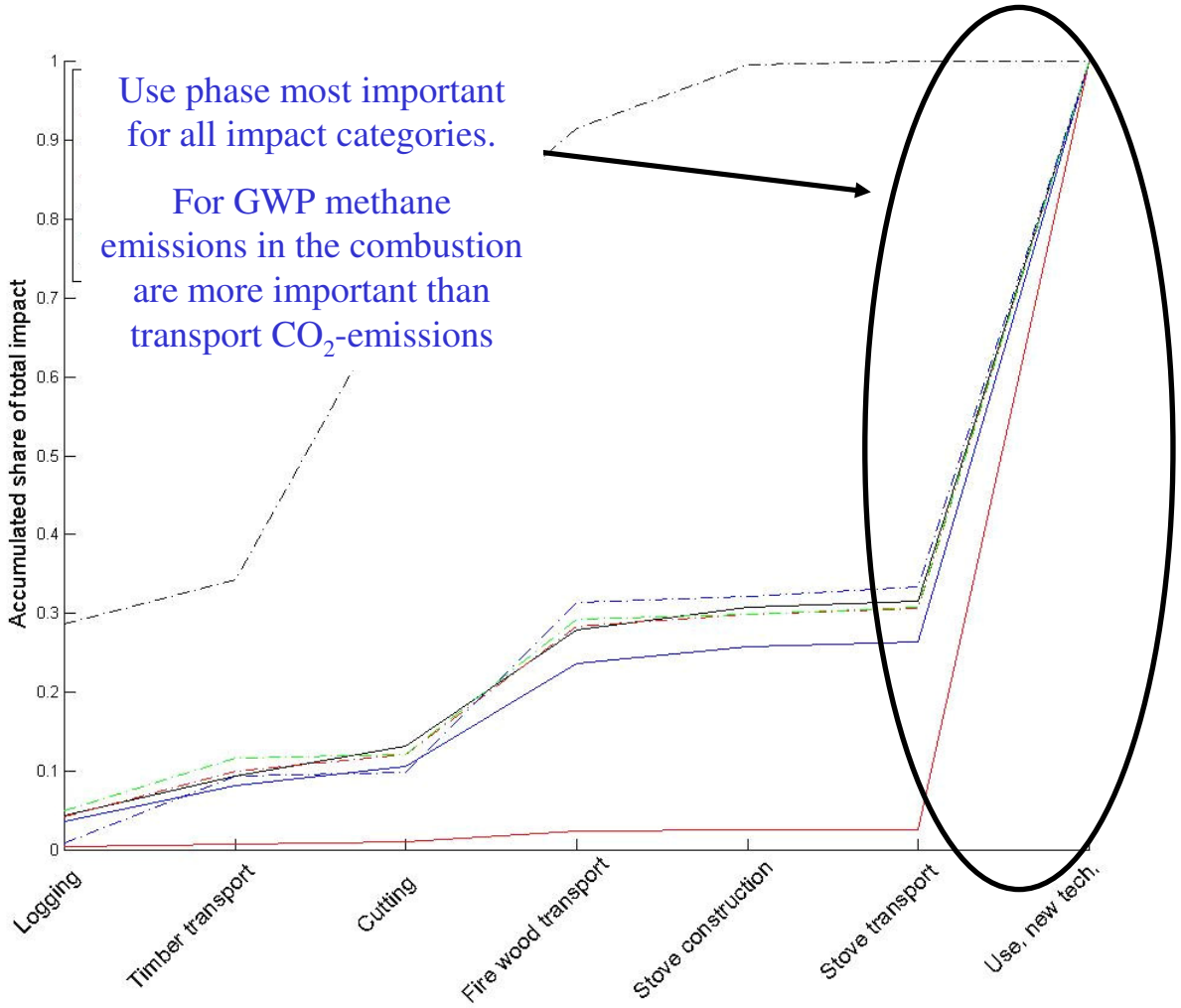
Caused by reduced emissions from combustion and reduced demand for fuel wood

