Dept. of Forest Economics

Seminar

SLU

# Peter Lohmander

Dept. of Forest Economics
SLU Umeå

is giving a talk on

## Economic forest production

with consideration of the forest and energy industries

Thursday January 29, 14.00

Seminar room

# Contents



***This presentation is very short. It includes a few partial fragments of the project. Please investigate the list of references and conferences with links for more information!***

## Projektets mål och inriktning

## Project Objectives and direction

Målsättningen är att analysera hur ekonomiskt optimal skogsproduktion kan uppnås med hänsyn till såväl skogsindustrins som energiindustrins råvaruefterfrågan för olika möjliga framtida utvecklingar.

**Objective: To determine optimal forest production with consideration of possible future input demand levels from the forest products industry and the energy industry.**

- Här studeras både skogens tillväxt och avverkning ur ett ekonomiskt perspektiv med användning av de intäkter och kostnader som beror av såväl timmer och massavedsproduktion som GROT och andra energisortiment.
- **Forest growth and harvesting are studied from an economic perspective, considering costs and revenues from timber, pulpwood, GROT and other energy assortments.**

- Skogsproduktionen optimeras dels i befintliga skogsbestånd och dels i skogsbestånd som kommer att anläggas i framtiden.
- **The forest production, in presently existing forest stands and in future forest generations, is optimized.**

- Samtliga relevanta regelverk inklusive skogsvårdslagen och dess föreskrifter samt möjliga justeringar beaktas i analyserna.
- **All relevant prescriptions and legal documents, including the forest act and possible future adjustments, are considered in the analyses.**

- När det gäller framtida skogsproduktion ska möjligheterna att använda högproducerande hybrider av asp och poppel inkluderas liksom alla andra möjligheter som står till buds med hänsyn till genetiska förbättringar och andra omständigheter.
- **The options to change tree species and to take advantage of genetical improvements in new forest plantations will be considered in the analyses.**

- Årliga rapporter samt seminarier genomföres.
- **Yearly reports and seminars will be included in the project.**

- Projektet inkluderar en utförlig ”case study” inom en region där skogs- och energiindustrin samt skogsproducenterna ingår. Denna studie avslutas med ett kombinerat evenemang bestående av ett seminarium och en tvådagars exkursion.”
- **The project includes a detailed ”case study” in a region, where the forest products industry, the energy industry and the forest producers are integrated. The case study finally ends with a seminar and a two day excursion.**

***My warmest "Thanks" to E.ON Sweden for economic support to the project "Economic forest production with consideration of the forest- and energy- industries"!***

**Peter Lohmander**

*Professor of Forest Management and Economic Optimization, Swedish University of Agricultural Sciences*

**http://www.Lohmander.com**

**Peter@Lohmander.com**

# Links to conferences and publications

- **http://www.lohmander.com/Kurser/Kurser.htm**

- **http://www.lohmander.com/Information/Ref.htm**

# Conference presentations 2008

- **Integrated Regional Study Stage 1**., Presentation at the E.ON - Holmen - Sveaskog - SLU Research Meeting, **Norrköping**, Sweden, 2008-12-10 – 2008-12-11
- The European Forest-based Sector: **Bio-Responses to Address New Climate and Energy Challenges**? (**Nancy** Nov 2008)
- **Economic forest production with consideration of the forest and energy industries**, E.ON International Bioenergy Conference, **Malmo**, Sweden, 2008-10-30

# Conference presentations 2008 cont.

**Optimal CCS, Carbon Capture and Storage, Under Risk**, International Seminars in Life Sciences, **Universidad Politécnica de Valencia**, Thursday 2008-10-16

- **Tools for optimal coordination of CCS, power industry capacity expansion and bio energy raw material production and harvesting**, 2nd Annual EMISSIONS REDUCTION FORUM: - Establishing Effective CO2, NOx, SOx Mitigation Strategies for the Power Industry, 29th & 30th September 2008 **Madrid**, Spain
- **Optimal resource control model & General continuous time optimal control model of a forest resource, comparative dynamics and CO2 consideration effects**, Seminar at **SLU**, Umea, Sweden, 2008-09-18

# Conferences 2008 cont.

**European Biomass Forum** 2008 (**Amsterdam**)

- **16th European Biomass Conference** 2008 (**Valencia**)
- **Energy Forum**, **Stockholm**, 6-7 Feb 2008

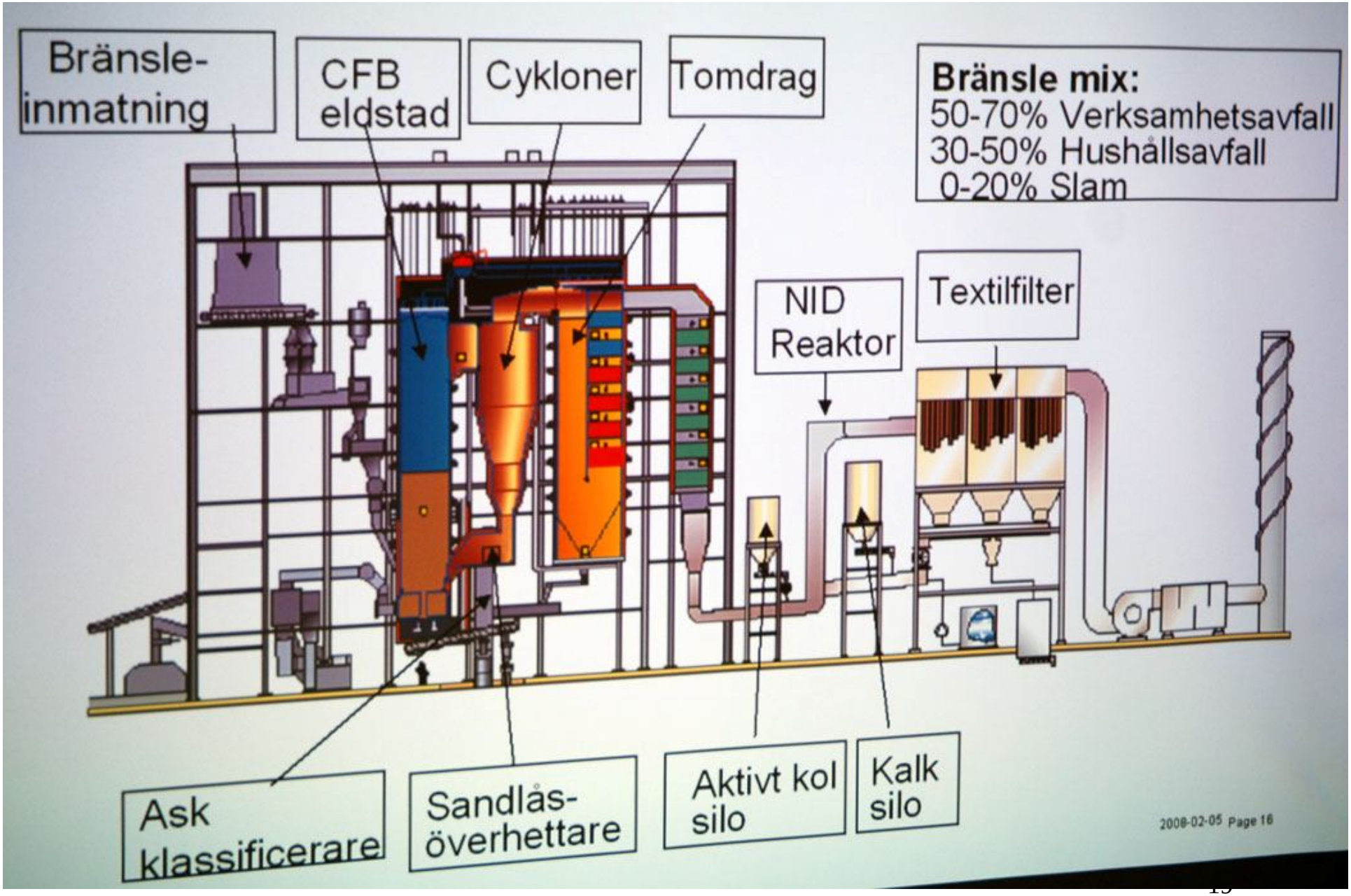
# The forest, the forest products industry and the energy industry in Sweden

*Illustrations*

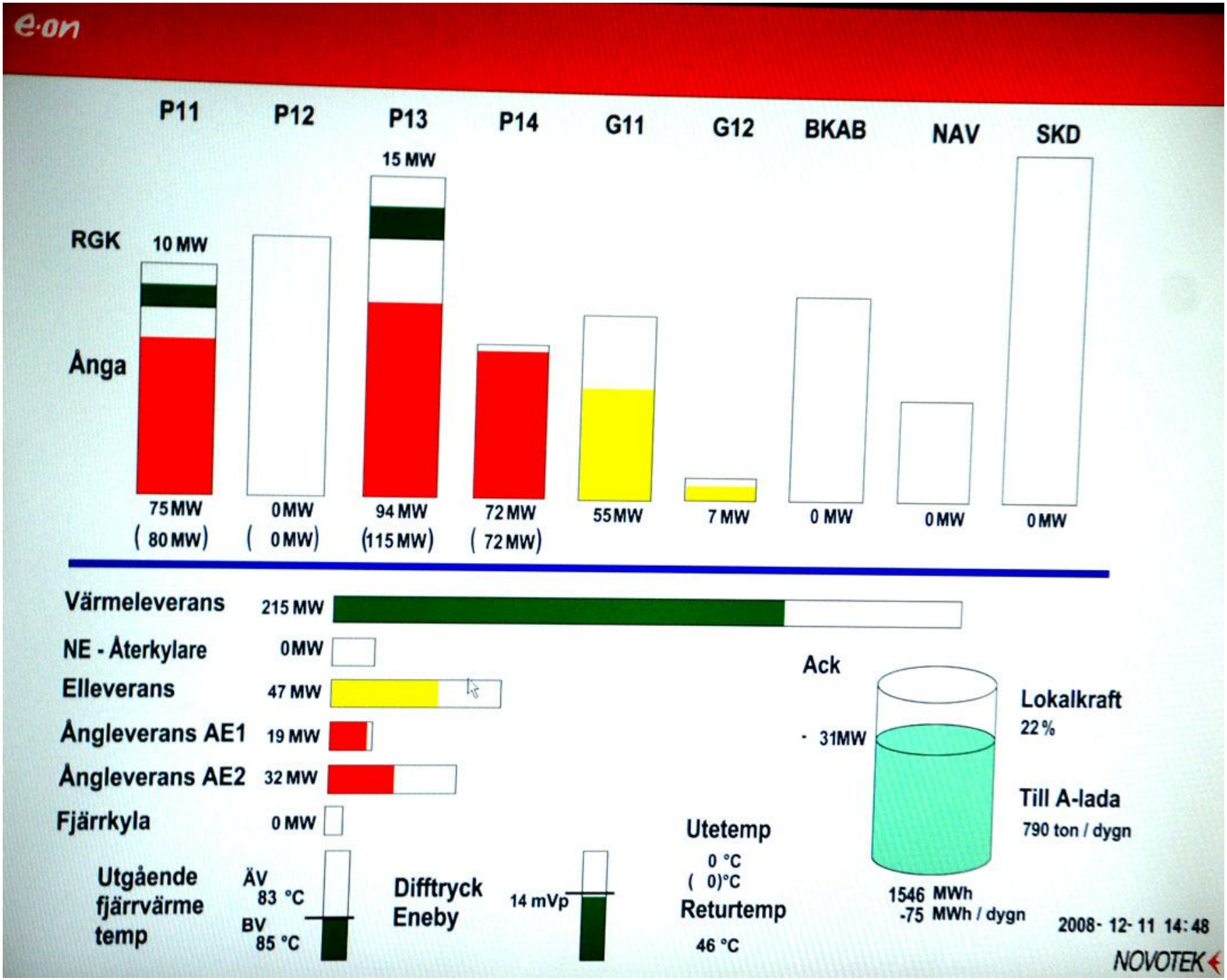

# e.on

*Händelö CHP*
*Norrköping, Sweden*

***Pictures by***
***Peter Lohmander***
***2008-12-11***


Bränsle-
inmatning
CFB
eldstad
Cykloner
Tomdrag
Bränsle mix:
50-70% Verksamhetsavfall
30-50% Hushållsavfall
0-20% Slam
NID
Reaktor
Textilfilter
Ask
klassificerare
Sandlås-
överhettare
Aktivt kol
silo
Kalk
silo
2008-02-05 Page 16


ASEA


e·on
P11
P12
P13
P14
G11
G12
BKAB
NAV
SKD
15 MW
RGK
10 MW
Ånga
75 MW
( 80 MW)
0 MW
( 0 MW)
94 MW
(115 MW)
72 MW
( 72 MW)
55 MW
7 MW
0 MW
0 MW
0 MW
Värmeleverans
215 MW
NE - Återkylare
0 MW
Elleverans
47 MW
Ångleverans AE1
19 MW
Ångleverans AE2
32 MW
Fjärrkyla
0 MW
Ack
- 31MW
Lokalkraft
22 %
Till A-lada
790 ton / dygn
1546 MWh
-75 MWh / dygn
Utetemp
0 °C
( 0)°C
Returtemp
46 °C
Utgående fjärrvärme temp
ÄV
83 °C
BV
85 °C
Difftryck Eneby
14 mVp
2008- 12- 11 14:48
NOVOTEK

# Händelöverket - Sammförbränningsanläggning

RGK
38 MW

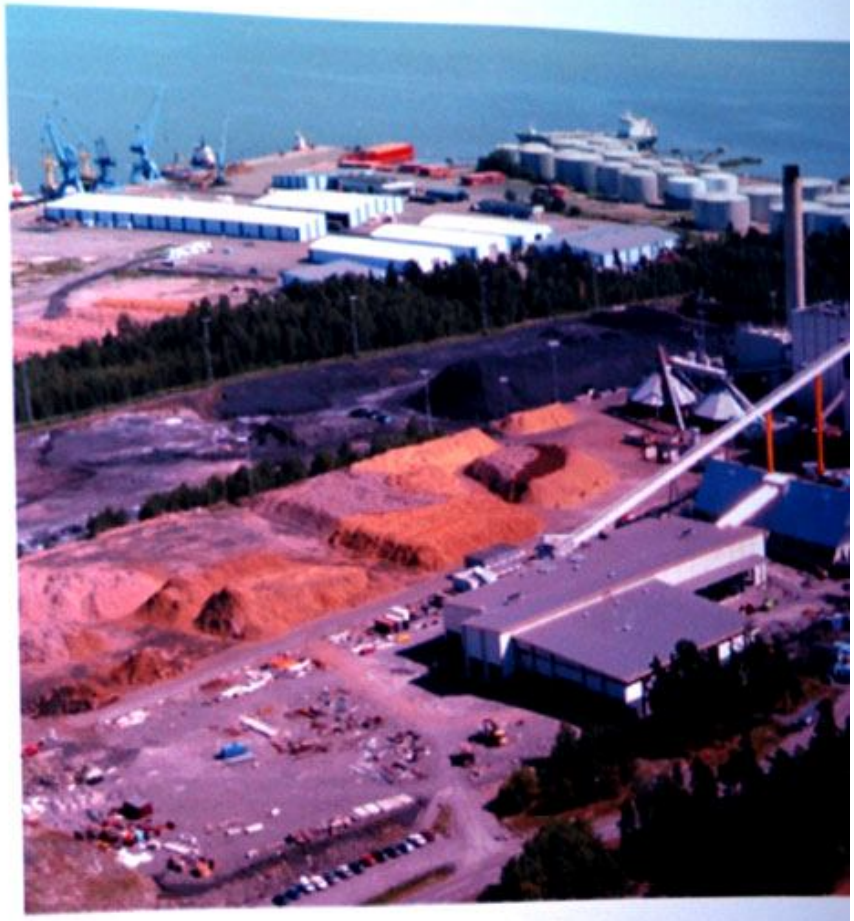
| P11 Vibrationsrost 90MW | P12 Wanderrost 125 MW | P13 CFB 125 MW | P14 CFB 75 MW |
|---|---|---|---|
| Returflis, skogsbränsle | Kol, gummi | Skogsbränsle, gummi | Hushållsavfall, industriavfall |

# Händelöverket

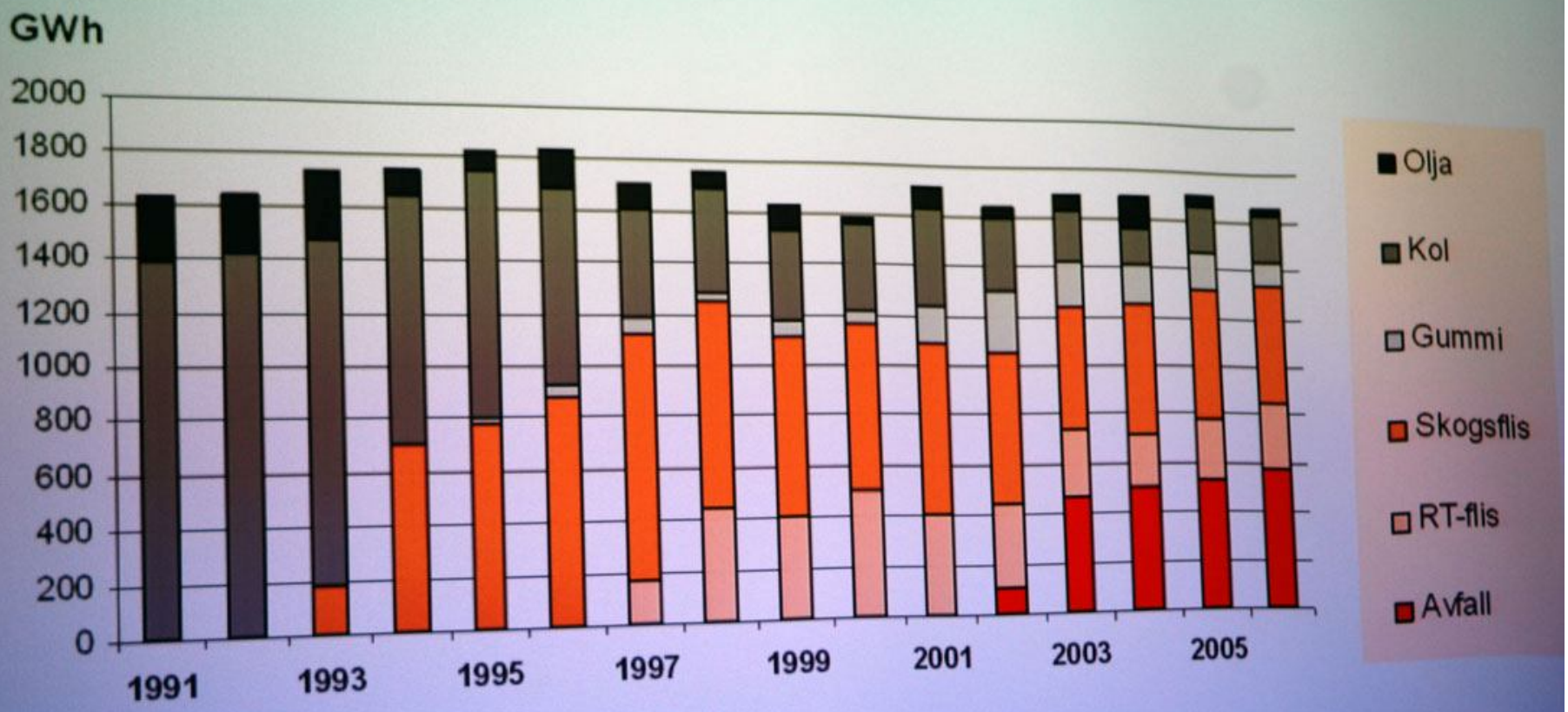
Lagringsytor för bränsle på Händelöverket ca 80 000 m2

Hanterade mängder/ år

| | |
|---|---|
| Flis | 85 000 ton |
| Grot | 85 000 ton |
| Stamved | 80 000 ton |
| RT-Flis | 75 000 ton |
| Gummiflis | 12 000 ton |
| Kol | 20 000 ton |
| Impregnerat trä | 15 000 ton |
| Hushållsavfall | 85 000 ton |
| Industriavfall | 90 000 ton |



# Bränslemix 1991 - 2006




SKOGSTJÄNST

# The Initial Physical State

The information from the Swedish Board of Forestry (Yearbook of Forest Statistics and Internet) clearly shows that the stock of wood in the Swedish forest has increased very much since 1920. This is true for pine, spruce and birch.

