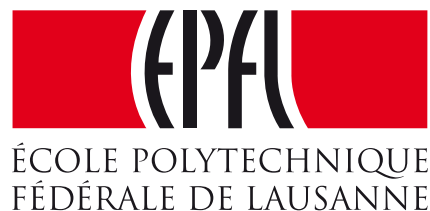


# Environomic optimization of SNG production from lignocellulosic biomass using Life Cycle Assessment

*Léda Gerber, Martin Gassner, François Maréchal*

*Industrial Energy Systems Laboratory, Ecole Polytechnique Fédérale de Lausanne*

*ECOS2010, 14-17 June 2010, Lausanne*



# Context

- Conceptual process design for renewable energy conversion systems
  - Environmental impact is a key performance indicator
    - Integration of Life Cycle Assessment in the process design methodology (I)
  - ➔ *Process engineers*: integrate LCA in the process design procedure
  - ➔ *LCA analysts*: work with realistic data
- Application in the optimization procedure?

(I) L. Gerber, M. Gassner and F. Maréchal, *Integration of LCA in a thermo-economic model for multi-objective process optimization of SNG production from woody biomass*, Proceedings of the 19th European symposium on CAPE, 2009

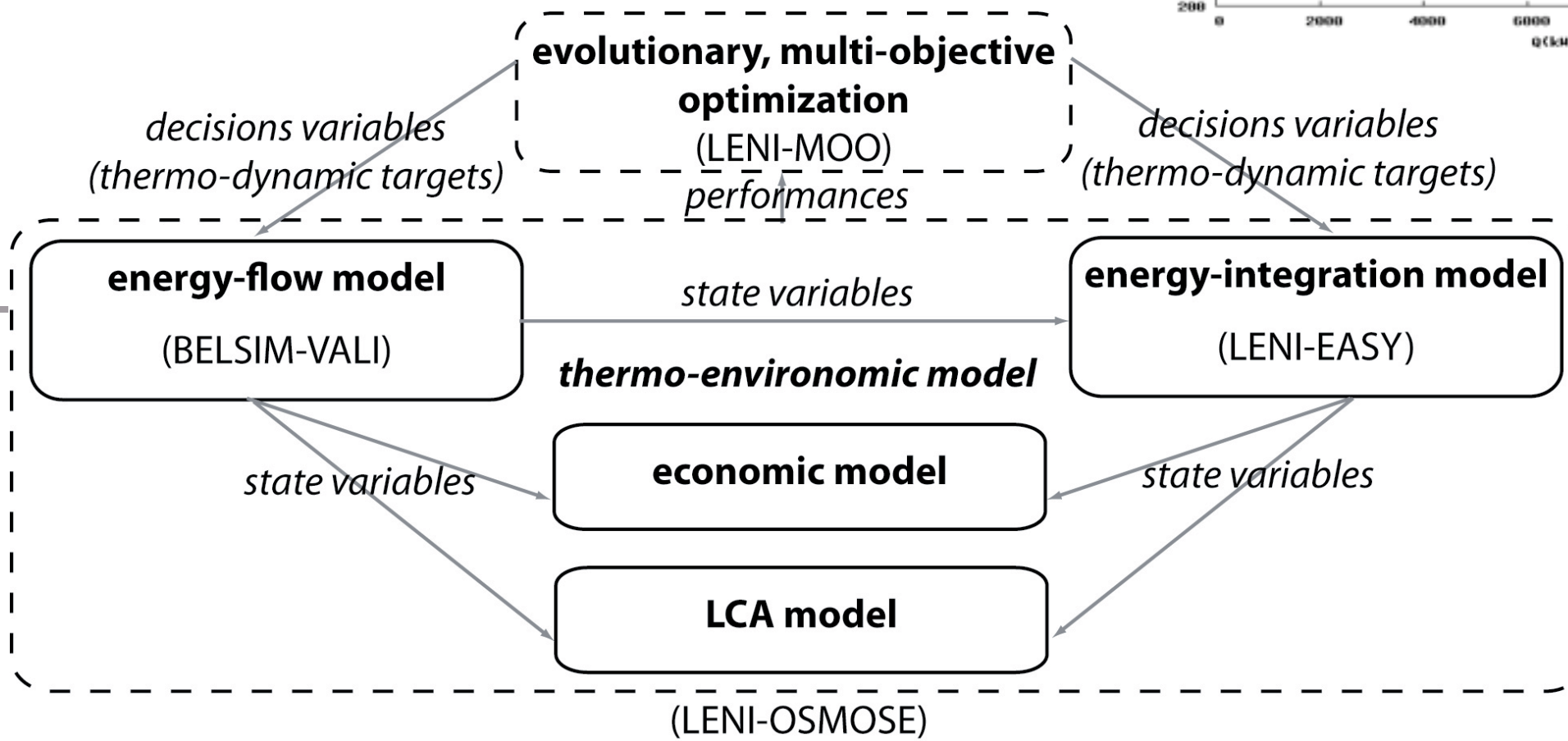
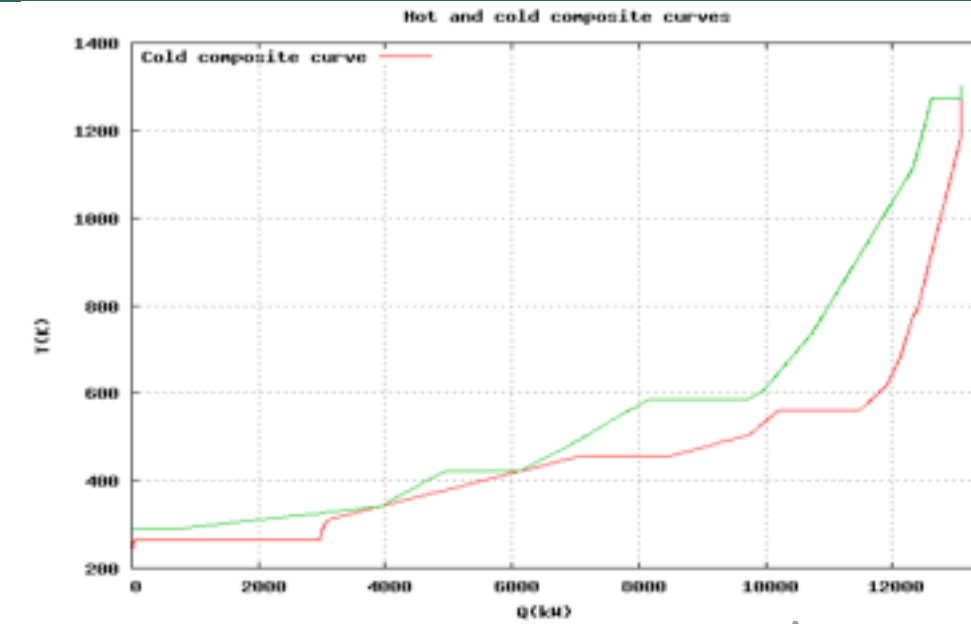
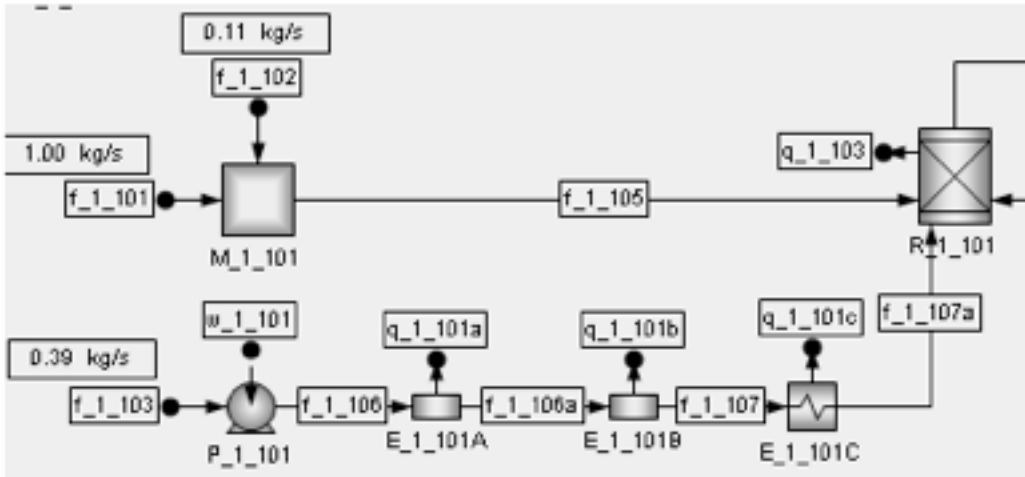