Value chain contributions

-New technology



Value chain contributions



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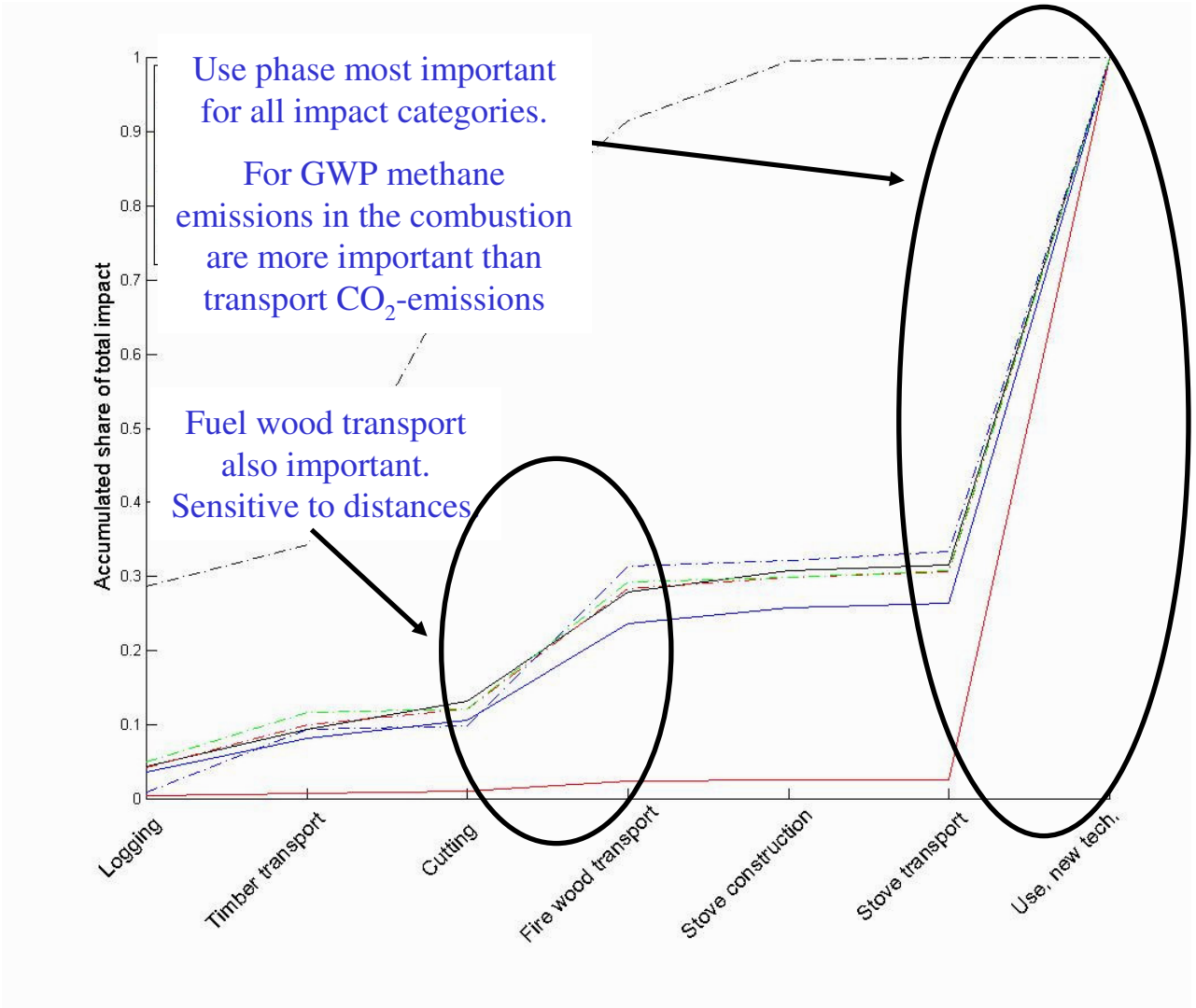


Results – Structural path analysis

-Top 15 ranking paths for GWP, new stove technology

68,5 %	Use					
8,8 %	Use	Fire wood transport				
3,5 %	Use	Fire wood transport	Cutting	Timber transport		
2,0 %	Use	Fire wood transport	Petroleum refining			
2,0 %	Use	Fire wood transport	Cutting	Timber transport	Logging	
1,0 %	Use	Fire wood transport	Petroleum refining	Oil and gas extraction		
0,6 %	Use	Stove transport	Stove construction	Manufacture of basic iron and steel		
0,6 %	Use	Fire wood transport	Land transport			
0,5 %	Use	Stove transport				
0,4 %	Use	Fire wood transport	Cutting	Timber transport	Petroleum refining	
0,4 %	Use	Fire wood transport	Cutting	Timber transport	Logging	Petroleum refining
0,4 %	Use	Fire wood transport	Cutting	Manufacture of wood		
0,3 %	Use	Fire wood transport	Cutting	Manufacture of chemicals		
0,3 %	Use	Fire wood transport	Cutting	Petroleum refining		
0,2 %	Use	Fire wood transport	Cutting	Timber transport	Land transport	