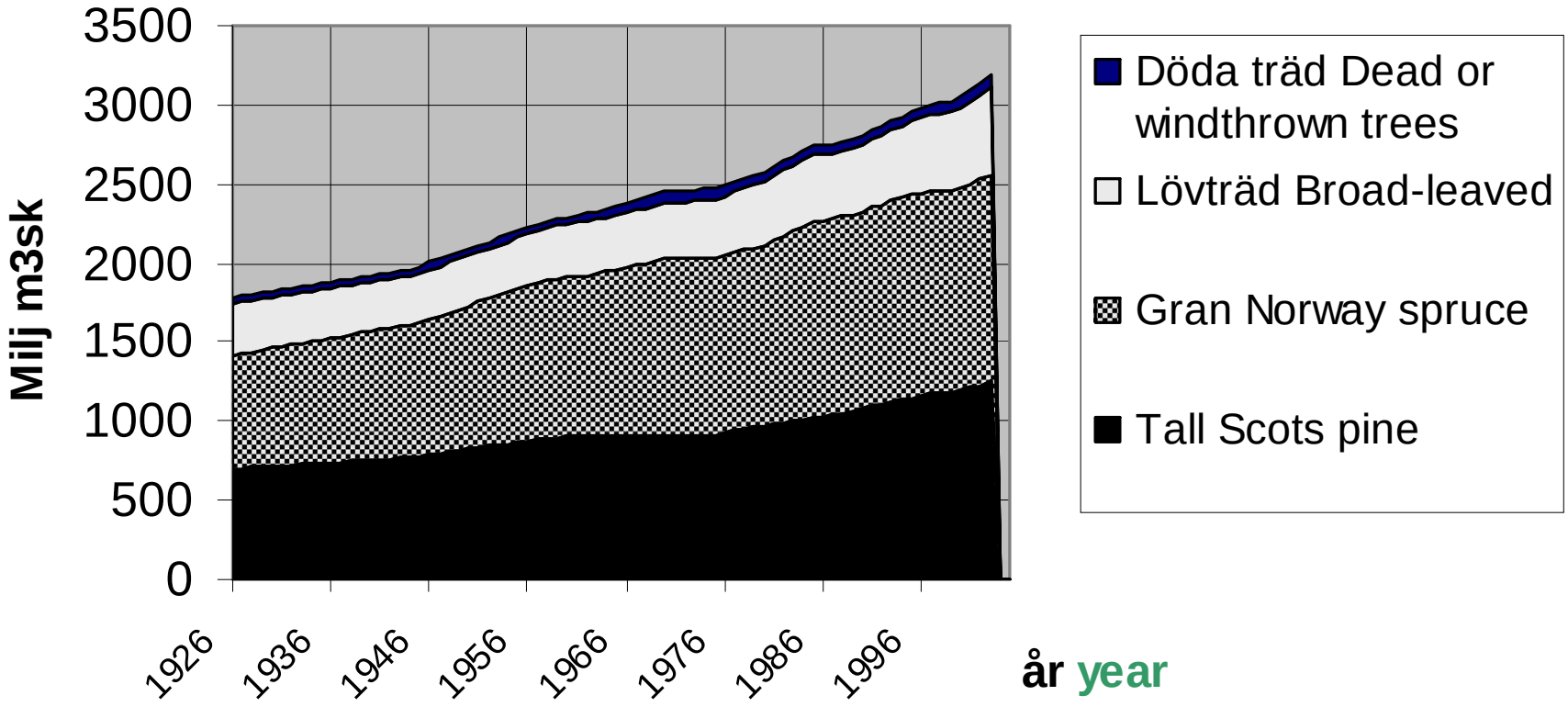
**Source:**

The Swedish Board of Forestry 2007-10-26:

http://www.svo.se/episerver4/templates/SFileListing.aspx?id=16583

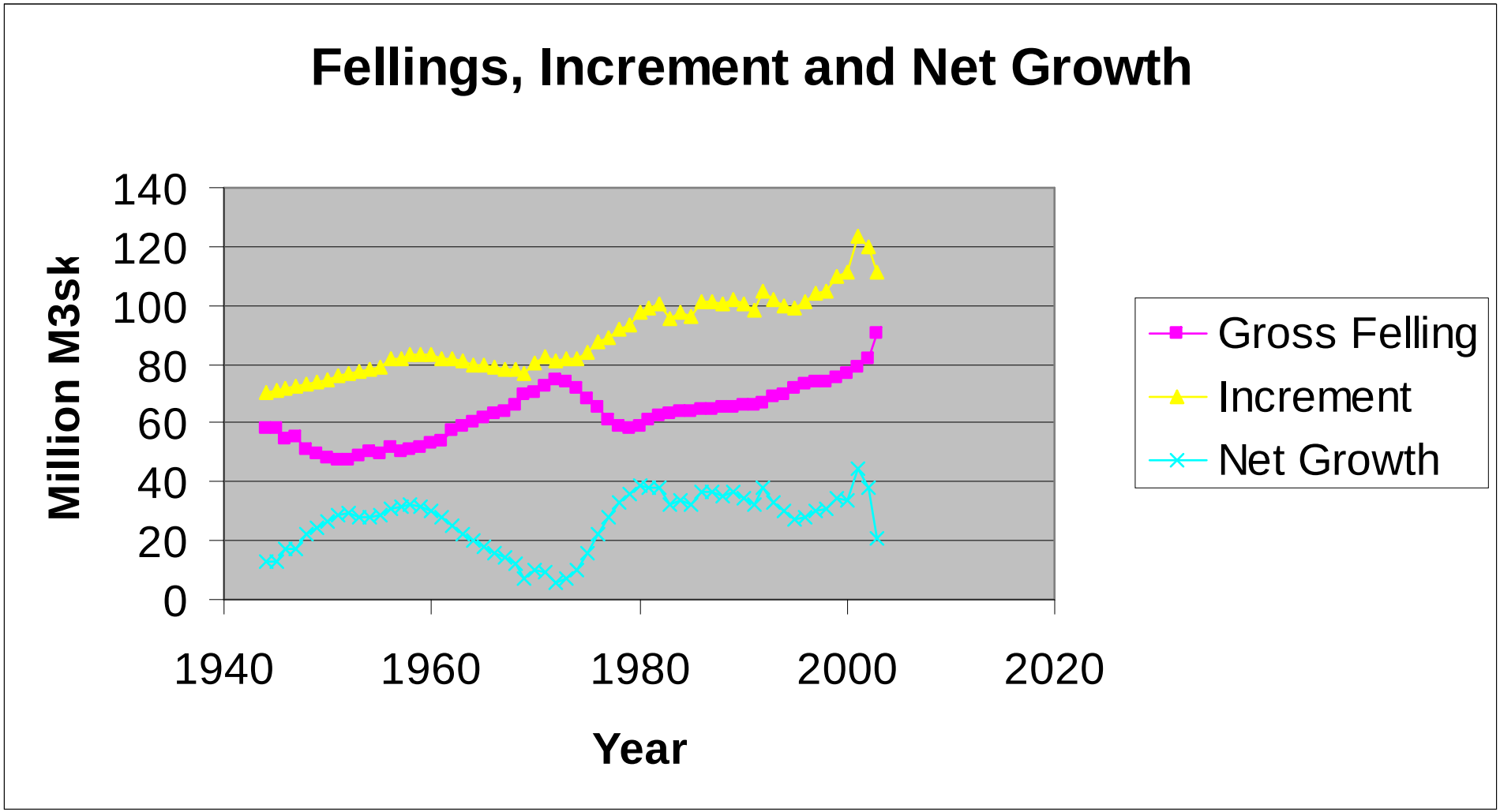
**Viirkesförrådets utveckling senda 1920-talet. Alla ägoslag 1**

**Trend for total standing volume since 1920, all land-use 1**

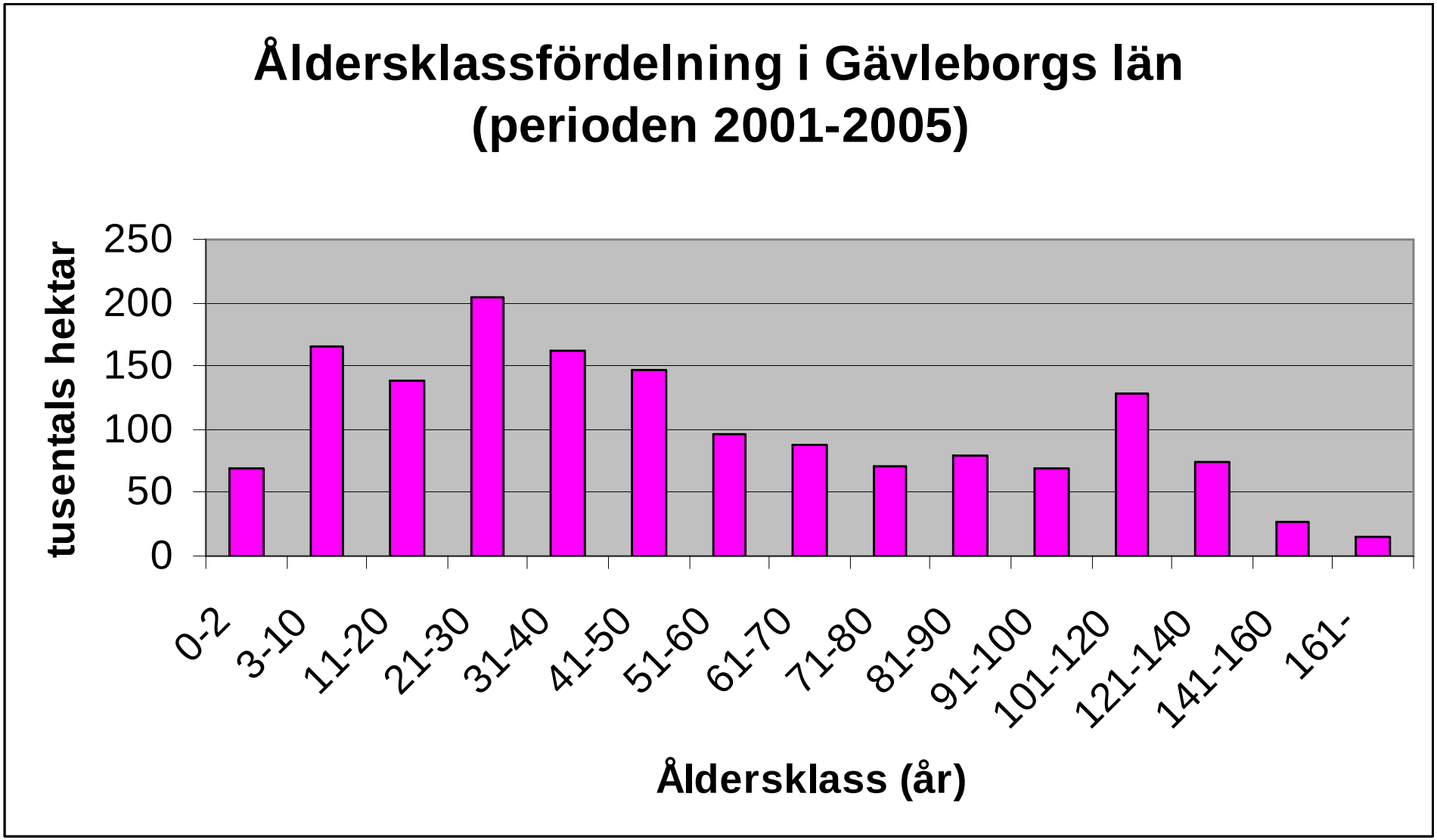



1 Exkl. fjäll, fridlyst mark, militära impediment, bebyggd mark samt söt- och saltvatten.
Excl. high mountains, restricted military areas, urban land and water surfaces.

Milj. M3sk Millions cubic metre standing volume (stem volume over bark from stump to tip)




Source: www.svo.se 2008-01-02

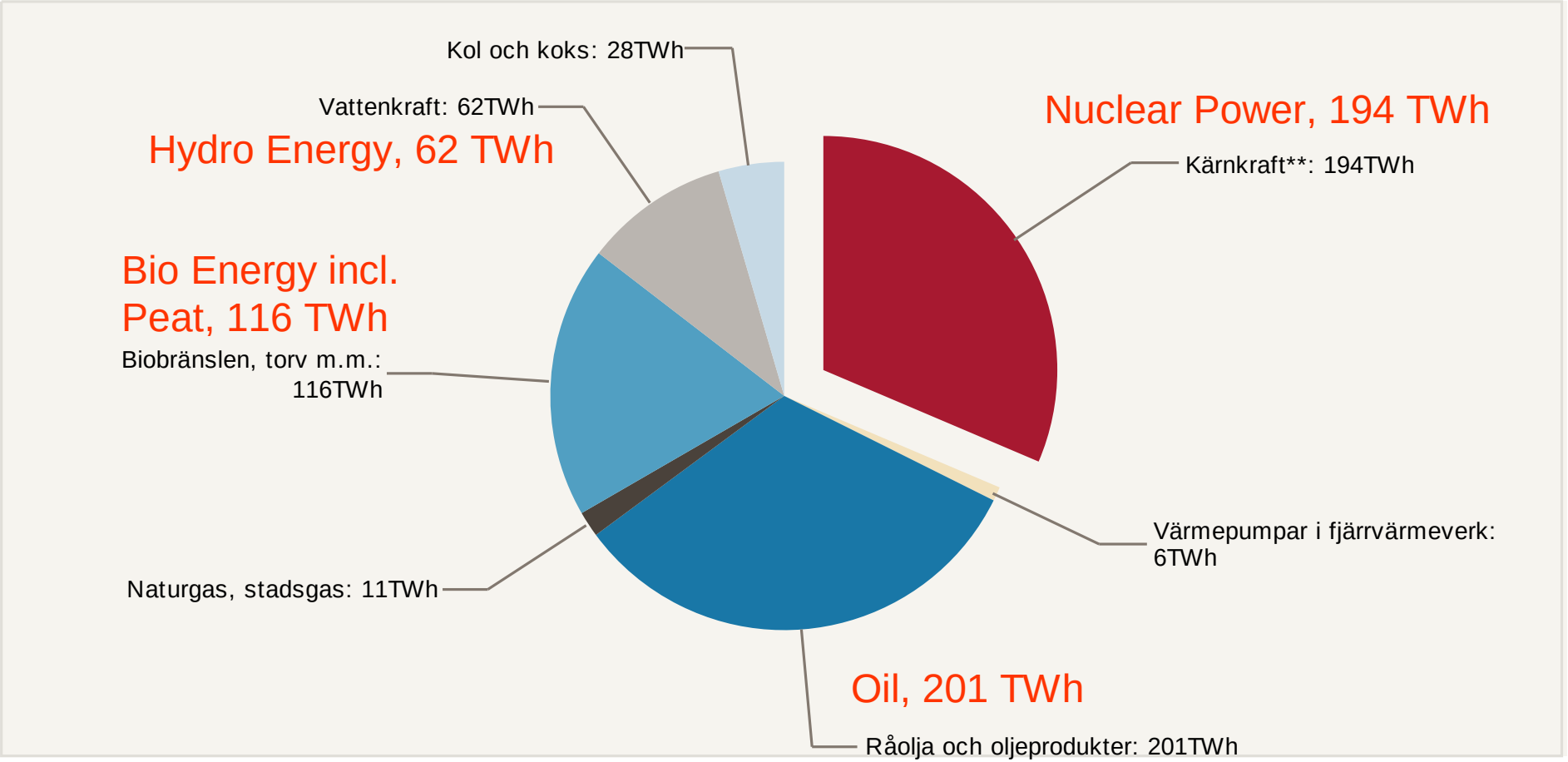



**Age distribution in the county of Gävleborg (2001-2005).**
**Thousands of hectares in different age classes (years).**

# Sveriges totala energitillförsel

## Fördelad på energislag*, 2006, TWh

## Total Energy Supply, Sweden (2006)




Källa: Energimyndigheten, Energiläget 2007

Hämtat: 2008-01-02

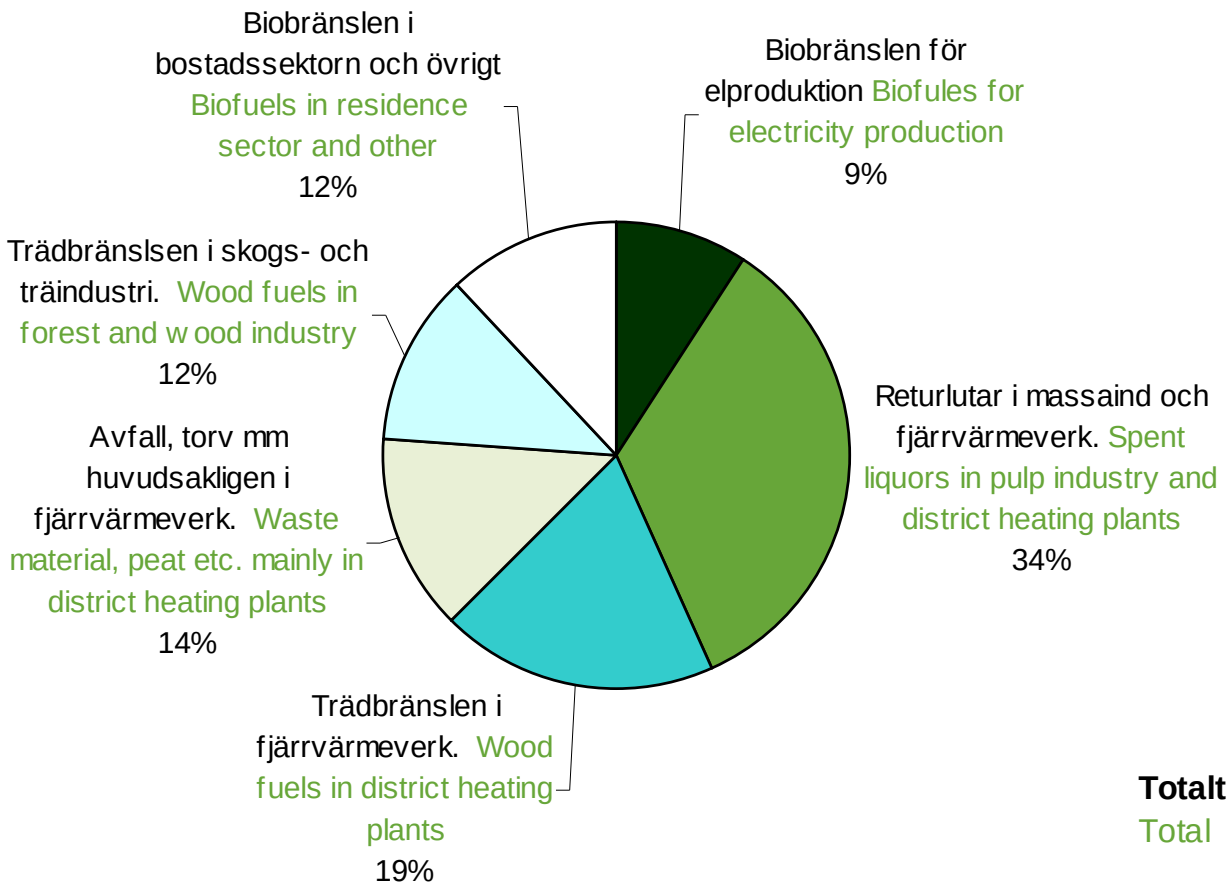
* Av presentationstekniska skäl redovisas inte vindkraften, som år 2006 stod för cirka 1 TWh av energitillförseln.