# Objectives

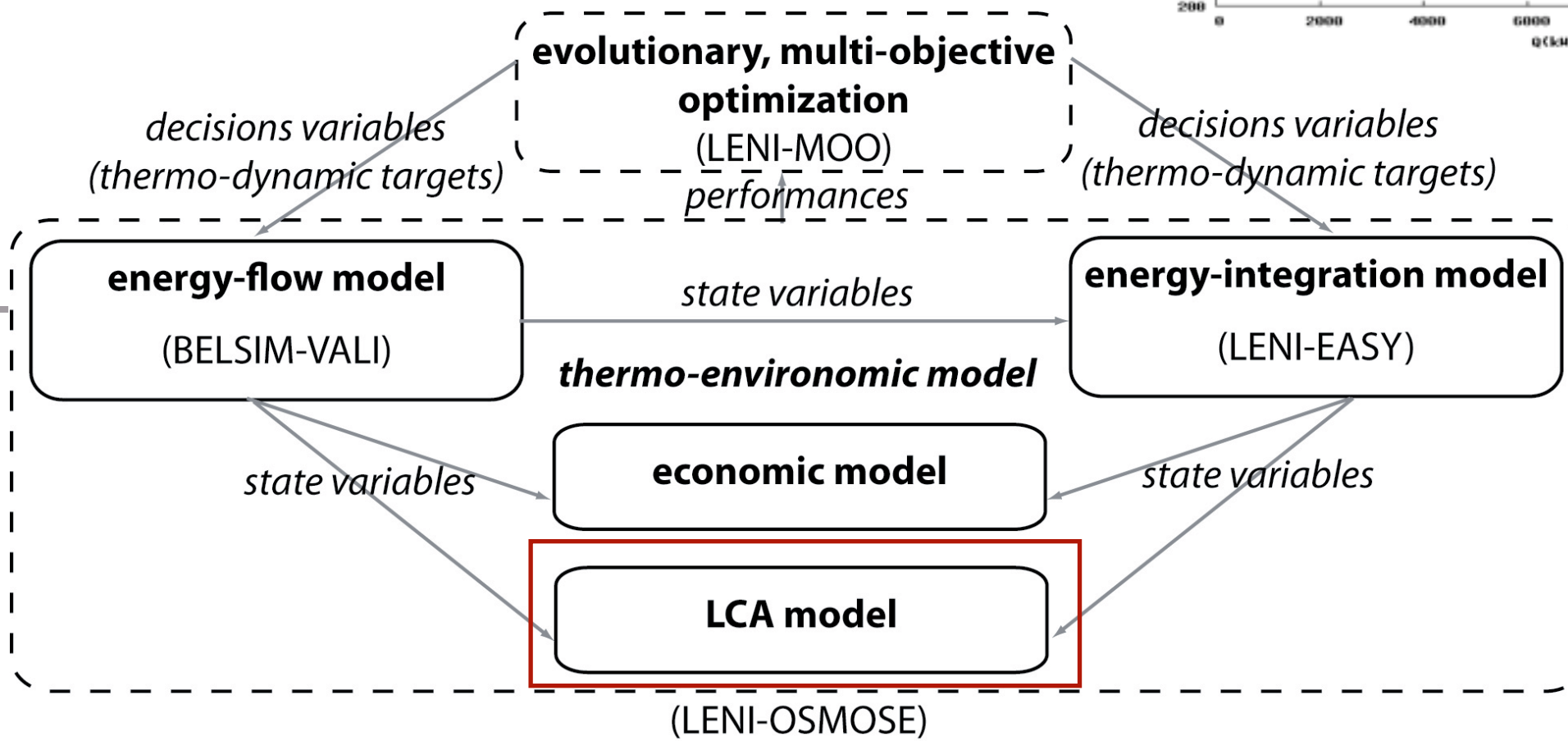
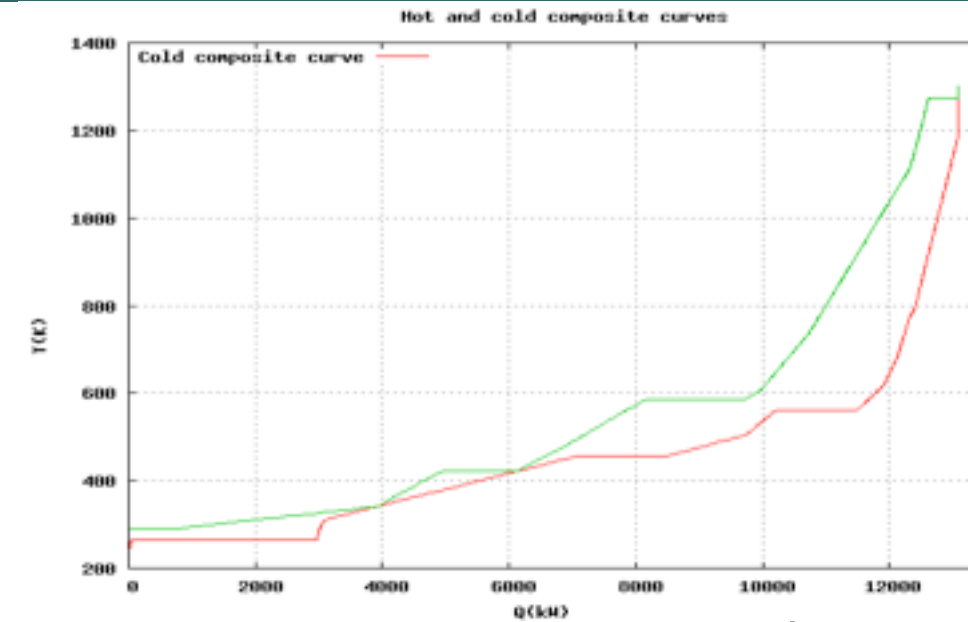
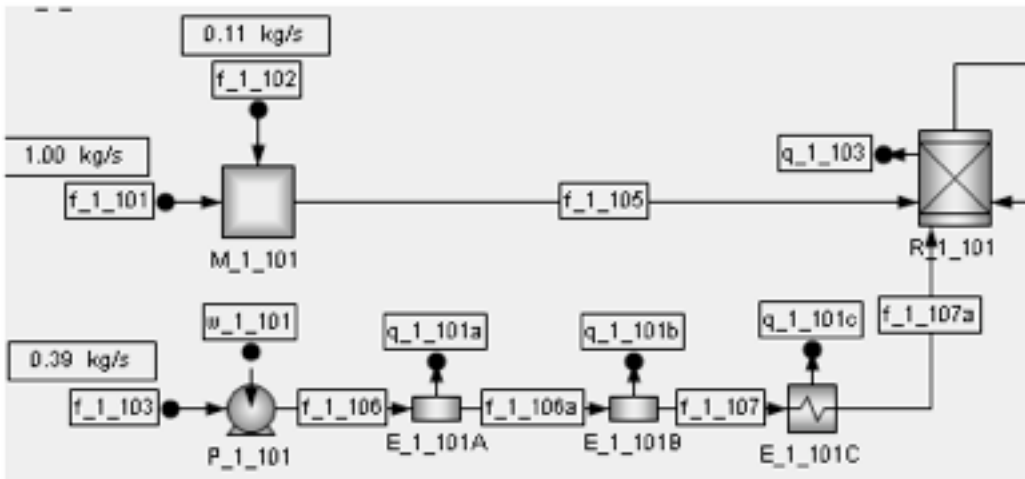
- Identification of optimal process configurations in environomic perspective
  - Optimal process scale
  - Environomic process design
    - Effect of efficiency
    - Impact of auxiliary materials
    - Multiple energy services
  - Application to biomass conversion process