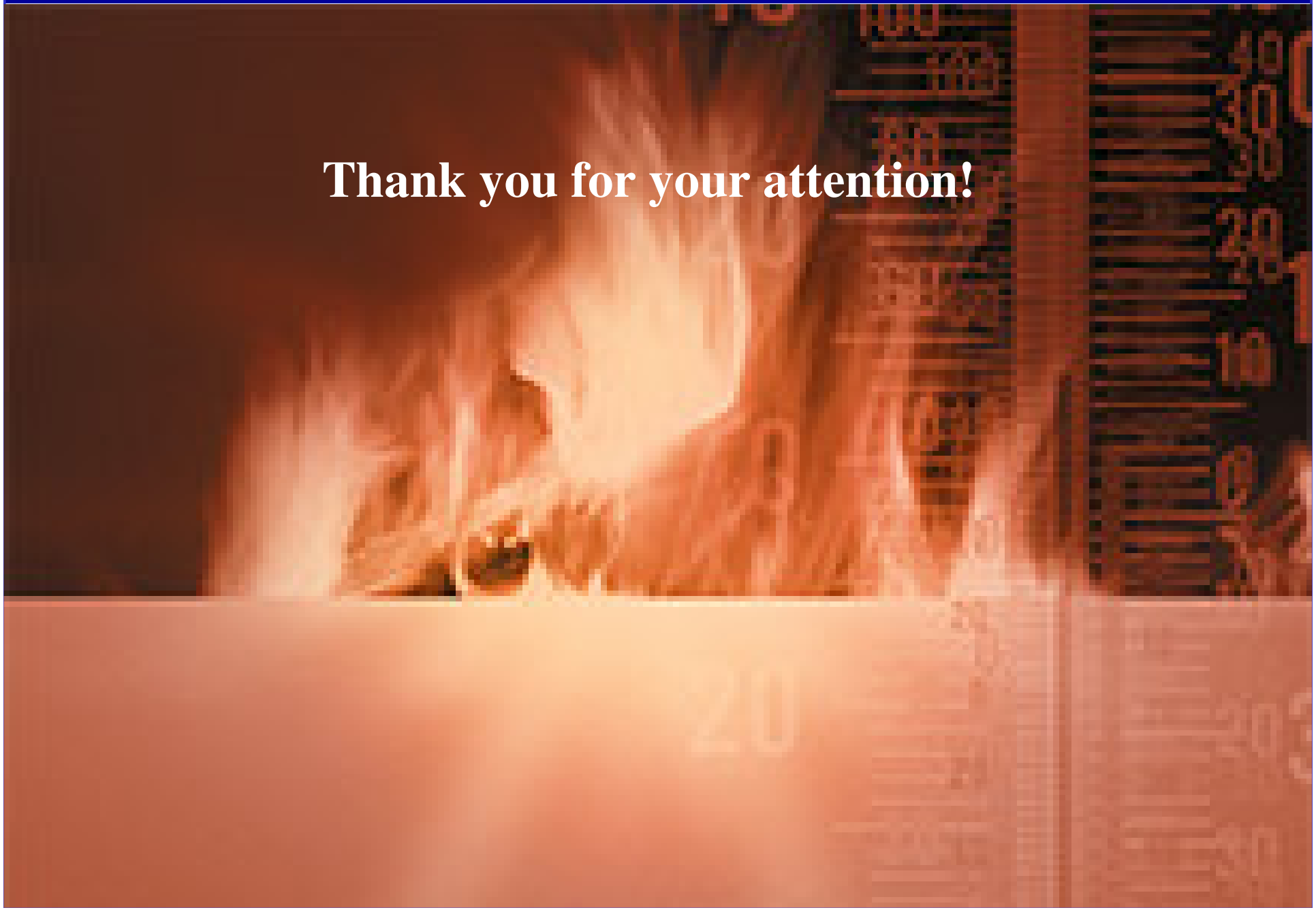
Results – Structural path analysis

-Top 15 ranking paths for value added, new stove technology

30,7 %	Use	Fire wood transport	Cutting				
22,3 %	Use	Fire wood transport	Cutting	Timber transport	Logging		
7,5 %	Use	Fire wood transport					
3,2 %	Use	Fire wood transport	Petroleum refining	Oil and gas extraction			
2,5 %	Use	Stove transport	Stove construction				
2,3 %	Use	Fire wood transport	Cutting	Timber transport			
1,2 %	Use	Fire wood transport	Wholesale and retail trade				
0,6 %	Use	Fire wood transport	Cutting	Timber transport	Petroleum refining	Oil and gas extraction	
0,6 %	Use	Fire wood transport	Cutting	Timber transport	Logging	Petroleum refining	Oil and gas extraction
0,6 %	Use	Fire wood transport	Cutting	Manufacture of wood			
0,6 %	Use	Fire wood transport	Cutting	Timber transport	Logging	Construction	
0,5 %	Use	Fire wood transport	Land transport				
0,5 %	Use	Stove transport	Stove construction	Manufacture of machinery			
0,5 %	Use	Fire wood transport	Cutting	Timber transport	Wholesale and retail trade		
0,5 %	Use	Fire wood transport	Cutting	Wholesale and retail trade			

Conclusions

- Wood based heat is not GWP-neutral even though the CO_2 from biomass combustion is considered to be.
- Methane emissions in combustion more important than transport CO_2 for GWP (using regional average distances)
- Reducing methane emissions from combustion is important for further improvement
- Combustion most important for all impacts
- Large improvement potential if more old stoves are replaced by new, clean burning, stoves.
- This is particularly true for human health impacts, to a large degree caused by PAH-emissions.
- Value added occurs most in the labor intensive processes in the value chain; cutting and logging. This is not surprising.



Thank you for your attention!