** Enligt den metod som används av FN/ECE för att beräkna tillförseln från kärnkraften.

ekonomifakta

## Användning av biobränslen, torv mm för energiändamål 2005

Utilisation of biofuels, peat etc, for energy production year 2005




**Totalt 110 TWh**

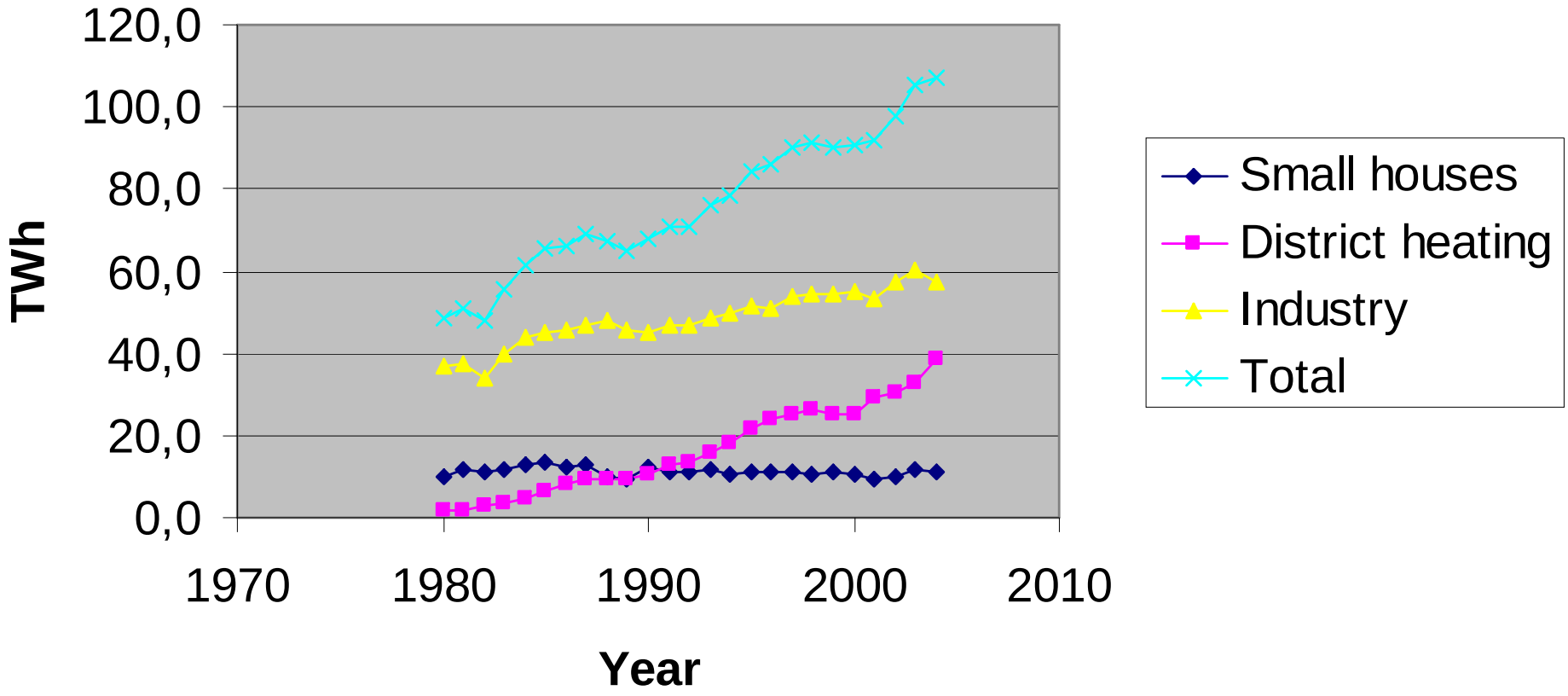
Total

Källa: Energimyndigheten, Energiläget i siffror 2006

Source: Sw edish Energy Agency, Energy in Sw eden, Facts and figures 2006

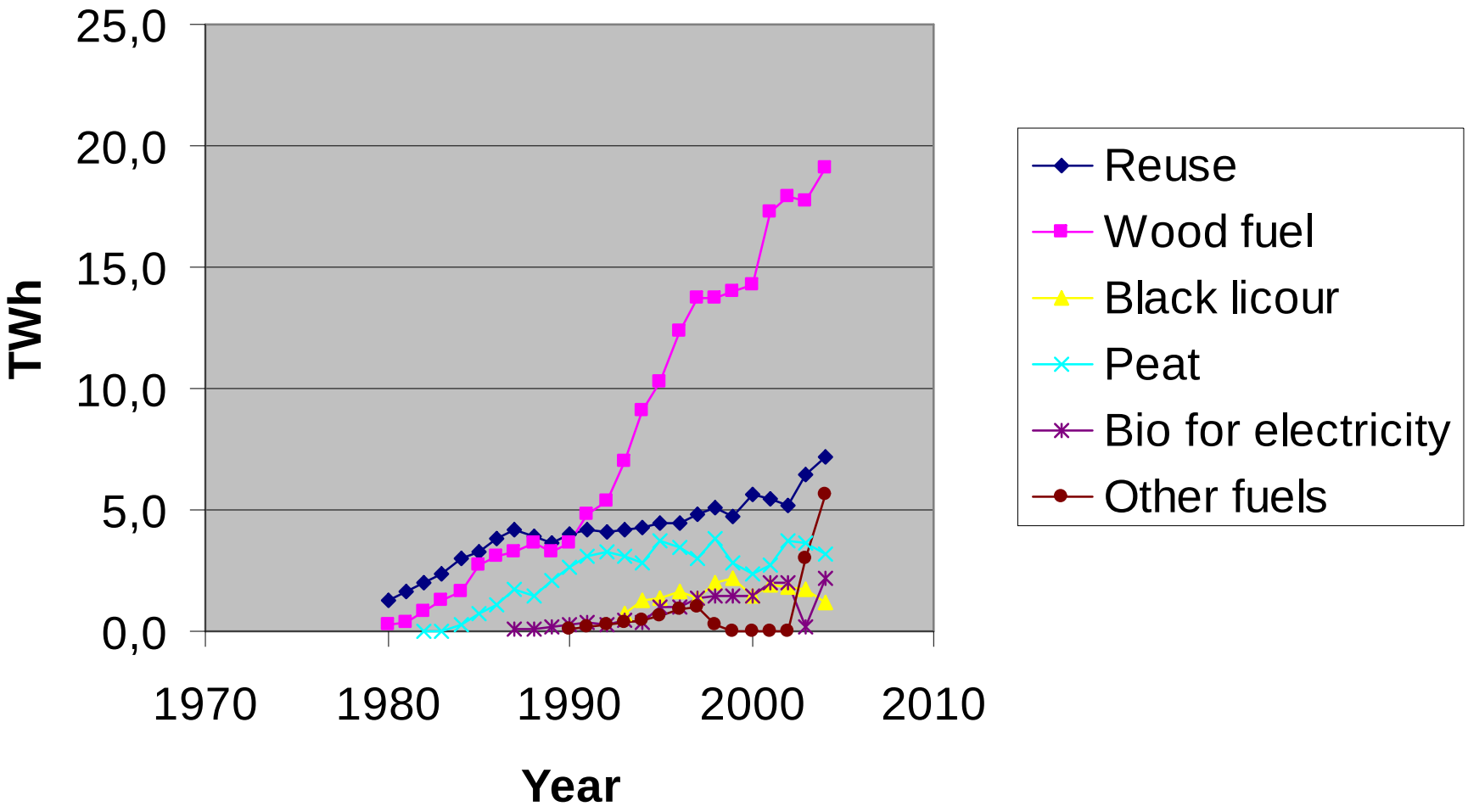
Sveriges officiella statistik

# Use of Bio Energy
# (office heating etc. not included)



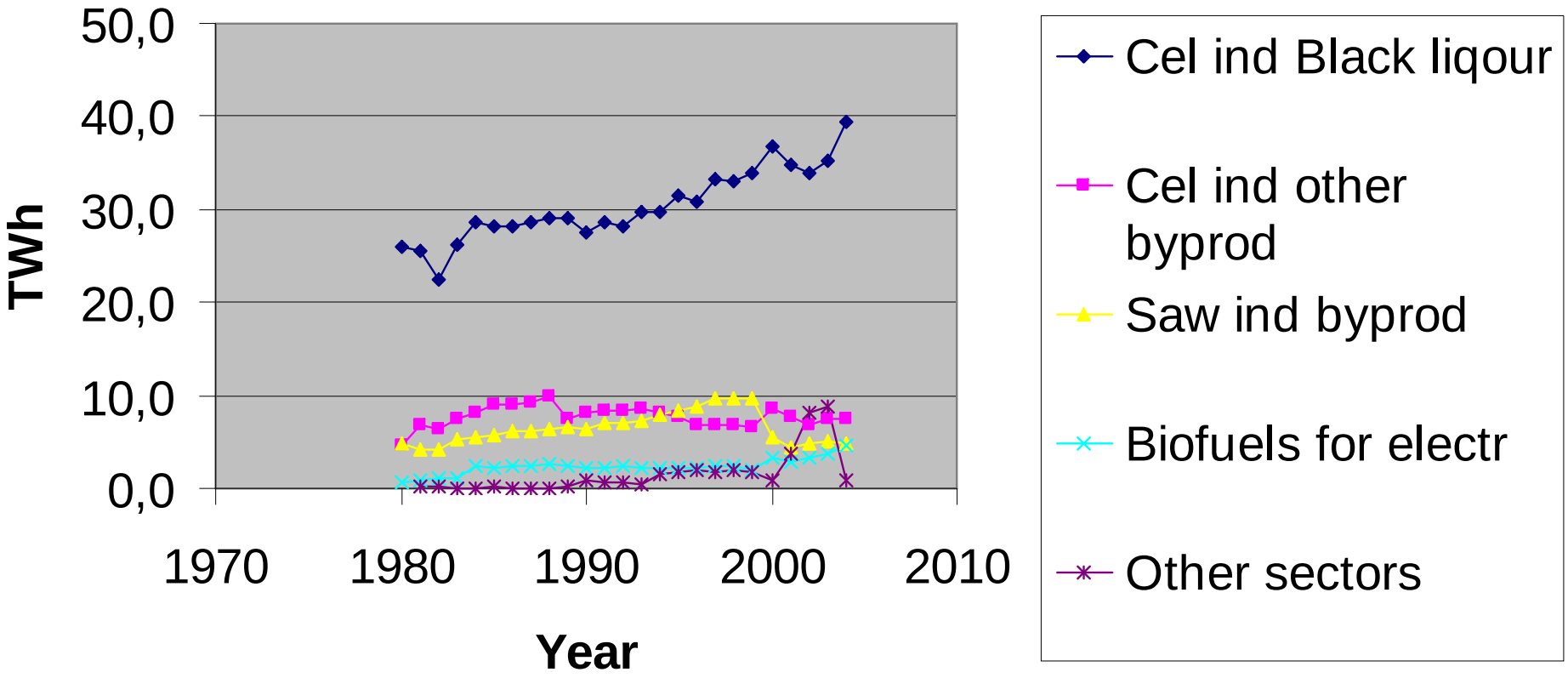

Source: Swedish Energy Agency: "Energy in Sweden, Facts and Figures 2005"

# Use of different fuels in district heating




**Source: Swedish Energy Agency: "Energy in Sweden, Facts and Figures 2005"**

# Use of fuels for bioenergy in industry




**Source: Swedish Energy Agency: "Energy in Sweden, Facts and Figures 2005"**

# Biomass flows in the Swedish Forest Sector 2004 (translated)

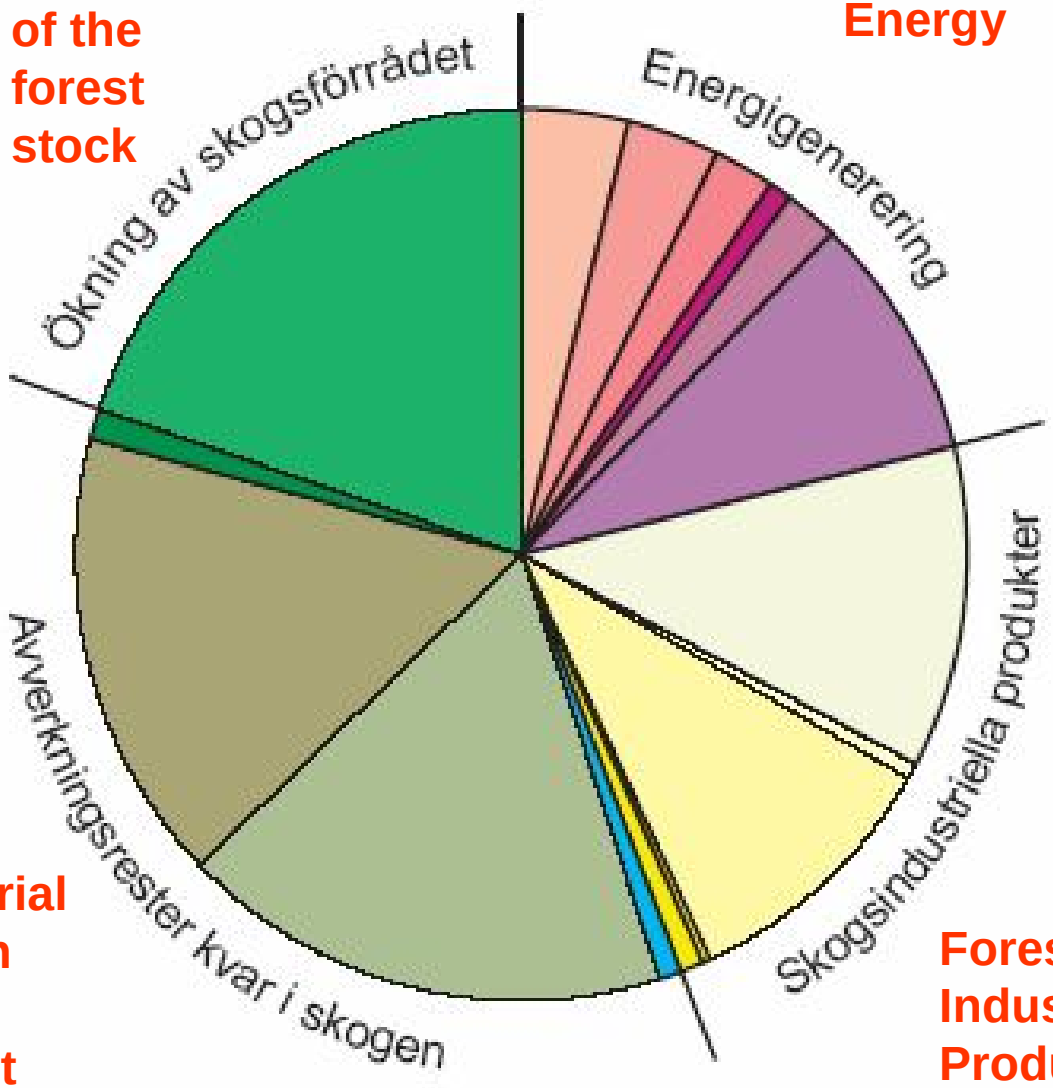
## Biomassaflöden i svensk skogsnäring 2004

Per Olov Nilsson
Professor emeritus i skogsbrukets energisystem

- http://www.svo.se/episerver4/dokument/sks/Statistik/dokumenten/Produktion/Tradbransle/ProjTradbr/Biomassaflöden%20i%20svensk%20skogsnäring%202004-2(förf%20P-O%20Nilsson,%20prof%20emer).pdf

**Increase of the forest stock**

**Energy**




**Raw material left in the forest**

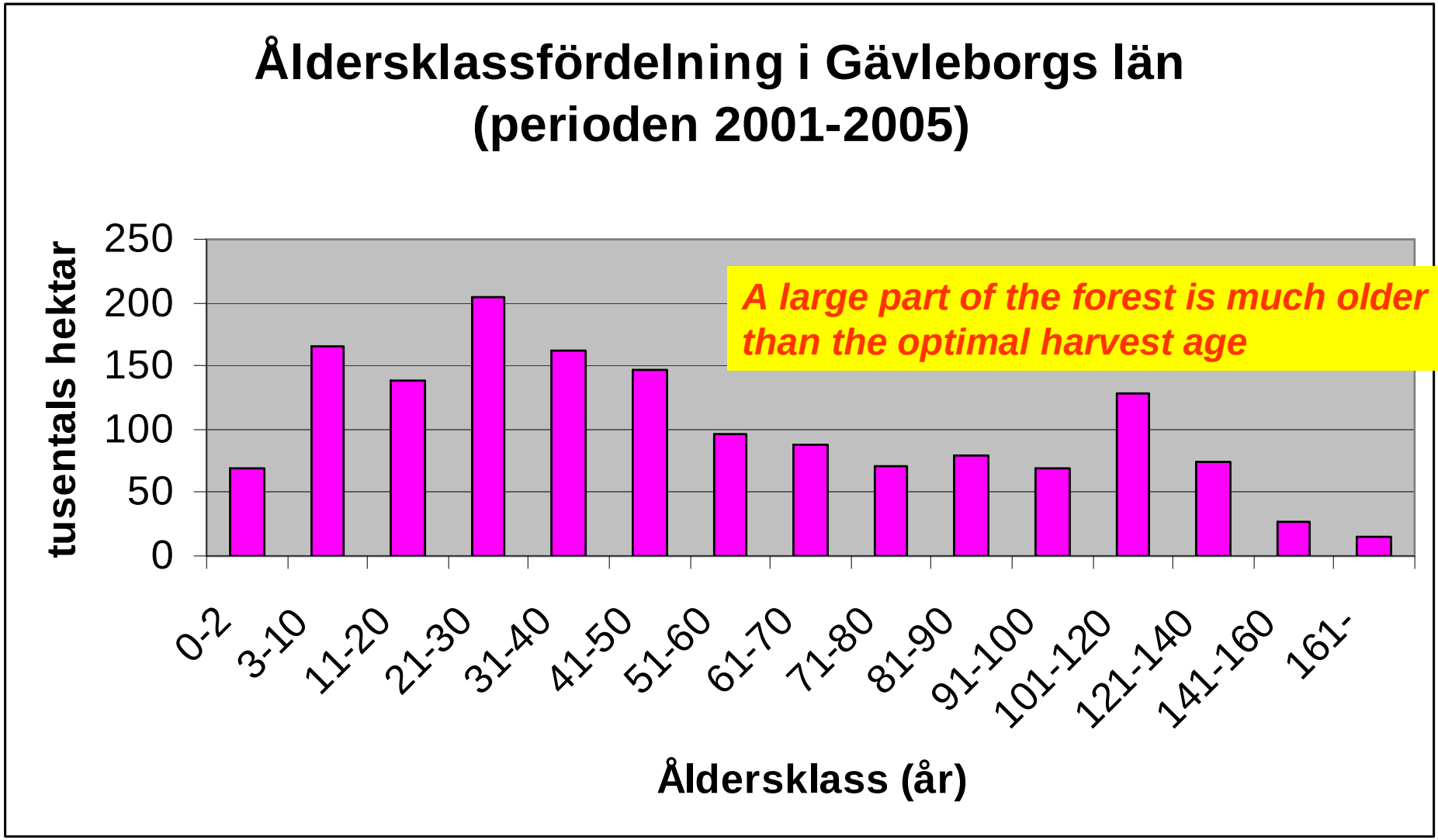
**Forest Industry Products**

Tillväxt, all biomassa: 75,9 megaton torrsubstans [$Mt_{ts}$]
Avverkning: 61,0 $Mt_{ts}$ biomassa

- Bränntved
- Bark o spån till fjärr-värme och bränsle-förädling
- Grot till fjärrvärme
- Sågverk internt
- Massa o skivor internt
- Returlutar
- Massa
- Skivor
- Sågade trävaror
- Övrigt
- Export av rundvirke
- Förluster
- Grot kvar i skogen
- Stubbar kvar i skogen
- Fällda träd kvar i skogen (stamdelen)
- Förrådsuppbyggnad

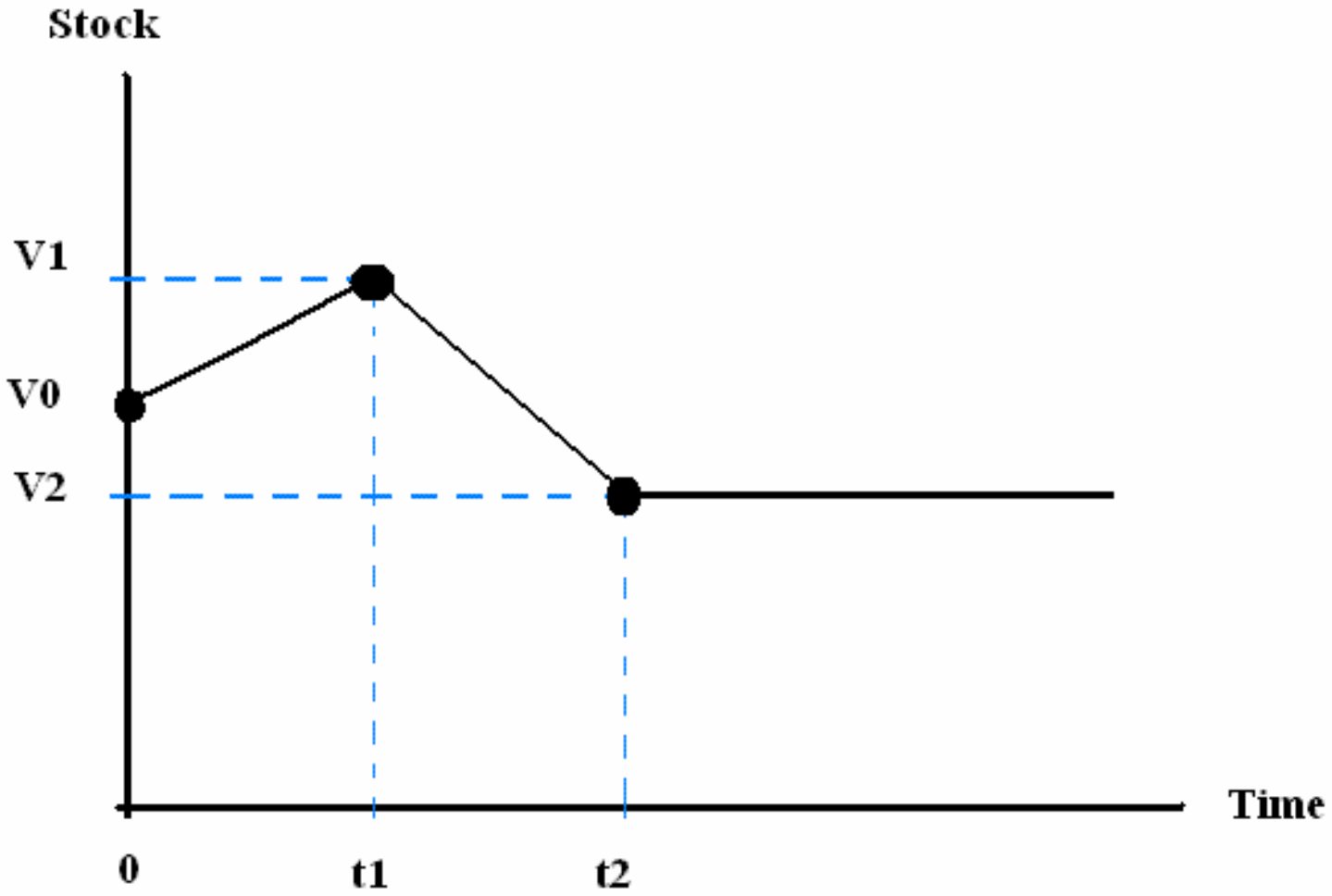
***Operations Research with Economic Optimization***

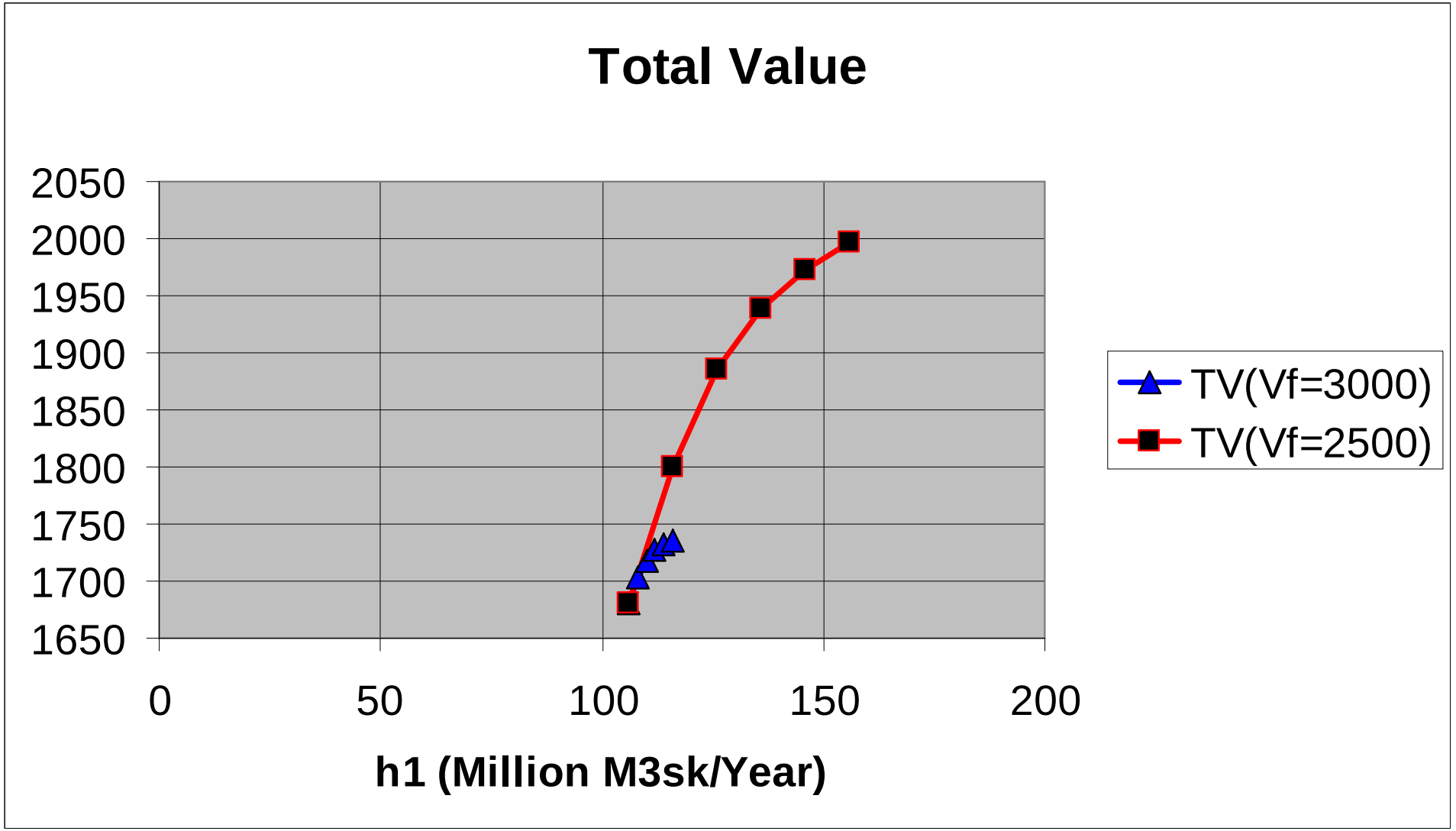
- ***Raw material Perspective***
- ***Total Perspective I***
- ***Total Perspective II***



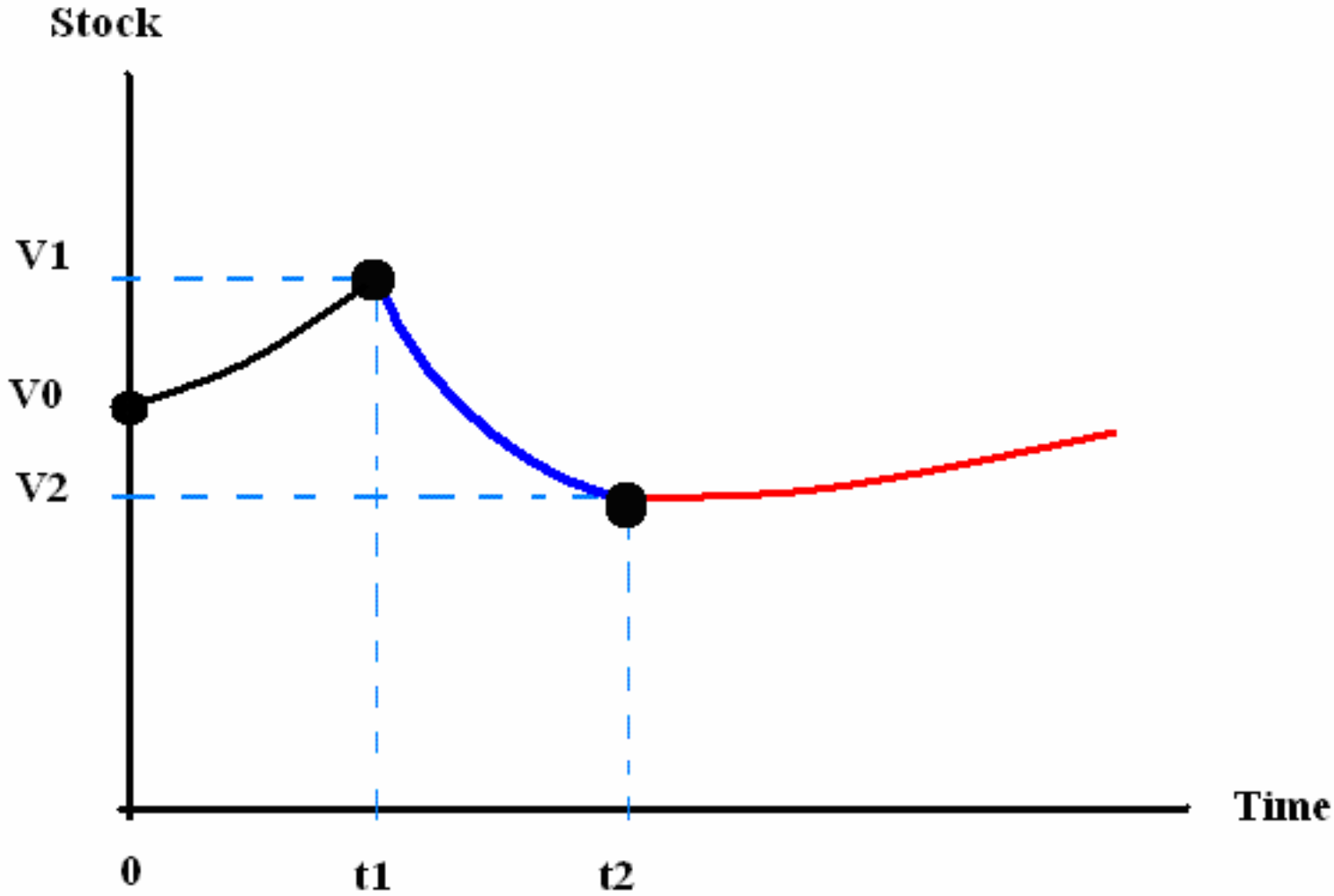

**Age distribution in the county of Gävleborg (2001-2005). Thousands of hectares in different age classes (years).**

# Total perspective I

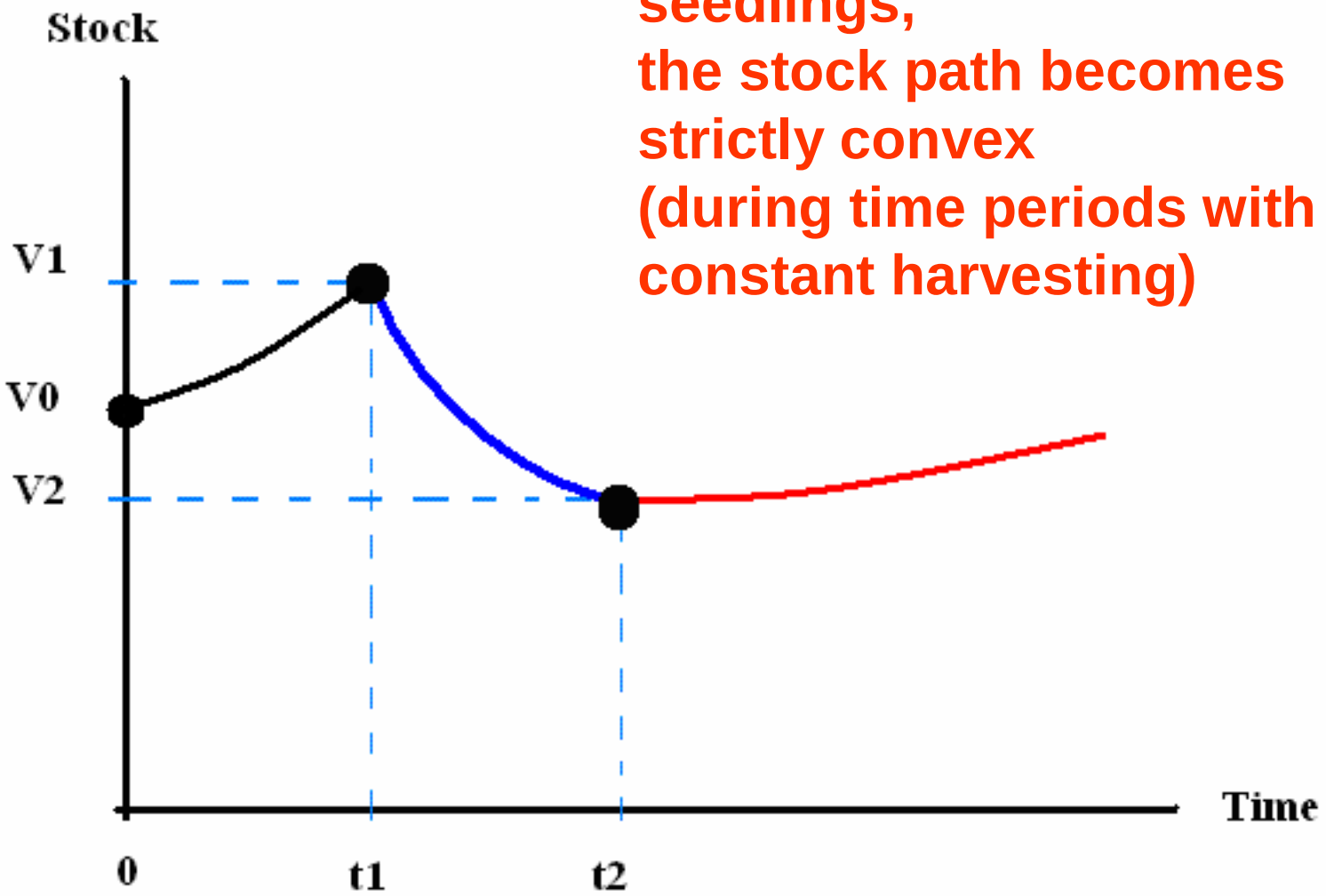



Total Value
2050
2000
1950
1900
1850
1800
1750
1700
1650
0
50
100
150
200
h1 (Million M3sk/Year)
TV(Vf=3000)
TV(Vf=2500)

# Total perspective II



**If harvested areas are replanted with more rapidly growing seedlings, the stock path becomes strictly convex (during time periods with constant harvesting)**



# Integrated regional study and risk management

**The optimal joint management strategy of the forests, the energy plants and the forest industry mills will be determined in a region.**

*Three coorporations are involved: E.ON Sweden, Holmen and Sveaskog.*

# Integrated regional study and risk management

**Preliminary map of the locations of the main energy plants (red filled circles) and forest industry mills (black filled squares) that will be included in the total optimization.**

**<u>Coorporations:</u> E.ON Sweden, Holmen and Sveaskog.**

# Integrated regional study with risk management

***Economic forest production with consideration of the forest- and energy- industries***

***Stage 1.***

RegMod_PP_081203

***Presentation at the E.ON - Holmen - Sveaskog - SLU Research Meeting, Norrköping, Sweden, 2008-12-10 – 2008-12-11***


## Peter Lohmander

***Professor of Forest Management and Economic Optimization***
***SLU, Swedish University of Agricultural Sciences***
***Umea, Sweden***
**http://www.Lohmander.com**

# ! Definitions of sets;

```
SETS:
   Per/1..10/: D, Stock, Prof,
         OCpulp, OCboard, OCsawn, OCenergy,
         Invpulp, Invboard, Invsawn, Invenergy,
         NCpulp, NCboard, NCsawn, NCenergy,
         Qharv, PWharv, TIharv, GRharv,
         PWpulp, PWboard, PWenergy,
         TIpulp, TIboard, TIsawn, TIenergy,
         GRenergy,
         Chipspulp, Chipsboard, Chipsenergy, Chips,
         Dustboard, Dustenergy, Dust,
         BLenergy, Blackliq,
         RMpulp, RMboard, RMsawn, RMenergy,
         qpulp, qboard, qsawn, qenergy,
         PHarv,PGROT, PPulp, PBoard, PSawn, PEnergy;

   ENDSETS
```

# ! Forest policy constraints and forest dynamics;

```
@FOR( Per(t) | t#GT#1:

   Stock(t) = Stock(t-1)
   + perlength* (Growth - QHarv(t-1))

   );
```

# Start of general time loop

@FOR( Per(t):

# ! Forest harvesting and forest raw material production;

[C_Harv]QHarv(t) <= Growth + ( Stock(t) - LAStock )/5 ;

[SharePW]PWHarv(t) = (1-TSS)*QHarv(t)*0.84;

[ShareTi]TIHarv(t) = TSS*QHarv(t)*0.84;

[ShareGR]GRHarv(t) <= GPC*QHarv(t);

# ! Raw material constraints;

[Con_PW]PWpulp(t) + PWboard(t) + PWenergy(t) <= PWHarv(t);

[Con_TI]TIpulp(t) + TIboard(t) + TIsawn(t) + TIenergy(t) <= TIHarv(t);

[Con_GR]GRenergy(t) <= GRHarv(t);

[Con_Ch]Chipspulp(t) + Chipsboard(t) + Chipsenergy(t) <= Chips(t);

[Con_Du]Dustboard(t) + Dustenergy(t) <= Dust(t);

[Con_BL]BLenergy(t) <= Blackliq(t);

# ! Raw material to each industrial type;

[C_RMpu]RMpulp(t) = PWpulp(t) + TIpulp(t) +
Chipspulp(t);

[C_RMbo]RMboard(t) = PWboard(t) + TIboard(t) +
Chipsboard(t) + 0.999*Dustboard(t);

[C_RMsa]RMsawn(t) = TIsawn(t);

[C_RMen]RMenergy(t) = 2.87* (PWenergy(t) + TIenergy(t))
+ 2.73* (Chipsenergy(t) + Dustenergy(t)) + BLenergy(t) +
GRenergy(t) ;

**! Industrial production capacity constraints;**

[RM_pulp] 3.7*qpulp(t) <= RMpulp(t);

[RM_board] 1.5*qboard(t) <= RMboard(t);

[RM_sawn] 2*qsawn(t) <= RMsawn(t);

[RM_energy] qenergy(t) <= RMenergy(t);

**! Production of intermediate raw materials;**

Chips(t) = 0.8*qsawn(t);

Dust(t) = 0.2*qsawn(t);

Blackliq(t) = PINDEEFF*3.016*qpulp(t);

# ! Production capacity constraints;

[C_Pulp]qpulp(t) <= OCpulp(t)+NCpulp(t);

[C_board]qboard(t) <= OCboard(t)+NCboard(t);

[C_sawn]qsawn(t) <= OCsawn(t)+NCsawn(t);

[C_energy]qenergy(t) <= Cenergy(t)+NCenergy(t);

***End of general time loop***

# ! Price dynamics;

@FOR( Per(t):

PHarv(t)= P0Harv + dPdqHarv*qHarv(t) + dPdtHarv*perlength*(t-1/2);

PGROT(t)= P0GROT + dPdqGROT*GRHarv(t) + dPdtGROT*perlength*(t-1/2);

PPulp(t)= P0Pulp + dPdqPulp*qPulp(t) + dPdtPulp*perlength*(t-1/2);

PBoard(t)= P0Board + dPdqBoard*qBoard(t) + dPdtBoard*perlength*(t-1/2);

PSawn(t)= P0Sawn + dPdqSawn*qSawn(t) + dPdtSawn*perlength*(t-1/2);

PEnergy(t)= P0Energy + dPdqEnergy*qEnergy(t) + dPdtEnergy*perlength*(t-1/2);

);

# ! Discounting calculations;

```
perlength = 5;
r = interest;
@FOR( Per(t): D(t) = @exp(-r* (perlength*(t-
   1/2 ))));
```

# ! Objective function;

Max = EPV;

EPV = perlength * @SUM( Per(t): D(t)*Prof(t) );

```
@for(Per(t): Prof(t) =

    (PPulp(t)-OVCPulp)*qpulp(t)        + (PBoard(t)-OVCBoard)*qboard(t)
  + (PSawn(t)-OVCSawn)*qsawn(t)        + (PEnergy(t)-OVCEnergy)*qenergy(t)
  -  PHarv(t)*QHarv(t)                 -  PGROT(t)*GRHarv(t)

  - MainOCPulp*OCpulp(t)               - MainOCBoard*OCboard(t)
  - MainOCSawn*OCsawn(t)               - MainOCEnergy*OCenergy(t)

  - MainNCPulp*NCpulp(t)               - MainNCBoard*NCboard(t)
  - MainNCSawn*NCsawn(t)               - MainNCEnergy*NCenergy(t)

  - InvCPulp*Invpulp(t)                - InvCBoard*Invboard(t)
  - InvCSawn*Invsawn(t)                - InvCEnergy*Invenergy(t)

);
```

! (Remark: The NC costs include new (endogenous) yearly fix costs and maintenance costs);

# ! Initial capacity conditions;

OCpulp(1) = OC1Pulp;

OCboard(1) = OC1Board;

OCsawn(1) = OC1Sawn;

OCenergy(1) = OC1Energy;

# ! Capacity loops of initially existing production capacities;

```
CapSurv = 1.00;

@FOR( Per(t)| t#GT#1: OCpulp(t) <= CapSurv*OCpulp(t-1) );

@FOR( Per(t)| t#GT#1: OCboard(t) <= CapSurv*OCboard(t-1) );

@FOR( Per(t)| t#GT#1: OCsawn(t) <= CapSurv*OCsawn(t-1) );

@FOR( Per(t)| t#GT#1: OCenergy(t) <= CapSurv*OCenergy(t-1) );
```

**! Capacity loops of new production capacities;**

NCpulp(1) = 0;

NCboard(1) = 0;

NCsawn(1) = 0;

NCenergy(1) = 0;

@FOR( Per(t)| t#GT#1: NCpulp(t) = NCpulp(t-1) + Invpulp(t-1));

@FOR( Per(t)| t#GT#1: NCboard(t) = NCboard(t-1) + Invboard(t-1));

@FOR( Per(t)| t#GT#1: NCsawn(t) = NCsawn(t-1) + Invsawn(t-1));

@FOR( Per(t)| t#GT#1: NCenergy(t) = NCenergy(t-1) + Invenergy(t-1));

# ! Constraints on investments in new production capacities over time;

```
@FOR( Per(t)| t#GT#0: Invpulp(t) <=
   HPCIPulp*(OCpulp(t)+NCpulp(t)) ;);

@FOR( Per(t)| t#GT#0: Invboard(t) <=
   HPCIBoard*(OCboard(t)+NCboard(t)));

@FOR( Per(t)| t#GT#0: Invsawn(t) <=
   HPCISawn*(OCsawn(t)+NCsawn(t)));

@FOR( Per(t)| t#GT#0: Invenergy(t) <=
   HPCIEnergy*(OCenergy(t)+NCenergy(t)));
```

# ! Constraints on forest management changes over time;

**@FOR( Per(t)| t#GT#1: Qharv(t) >= minleft*Qharv(t-1));**

# ! Constraints on industrial production changes over time;

**qpulp(1) >= minleft*OCpulp(1);**

**qboard(1) >= minleft*OCboard(1);**

**qsawn(1) >= minleft*OCsawn(1);**

**qenergy(1) >= minleft*OCenergy(1);**

**@FOR( Per(t)| t#GT#1: qpulp(t) >= minleft*qpulp(t-1));**

**@FOR( Per(t)| t#GT#1: qboard(t) >= minleft*qboard(t-1));**

**@FOR( Per(t)| t#GT#1: qsawn(t) >= minleft*qsawn(t-1));**

**@FOR( Per(t)| t#GT#1: qenergy(t) >= minleft*qenergy(t-1));**

**! Sustainable steady state forest resource management limit;**

**Qharv(10) <= Growth;**

# ! Initial conditions and selected parameters;

! Initial conditions in the forest;

Stock(1) = Stock1;

# ! Negative parameter signs are feasible in some cases;

- @free(dPdqHarv);
- @free(dPdqGROT);
- @free(dPdqPulp);
- @free(dPdqBoard);
- @free(dPdqSawn);
- @free(dPdqEnergy);

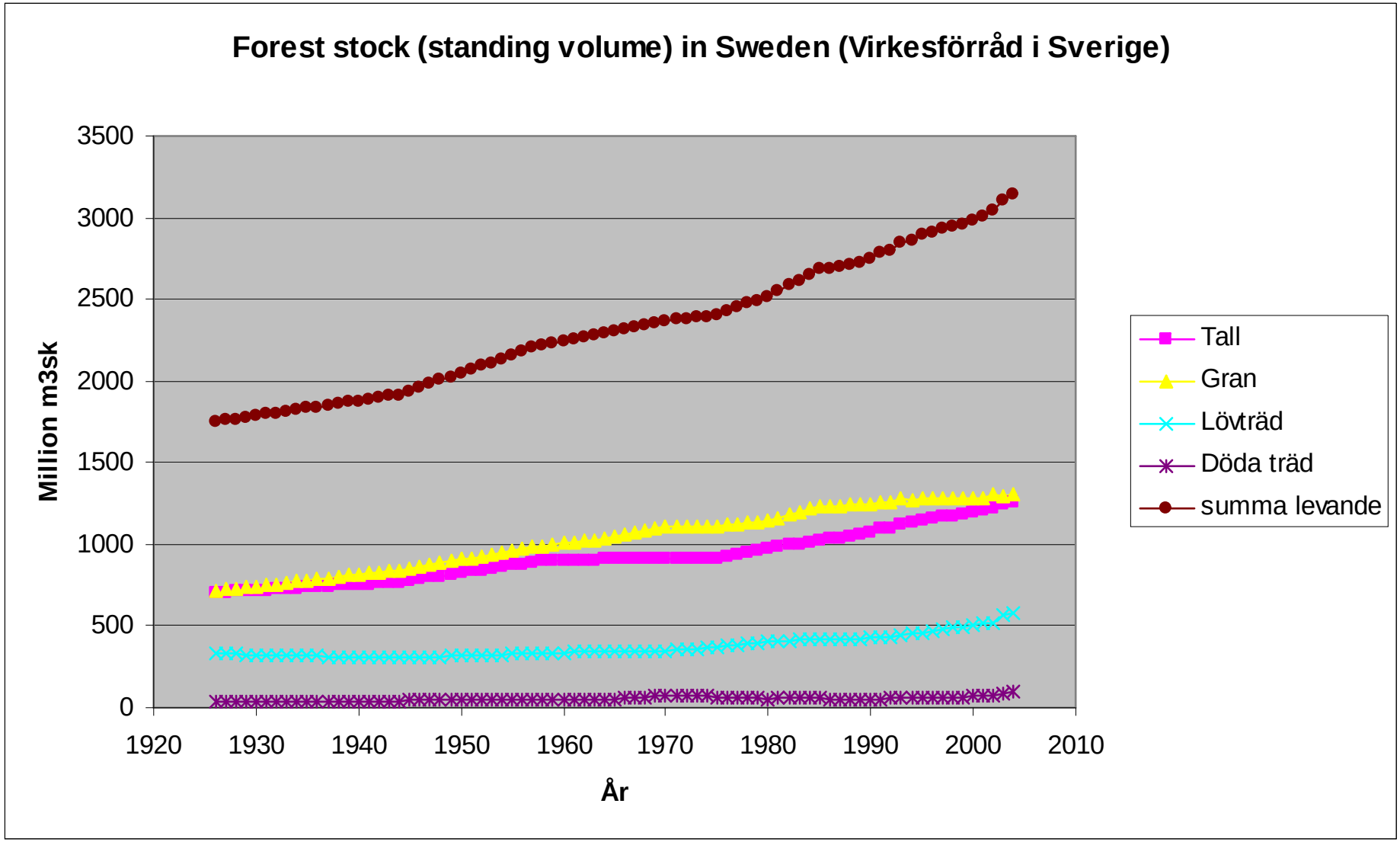
- @free(dPdtHarv);
- @free(dPdtGROT);
- @free(dPdtPulp);
- @free(dPdtBoard);
- @free(dPdtSawn);
- @free(dPdtEnergy);

# ! Communication with an Excel file for selected parameters and results;

```
DATA:
•       interest, LAStock, Growth, minleft, PINDEEFF, Stock1,
•       P0Harv, dPdqHarv, dPdtHarv,
•       P0GROT, dPdqGROT, dPdtGROT,
•       P0Pulp, dPdqPulp, dPdtPulp,
•       P0Board, dPdqBoard, dPdtBoard,
•       P0Sawn, dPdqSawn, dPdtSawn,
•       P0Energy, dPdqEnergy, dPdtEnergy,
•       OC1Pulp, OC1Board, OC1Sawn, OC1Energy
•       InvCPulp, InvCBoard, InvCSawn, InvCEnergy,
•       MainOCPulp, MainOCBoard, MainOCSawn, MainOCEnergy,
•       MainNCPulp, MainNCBoard, MainNCSawn, MainNCEnergy,
•       OVCPulp, OVCBoard, OVCSawn, OVCEnergy,
•       HPCIPulp, HPCIBoard, HPCISawn, HPCIEnergy,
•       TSS, GPC
•       = @OLE( 'RegRes.XLS');

•       @OLE( 'RegRes.XLS') = Stock, Qharv, qpulp, qboard, qsawn, qenergy,
•                       EPV, GRHarv,
•                       PHarv, PGROT, PPulp, PBoard, PSawn, PEnergy;
ENDDATA

end
```




**(Exkluding high mountains, nature reserves, restricted military areas and water surfaces.)**

Source: Swedish National Forest Inventory

**Tabell 3.13** **Tillväxt i virkesförrådet, i genomsnitt för perioden 2002-2006. Inklusive tillväxt för avverkade träd**

Mean annual volume increment 2002-2006. Including growth on felled trees

| Län och landsdel[1] Counties and regions[1] | Skogsmark Forest land | | | | | | Alla ägoslag[2] All land use classes[2] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tall Scots pine | Gran Norway spruce | Björk Birch | Övr löv Other broad-leaves | Summa Total | volym/ha volume per ha | Tall Scots pine | Gran Norway spruce | Björk Birch | Övr löv Other broad-leaves | Summa Total |
| | milj. m³sk per år | | | | | m³sk/ha | milj. m³sk per år | | | | |
| Norrbottens | 5,34 | 1,98 | 1,80 | 0,17 | 9,30 | 2,59 | 5,71 | 2,27 | 2,10 | 0,21 | 10,29 |
| Västerbotter | 4,60 | 3,28 | 1,95 | 0,18 | 10,01 | 3,13 | 4,98 | 3,43 | 2,15 | 0,20 | 10,76 |
| Jämtlands | 3,43 | 3,94 | 1,47 | 0,24 | 9,09 | 3,41 | 3,63 | 4,19 | 1,70 | 0,27 | 9,79 |
| Västernorrla | 2,67 | 3,94 | 1,38 | 0,51 | 8,50 | 5,00 | 2,84 | 4,01 | 1,43 | 0,55 | 8,83 |
| Gävleborgs | 3,78 | 3,02 | 1,08 | 0,26 | 8,15 | 5,25 | 3,89 | 3,05 | 1,14 | 0,33 | 8,41 |
| Dalarnas | 3,71 | 2,66 | 0,88 | 0,15 | 7,40 | 3,92 | 3,84 | 2,69 | 0,96 | 0,17 | 7,66 |
| Värmlands | 2,40 | 4,21 | 1,04 | 0,27 | 7,92 | 5,93 | 2,62 | 4,24 | 1,10 | 0,32 | 8,28 |
| Örebro | 1,07 | 1,87 | 0,54 | 0,25 | 3,72 | 6,51 | 1,15 | 1,88 | 0,58 | 0,33 | 3,94 |
| Västmanlanc | 0,75 | 1,11 | 0,31 | 0,15 | 2,31 | 6,31 | 0,79 | 1,11 | 0,33 | 0,22 | 2,45 |
| Uppsala | 0,82 | 1,15 | 0,33 | 0,22 | 2,52 | 6,01 | 0,87 | 1,17 | 0,34 | 0,30 | 2,68 |
| Stockholms | 0,43 | 0,68 | 0,25 | 0,24 | 1,60 | 5,84 | 0,55 | 0,70 | 0,30 | 0,37 | 1,92 |
| Södermanlar | 0,83 | 1,14 | 0,22 | 0,18 | 2,37 | 6,95 | 0,90 | 1,15 | 0,26 | 0,24 | 2,55 |
| Östergötland | 1,44 | 2,36 | 0,48 | 0,43 | 4,71 | 7,42 | 1,60 | 2,37 | 0,52 | 0,53 | 5,02 |
| Västra Götal | 1,73 | 5,96 | 1,17 | 0,69 | 9,56 | 7,60 | 1,98 | 6,04 | 1,31 | 0,89 | 10,22 |
| Jönköpings | 1,10 | 3,25 | 0,60 | 0,28 | 5,23 | 7,19 | 1,17 | 3,27 | 0,66 | 0,38 | 5,48 |
| Kronobergs | 0,89 | 3,03 | 0,56 | 0,24 | 4,72 | 7,30 | 0,94 | 3,05 | 0,60 | 0,29 | 4,88 |
| Kalmar | 1,56 | 2,27 | 0,51 | 0,51 | 4,84 | 6,68 | 1,65 | 2,28 | 0,56 | 0,62 | 5,11 |
| Gotlands | 0,22 | 0,05 | 0,03 | 0,03 | 0,34 | 2,93 | 0,24 | 0,05 | 0,04 | 0,05 | 0,38 |
| Hallands | 0,29 | 1,88 | 0,25 | 0,23 | 2,66 | 8,66 | 0,34 | 1,89 | 0,28 | 0,27 | 2,78 |
| Blekinge | 0,12 | 1,12 | 0,19 | 0,27 | 1,70 | 8,90 | 0,13 | 1,12 | 0,20 | 0,32 | 1,77 |
| Skåne | 0,26 | 2,30 | 0,31 | 0,73 | 3,59 | 9,25 | 0,29 | 2,31 | 0,35 | 0,81 | 3,76 |
| N Norrland | 9,94 | 5,26 | 3,76 | 0,35 | 19,31 | 2,84 | 10,69 | 5,70 | 4,26 | 0,40 | 21,05 |
| S Norrland | 9,88 | 10,91 | 3,94 | 1,02 | 25,75 | 4,35 | 10,36 | 11,25 | 4,27 | 1,15 | 27,03 |
| Svealand | 10,00 | 12,82 | 3,57 | 1,46 | 27,84 | 5,36 | 10,71 | 12,95 | 3,88 | 1,95 | 29,49 |
| Götaland | 7,60 | 22,22 | 4,10 | 3,42 | 37,34 | 7,48 | 8,34 | 22,39 | 4,53 | 4,16 | 39,42 |
| Hela landet Entire country | 37,42 | 51,21 | 15,37 | 6,24 | 110,24 | 4,81 | 40,10 | 52,30 | 16,93 | 7,66 | 116,99 |

1. Exklusive fjäll, fridlyst mark, militära impediment, bebyggd mark och söt och saltvatten.

1. Excluding high mountains, nature reserves, military wasteland, urban land and water

2. Beträffande områdesindelningen, se bilaga 7 fig 2. Boundaries of counties and regions are shown in Appendix 7, Figure 2

m³sk per år = cubic metre standing volume per year, from stump to tip including bark

m³sk per ha = cubic metre standing volume per hectare, from stump to tip including bark

Källa: Riksskogstaxeringen Source: Swedish National Forest Inventory

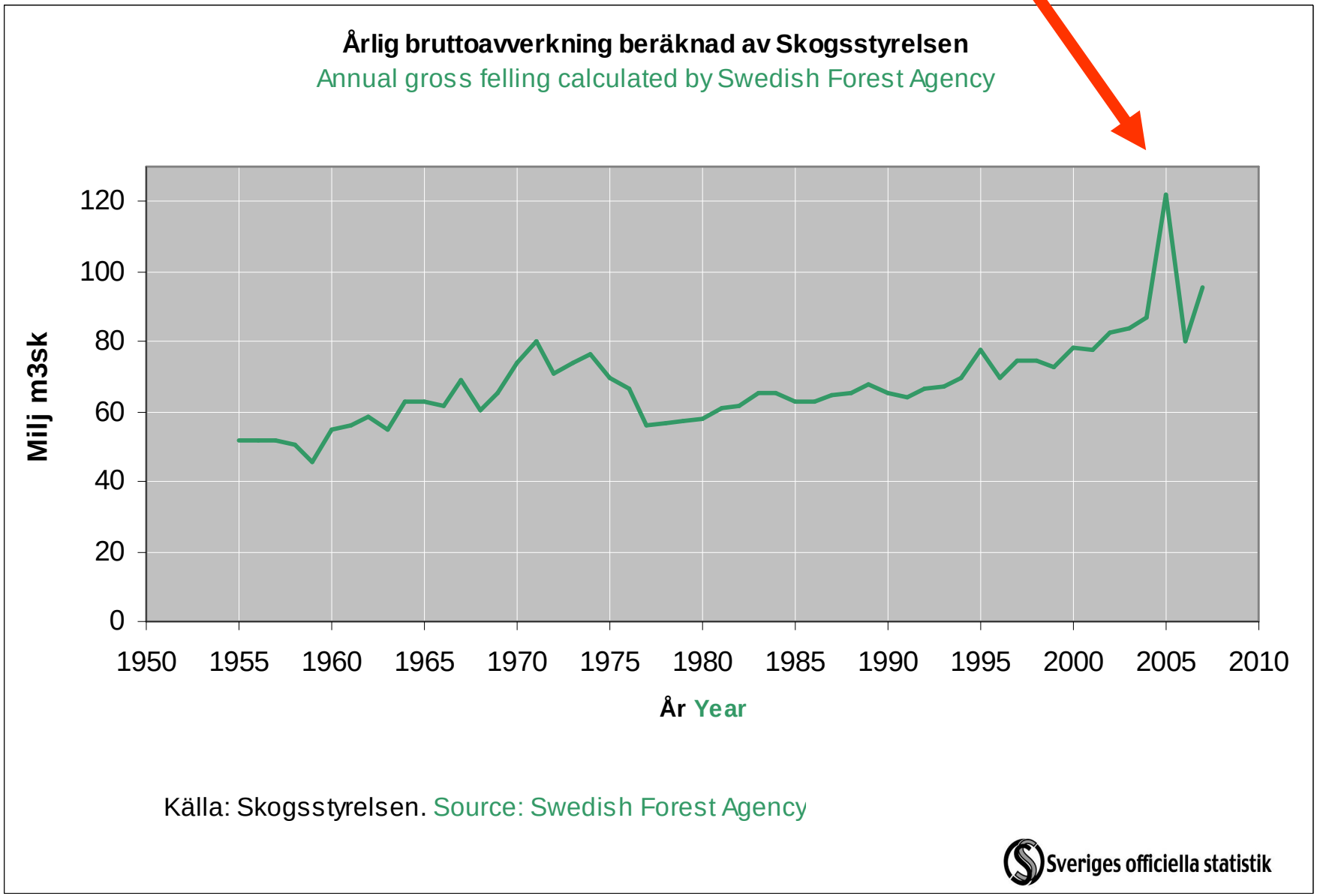
Sveriges officiella statistik

# Annual volume growth

***(increment)***

**116.99**

## *2005 = The year of the extreme windthrows caused by the storm ”Gudrun”*



# Examples:

***All decisions have been optimized in 3 alternative cases.***

***(Preliminary figures from Sweden)***

# *Case 0*

**Stock >= 2500**

Case 0___Stock >= 2500

# Regional Forest and Energy Sector Optimization Model

**Peter Lohmander** *Version 2008-11-26*

## ***Introduction***

*This Excel document contains parameters and some results from the optimization model RegMod created by Peter Lohmander.*

***Please input the parameter values below the green headlines. Then, save the document.***

***Price and cost function parameters:***

| (Relevant currency/unit) | | P0 | dPdq | dPdt |
|---|---|---|---|---|
| Mm3sk/Year | Harv | 163 | 0,1 | 0 |
| TWh/Year | GROT | 150 | 0,2 | 0 |
| Mton/Year | Pulp | 4500 | -20 | 0 |
| Mm3/Year | Board | 1300 | -5 | 0 |
| Mm3/Year | Sawn | 2200 | -5 | 0 |
| TWh/Year | Energy | 950 | -2 | 0 |

***Initial capacity states:***

| | | OC1 |
|---|---|---|
| *Mton/Year* | **Pulp** | **12,4** |
| *Mm3/Year* | **Board** | **0,852** |
| *Mm3/Year* | **Sawn** | **18,6** |
| *TWh/Year* | **Energy** | **60** |

***Capacity costs:***

*(Relevant currency/unit)*

| | InvC | MainOC | MainNC |
|---|---|---|---|
| *Mton/Year* **Pulp** | 20 | 600 | 700 |
| *Mm3/Year* **Board** | 10 | 150 | 300 |
| *Mm3/Year* **Sawn** | 10 | 150 | 200 |
| *TWh/Year* **Energy** | 10 | 80 | 100 |

***Other Variable Costs in the industrial processes (except for the forest raw material costs):***

*(Relevant currency/unit)*

| | OVC |
|---|---|
| *Mton/Year* Pulp | 1000 |
| *Mm3/Year* Board | 600 |
| *Mm3/Year* Sawn | 400 |
| *TWh/Year* Energy | 200 |

***The highest possible level of capacity investment from one period to the next:***

*(Shares of the capacities that already exist in the same period via earlier investments.)*

| | HPCI |
|---|---|
| Pulp | 0,25 |
| Board | 0,25 |
| Sawn | 0,25 |
| Energy | 0,25 |

***Other Parameters:***

*Interest = Rate of interest in the capital market*
*LAStock = Lowest allowable stock of the forest resource during the planning period*
*Stock1 = Initial stock level of the forest resource in the beginning of period 1*
*Growth = Yearly growth of the forest resource during the planning period*
*minleft = Lowest allowable ratios (production in period t+1)/(production in period t) in the industrial processes and in harvesting (except for GROT harvesting).*
*PINDEEFF = Share of black liquor production not internally used in pulp industry.*

| | *Mm3sk (Standing volume with bark and top)* | | | | | *Mm3fub (Solid volume under bark)* | |
|---|---|---|---|---|---|---|---|
| Interest | LAStock | Stock1 | Growth | minleft | PINDEEFF | sStock1 | sGrowth |
| 0,05 | 2500 | 3234 | 110 | 0,9 | 0,05 | 2716,56 | 92,4 |

**Observation!**

*Share of harvested wood (solid under bark) that can be used to produce sawn wood*

| | |
|---|---|
| TSS | 0,5 |

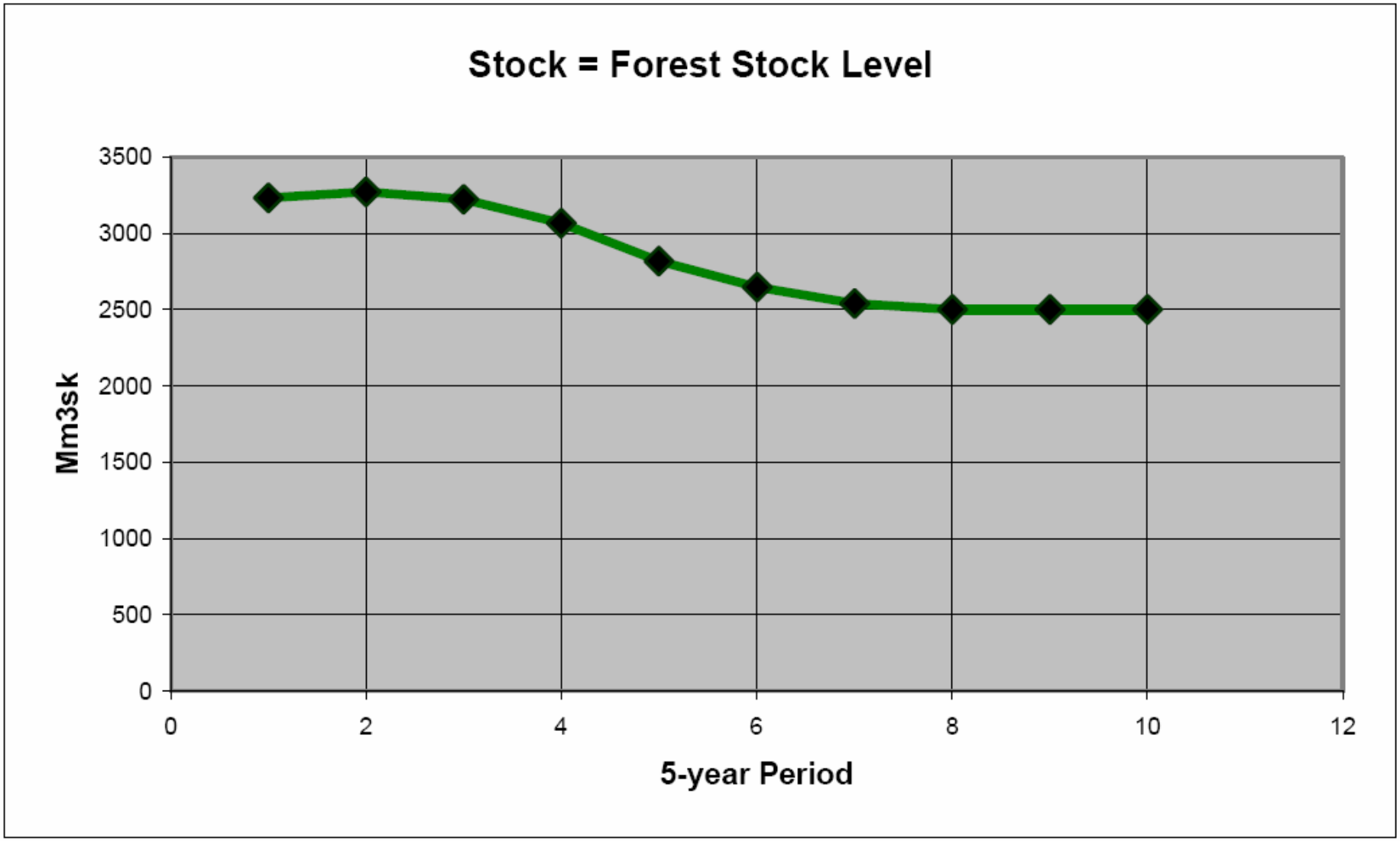
*MWh of GROT available per cubic meter solid under bark in harvest operations*

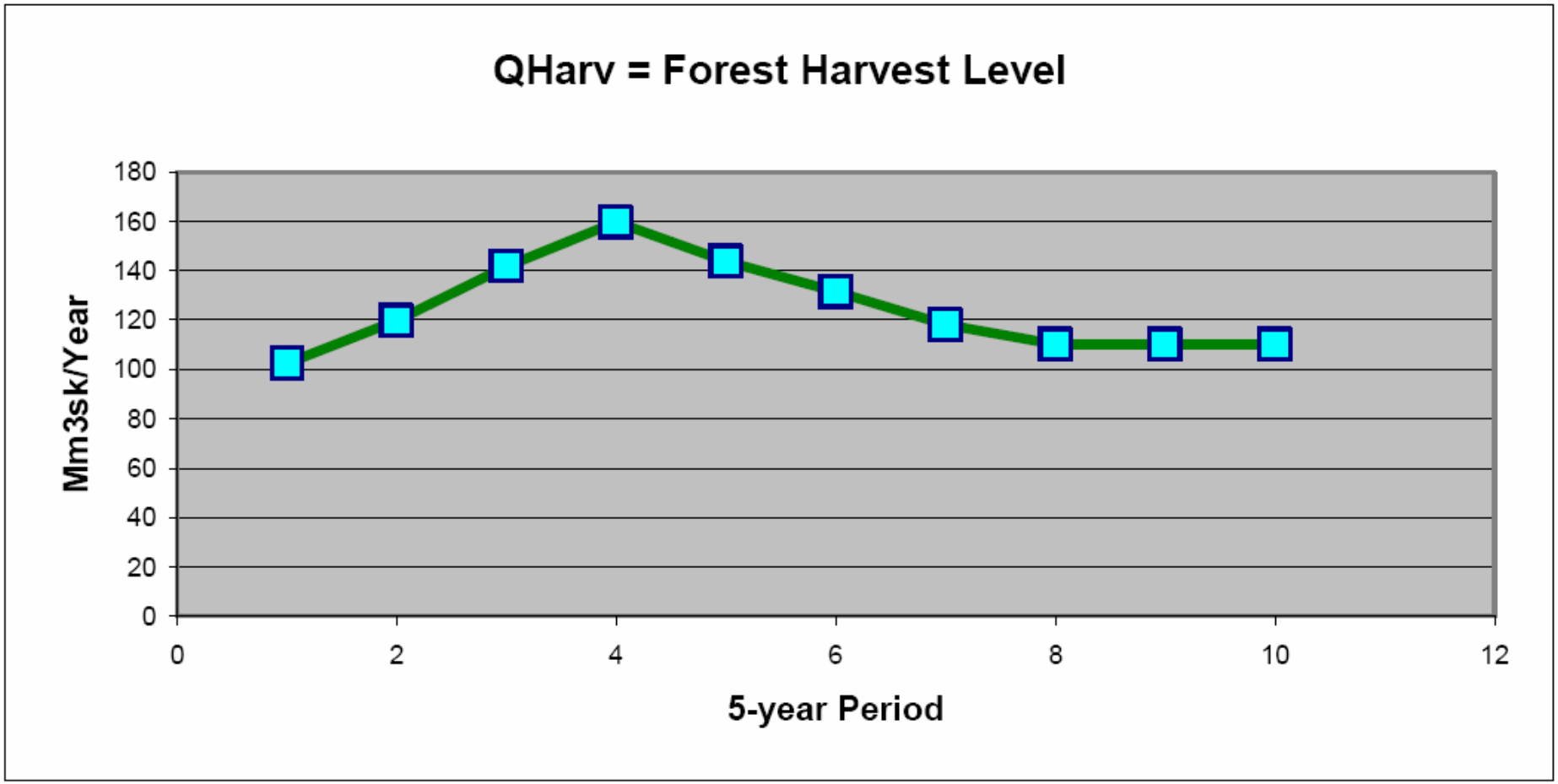
| | |
|---|---|
| GPC | 0,28 |

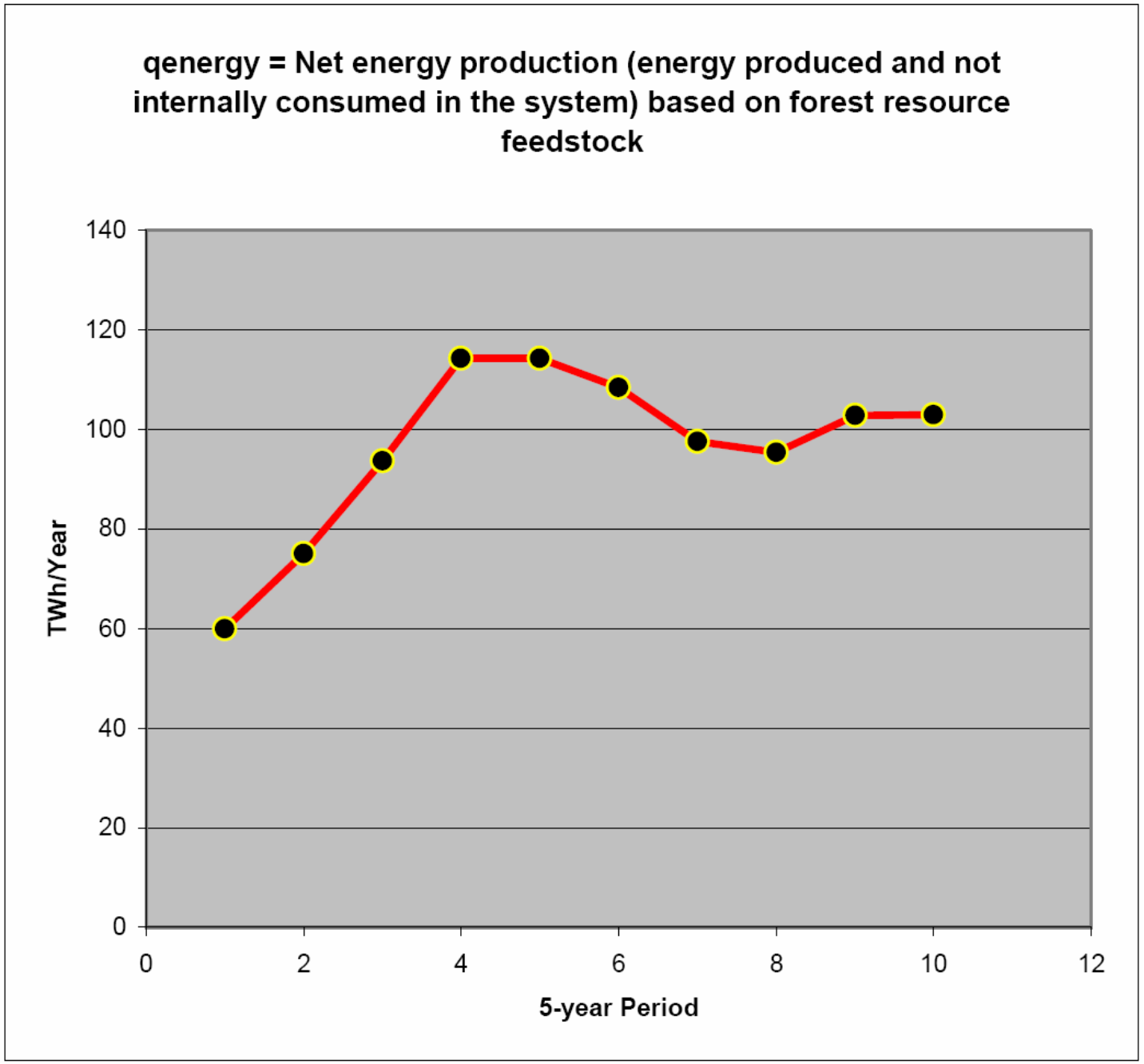
***Results: EPV = Optimal total present value.***

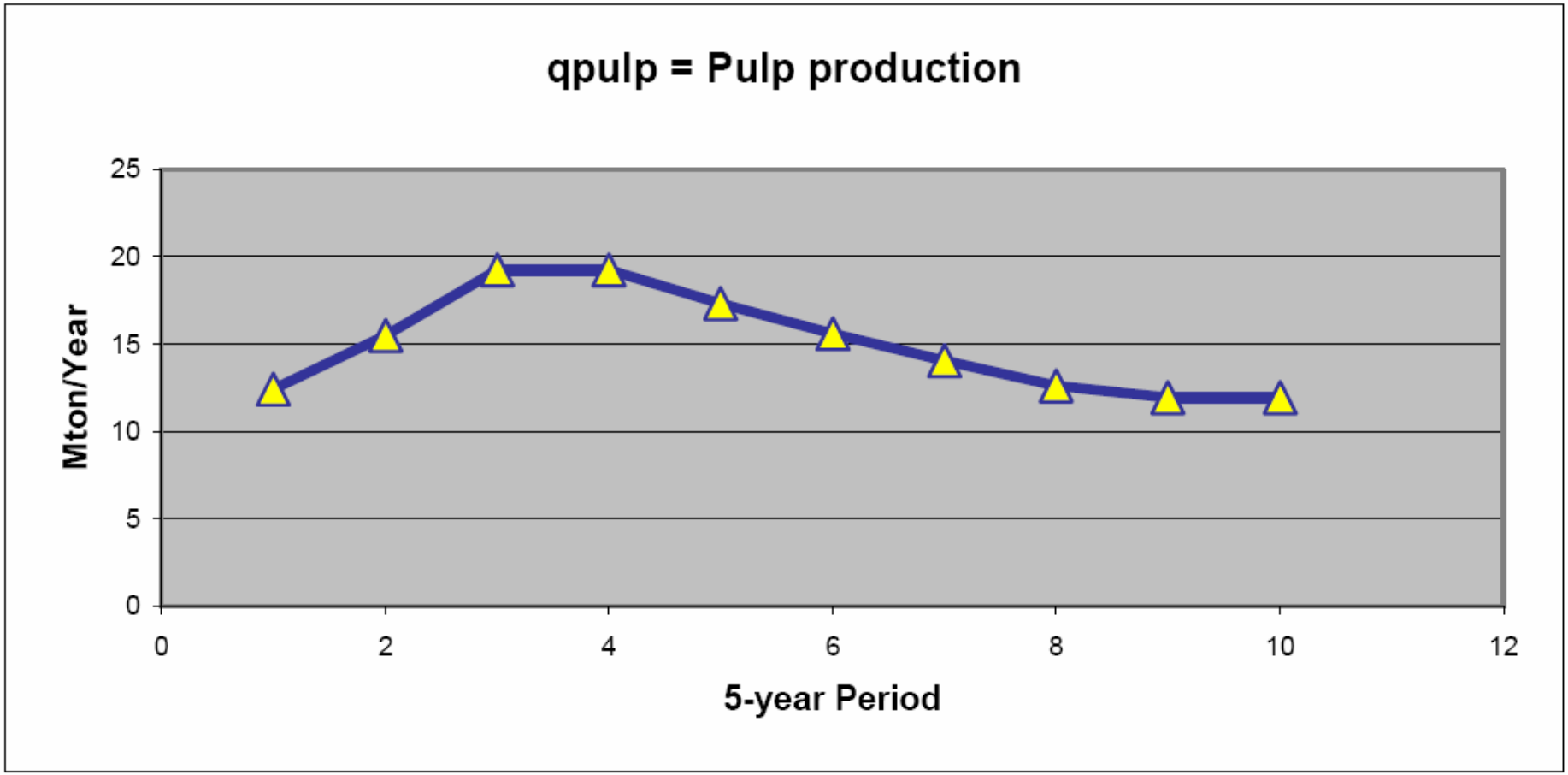
*(Relevant currency)*

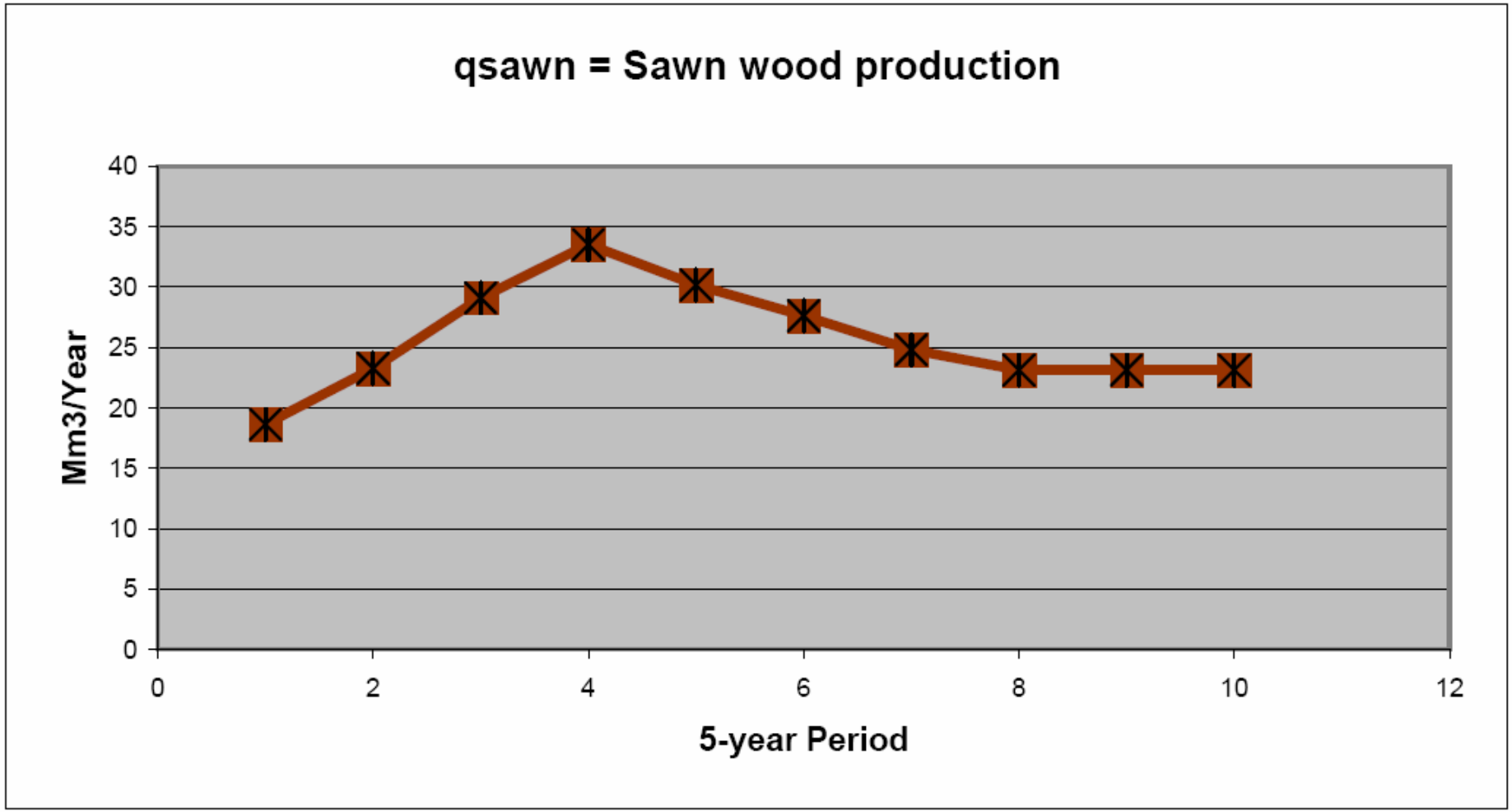
| EPV |
| --- |
| 1716664,9 |

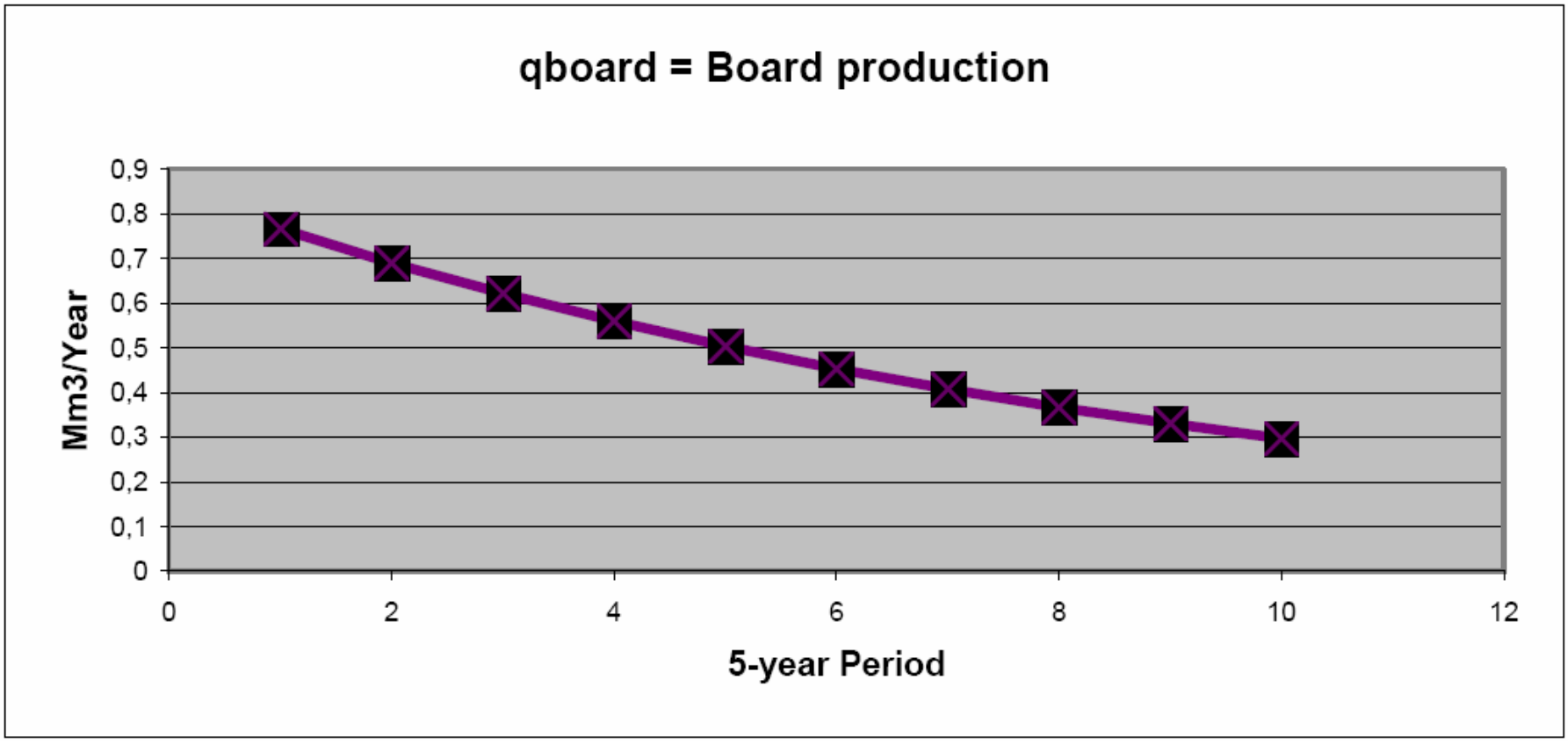

Stock = Forest Stock Level
Mm3sk
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
5-year Period

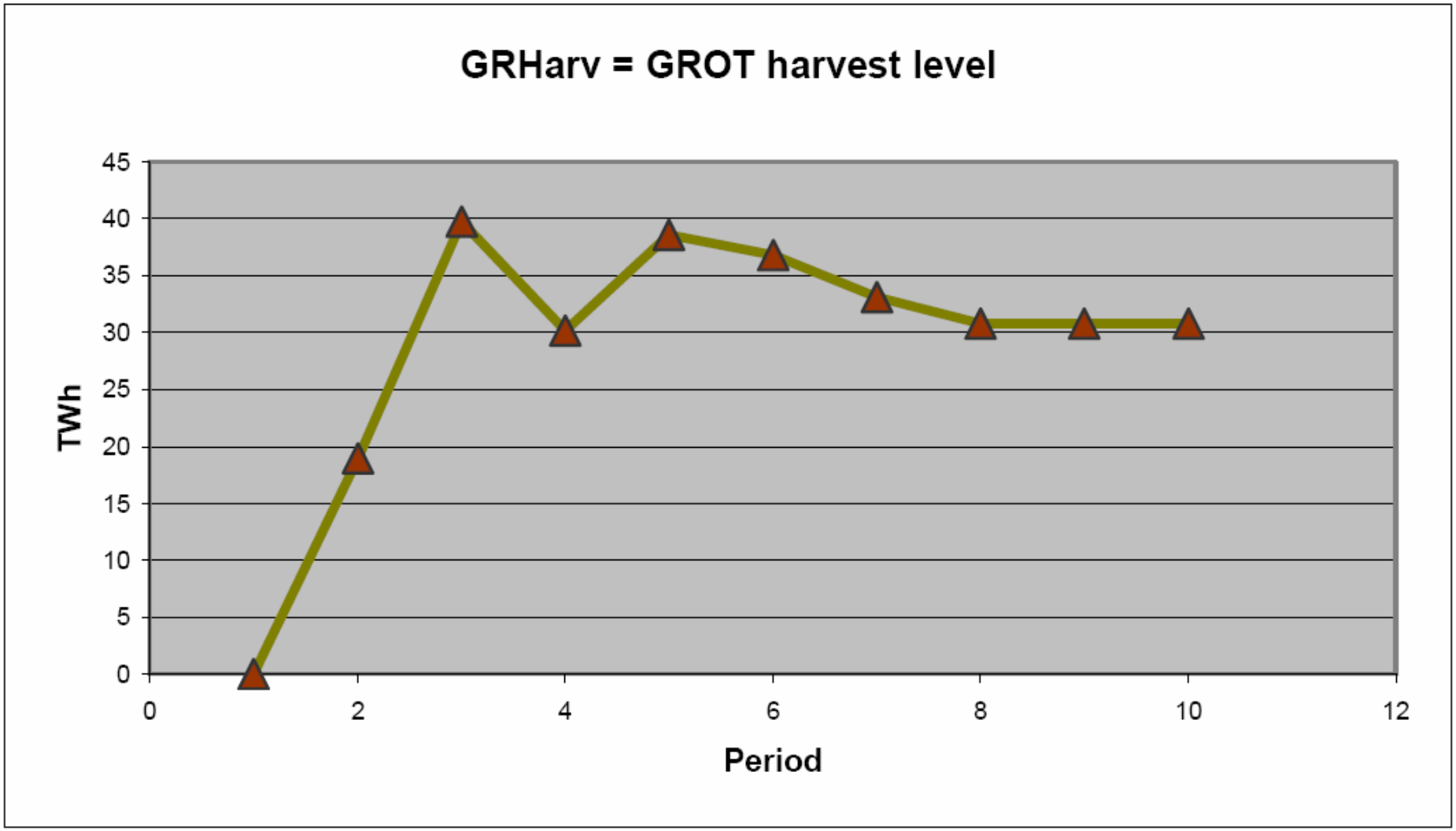

QHarv = Forest Harvest Level
Mm3sk/Year
180
160
140
120
100
80
60
40
20
0
0
2
4
6
8
10
12
5-year Period

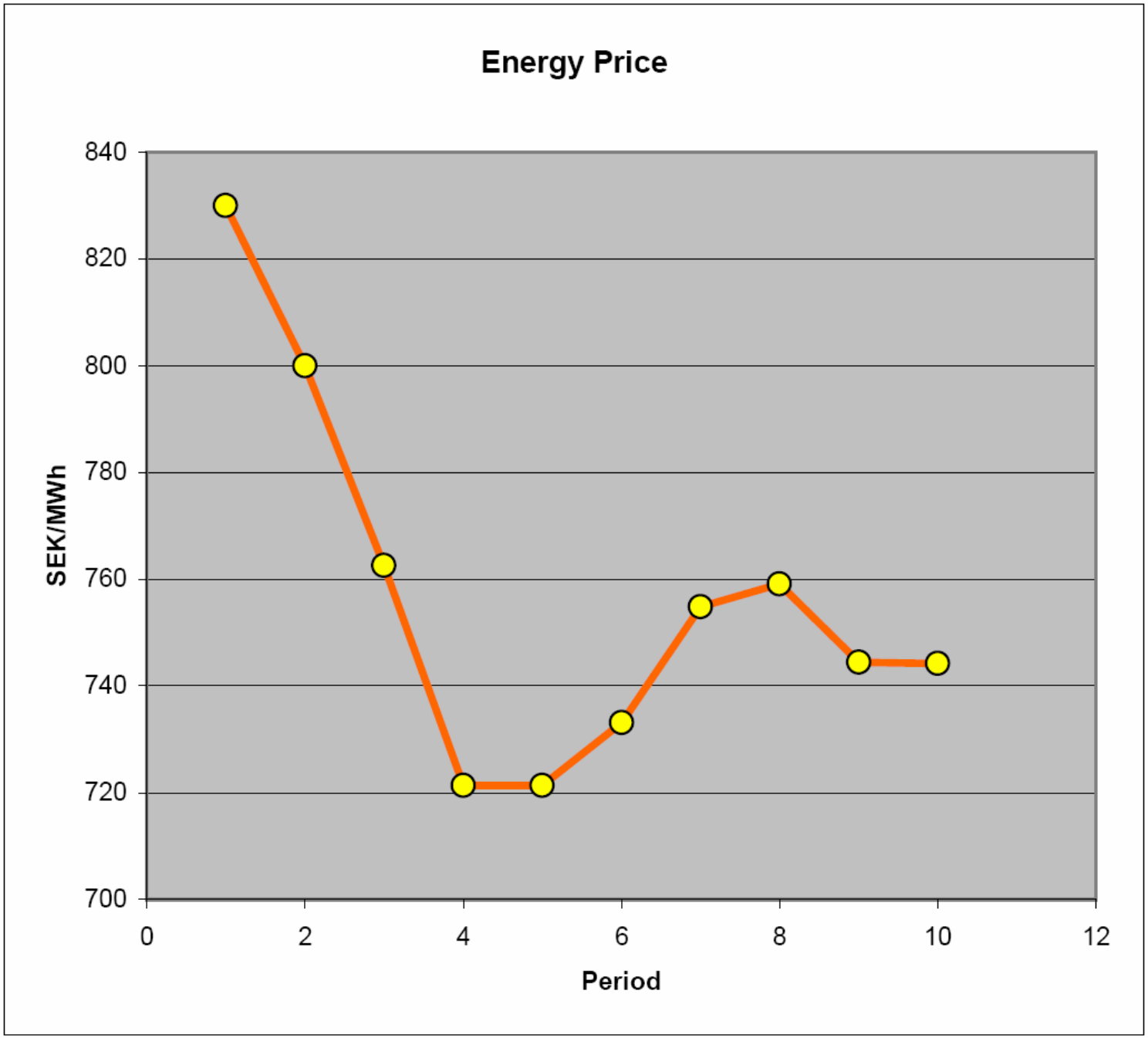

qenergy = Net energy production (energy produced and not internally consumed in the system) based on forest resource feedstock
TWh/Year
140
120
100
80
60
40
20
0
0
2
4
6
8
10
12
5-year Period

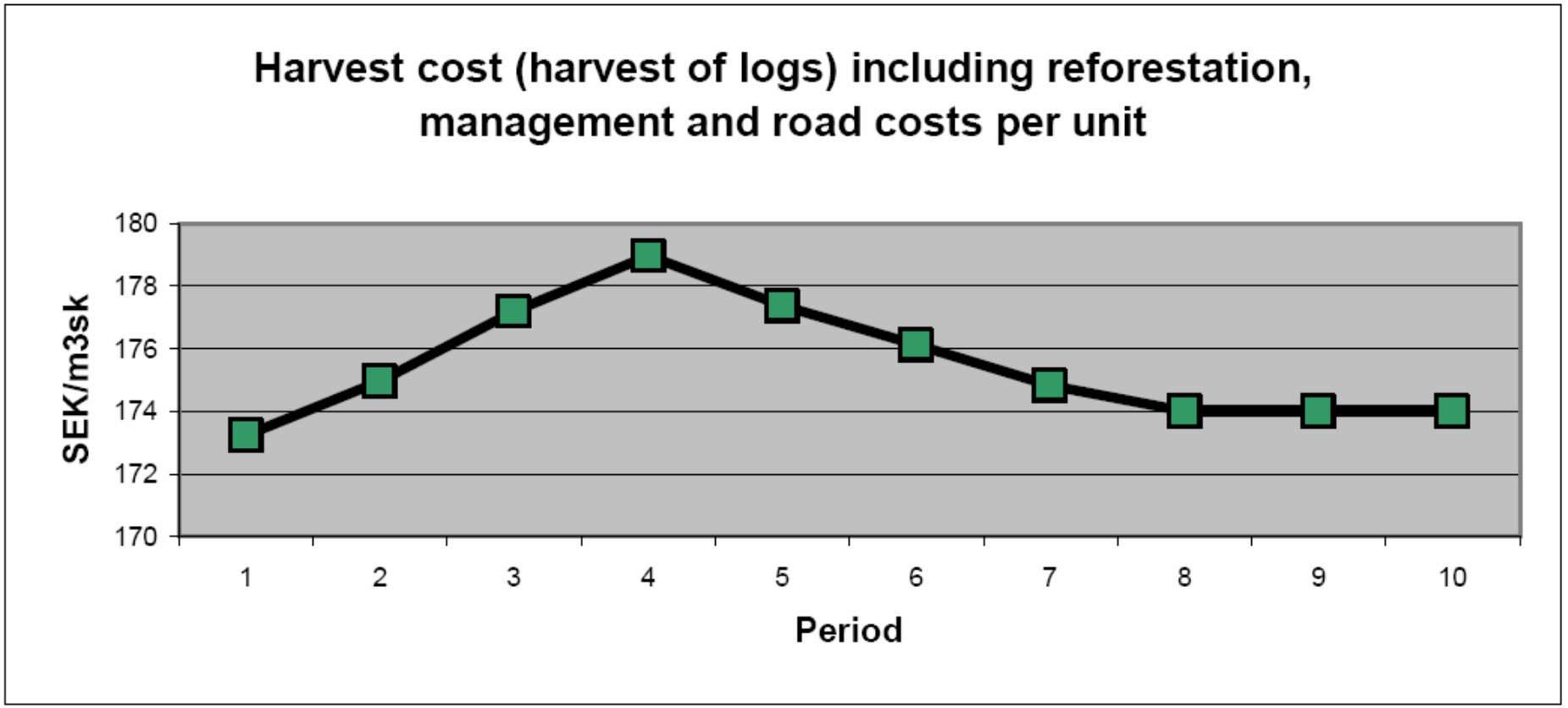

qpulp = Pulp production
Mton/Year
25
20
15
10
5
0
0
2
4
6
8
10
12
5-year Period

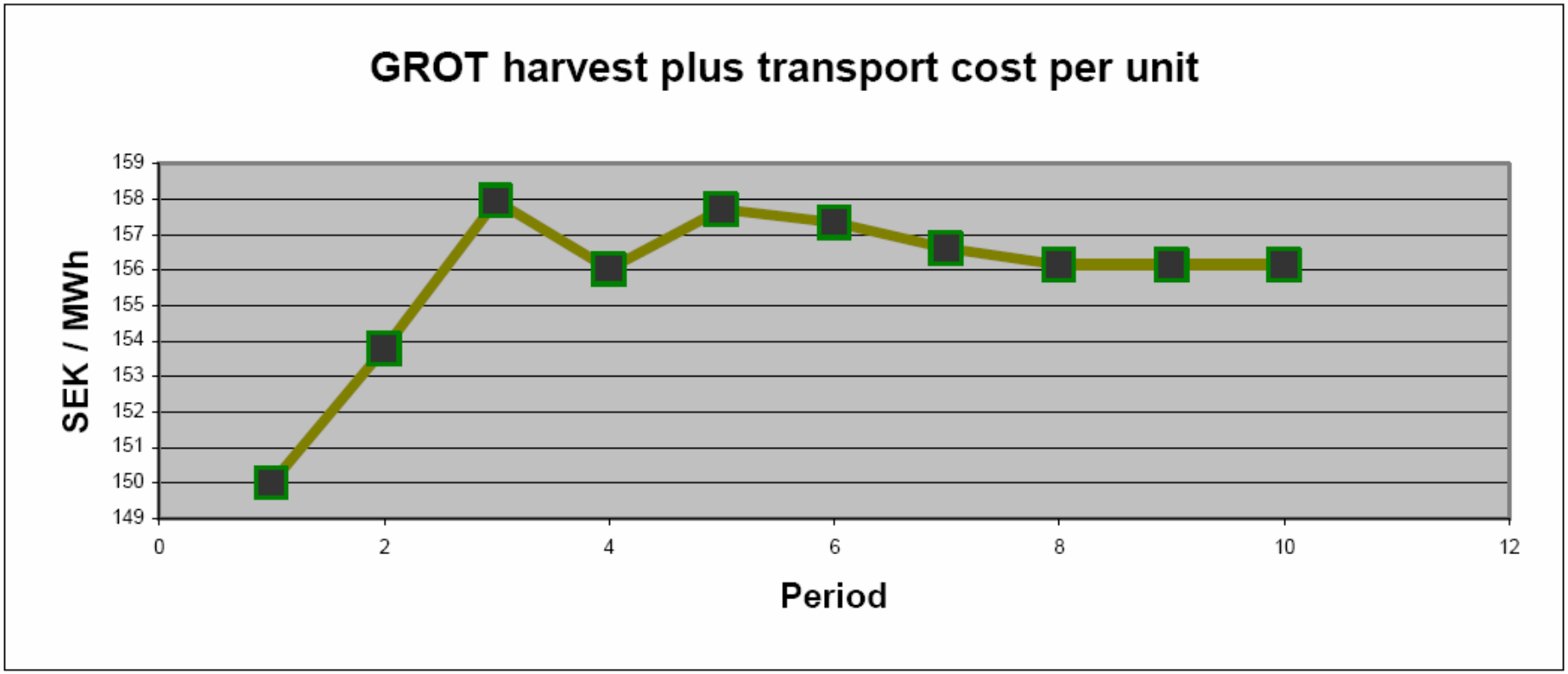

qsawn = Sawn wood production
Mm3/Year
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
5-year Period

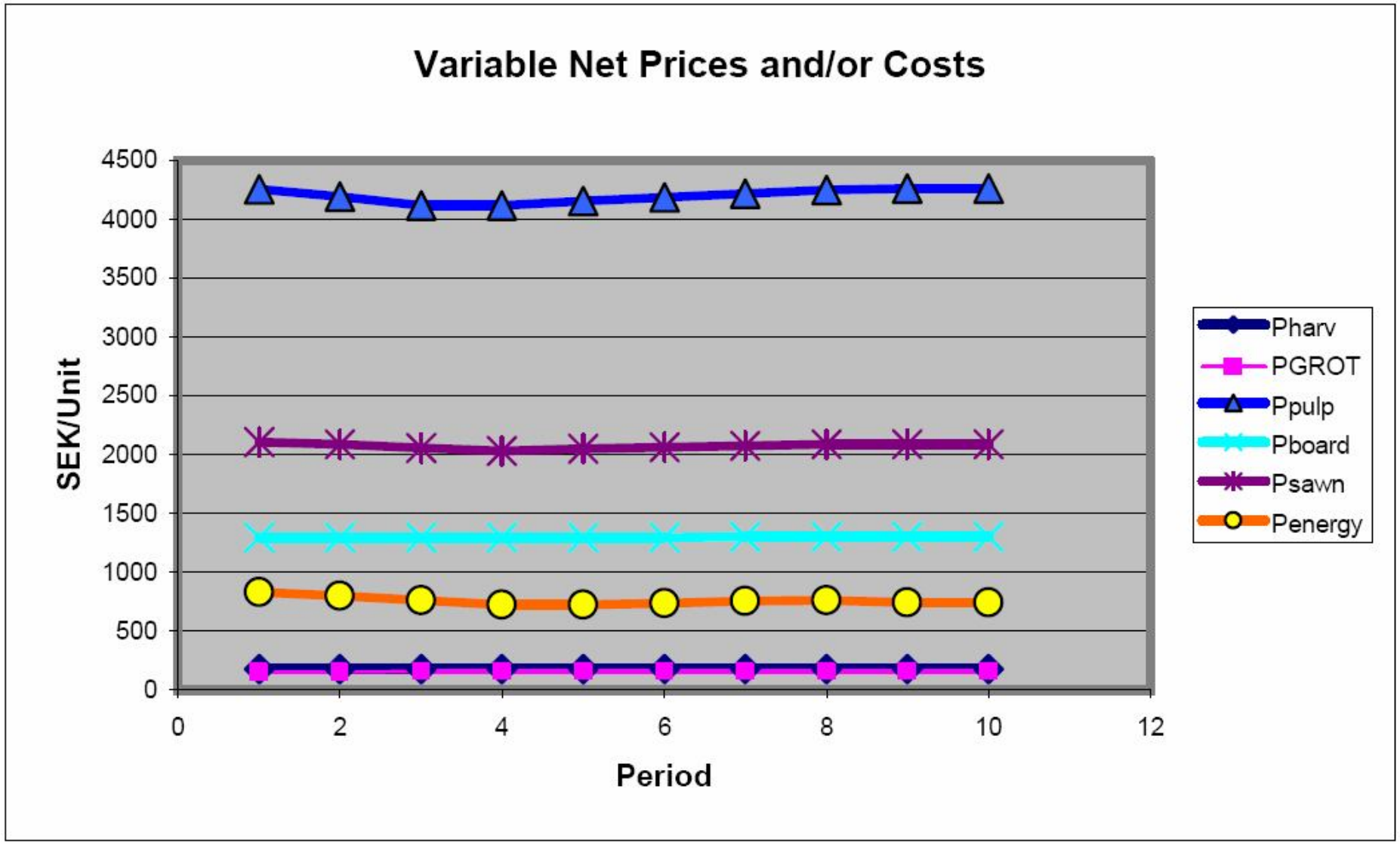

qboard = Board production
Mm3/Year
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
2
4
6
8
10
12
5-year Period


GRHarv = GROT harvest level
TWh
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
Period


Energy Price
840
820
800
780
760
740
720
700
SEK/MWh
0
2
4
6
8
10
12
Period


Harvest cost (harvest of logs) including reforestation, management and road costs per unit
SEK/m3sk
180
178
176
174
172
170
1
2
3
4
5
6
7
8
9
10
Period


GROT harvest plus transport cost per unit
SEK / MWh
159
158
157
156
155
154
153
152
151
150
149
0
2
4
6
8
10
12
Period


Variable Net Prices and/or Costs
SEK/Unit
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
Period
Pharv
PGROT
Ppulp
Pboard
Psawn
Penergy

| Per | Stock | Qharv | GRHarv | qpulp | qboard | qsawn | qenergy |
|---|---|---|---|---|---|---|---|
| 1 | 3234 | 102,3941 | 0 | 12,4 | 0,7668 | 18,6 | 60 |
| 2 | 3272,0296 | 119,6879 | 18,9208 | 15,5 | 0,69012 | 23,25 | 75 |
| 3 | 3223,5899 | 141,9034 | 39,73296 | 19,23107 | 0,621108 | 29,0625 | 93,75 |
| 4 | 3064,0727 | 159,6614 | 30,17158 | 19,23107 | 0,558997 | 33,5289 | 114,3106 |
| 5 | 2815,7656 | 143,6953 | 38,58548 | 17,30796 | 0,503097 | 30,17601 | 114,3106 |
| 6 | 2647,2891 | 131,2936 | 36,76221 | 15,57716 | 0,452788 | 27,57165 | 108,4613 |
| 7 | 2540,8212 | 118,1642 | 33,08598 | 14,01945 | 0,407509 | 24,81449 | 97,61513 |
| 8 | 2500 | 110 | 30,8 | 12,6175 | 0,366758 | 23,1 | 95,45829 |
| 9 | 2500 | 110 | 30,8 | 11,93266 | 0,330082 | 23,1 | 102,7777 |
| 10 | 2500 | 110 | 30,8 | 11,93266 | 0,297074 | 23,1 | 102,913 |

| Per | Pharv | PGROT | Ppulp | Pboard | Psawn | Penergy |
|---|---|---|---|---|---|---|
| 1 | 173,23941 | 150 | 4252 | 1296,166 | 2107 | 830 |
| 2 | 174,96879 | 153,7842 | 4190 | 1296,549 | 2083,75 | 800 |
| 3 | 177,19034 | 157,9466 | 4115,379 | 1296,894 | 2054,687 | 762,5 |
| 4 | 178,96614 | 156,0343 | 4115,379 | 1297,205 | 2032,355 | 721,3788 |
| 5 | 177,36953 | 157,7171 | 4153,841 | 1297,485 | 2049,12 | 721,3788 |
| 6 | 176,12936 | 157,3524 | 4188,457 | 1297,736 | 2062,142 | 733,0775 |
| 7 | 174,81642 | 156,6172 | 4219,611 | 1297,962 | 2075,928 | 754,7697 |
| 8 | 174 | 156,16 | 4247,65 | 1298,166 | 2084,5 | 759,0834 |
| 9 | 174 | 156,16 | 4261,347 | 1298,35 | 2084,5 | 744,4445 |
| 10 | 174 | 156,16 | 4261,347 | 1298,515 | 2084,5 | 744,1739 |

# Comparisions:

**Case 0**
**Stock >= 2500**

*DELTA1 = **42686.9***
*DELTA2 = 42686.9/300 = **142.3***

***Results: EPV = Optimal total present value.***
*(Relevant currency)*

| EPV |
| --- |
| 1716664,9 |

**Case 1**
**Stock >= 2800**

*DELTA1 = **79426***
*DELTA2 = 79426/434 = **183.0***

***Results: EPV = Optimal total present value.***
*(Relevant currency)*

| EPV |
| --- |
| 1673978 |

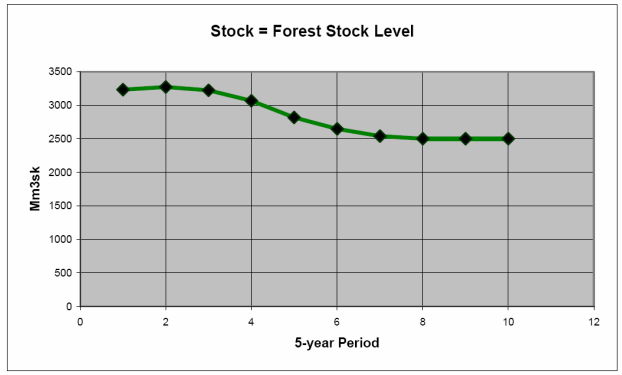
**Case 2**
**Stock >= 3234**

***Results: EPV = Optimal total present value.***
*(Relevant currency)*

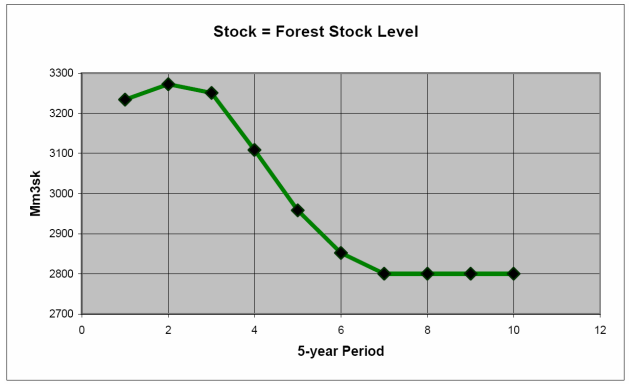
| EPV |
| --- |
| 1594552 |

# Comparisions:

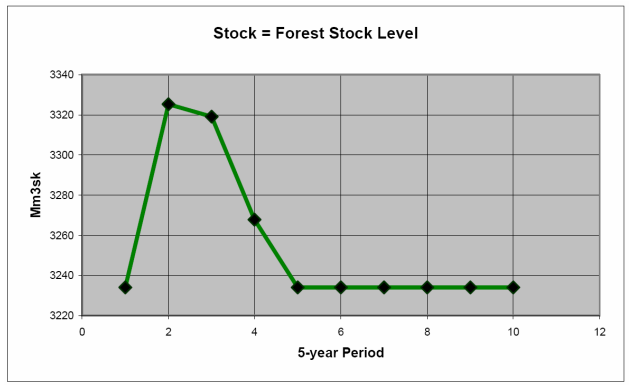
**Case 0**
**Stock >= 2500**




**Case 1**
**Stock >= 2800**

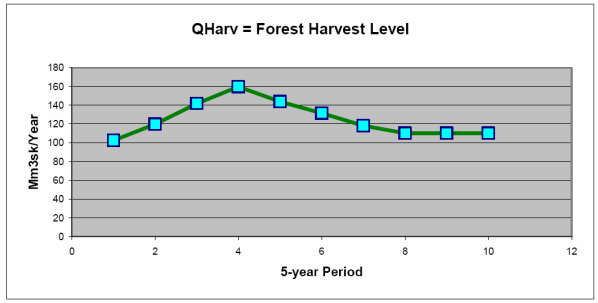



**Case 2**
**Stock >= 3234**

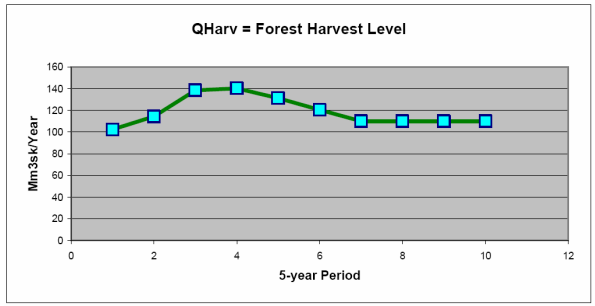


# Comparisions:

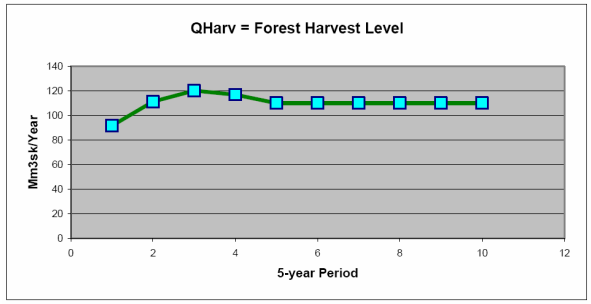
**Case 0**
**Stock >= 2500**




**Case 1**
**Stock >= 2800**

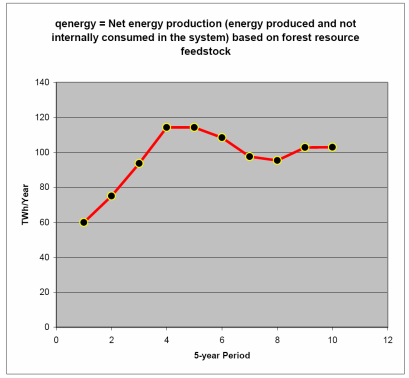



**Case 2**
**Stock >= 3234**

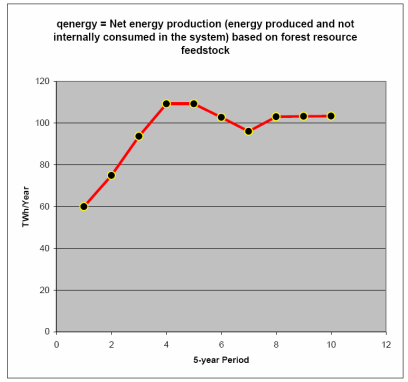


# Comparisions:

**Case 0**
**Stock >= 2500**




**Case 1**
**Stock >= 2800**

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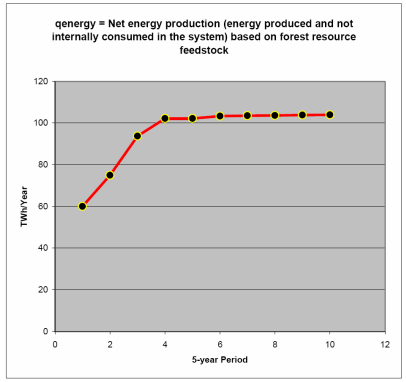

# Comparisions:

**Case 0**
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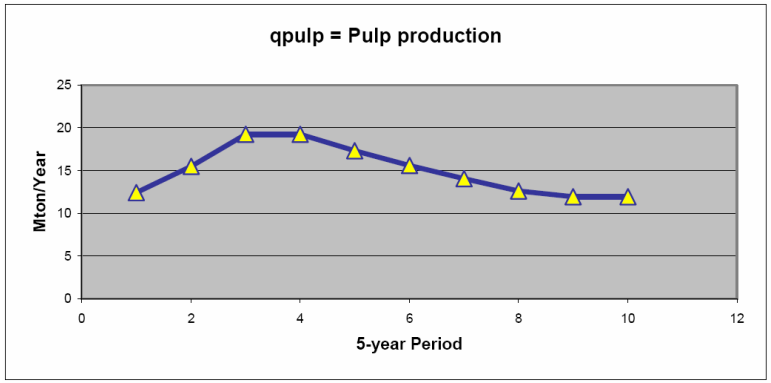


**Case 1**
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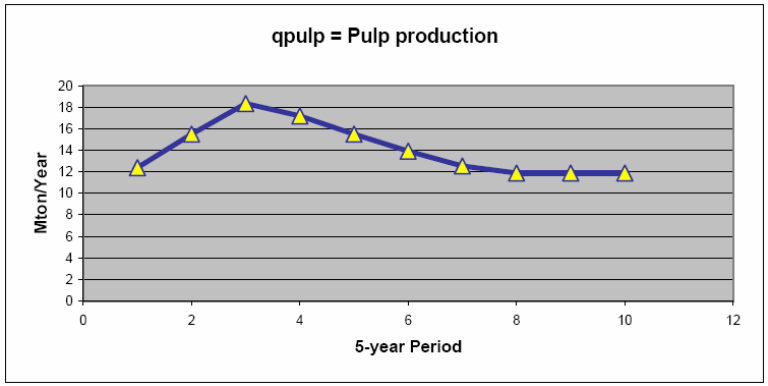


**Case 2**
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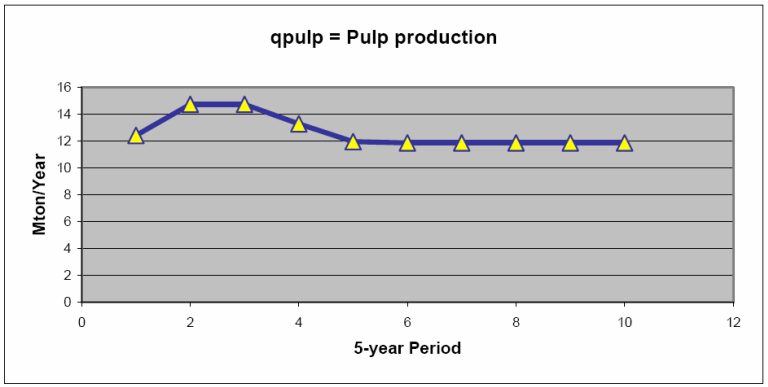

# Contents



***This presentation is very short. It includes a few partial fragments of the project. Please investigate the list of references and conferences with links for more information!***

***My warmest "Thanks" to E.ON Sweden for economic support to the project "Economic forest production with consideration of the forest- and energy- industries"!***

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