# Process design environment

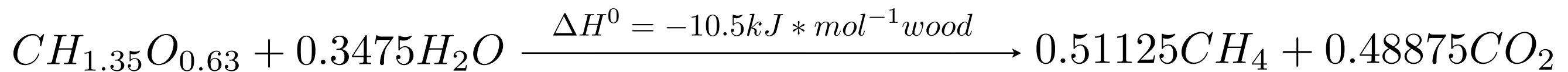
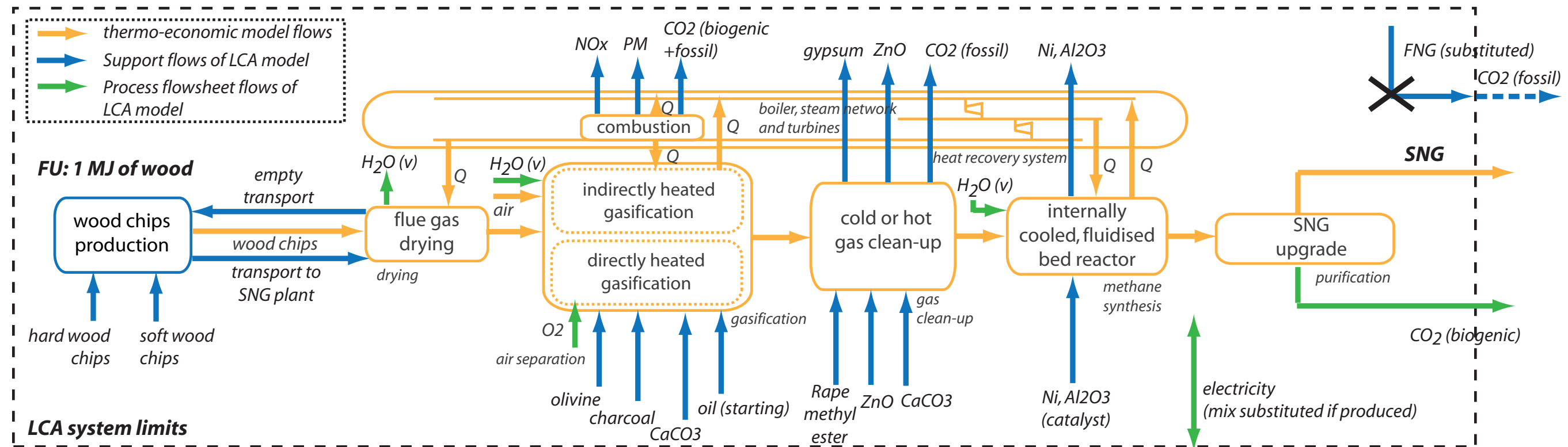


# Process design environment



# LCI model for SNG production

- Thermochemical production of SNG from lignocellulosic biomass (I)



(I) L. Gerber, M. Gassner and F. Maréchal, *Integration of LCA in a thermo-economic model for multi-objective process optimization of SNG production from woody biomass*, Proceedings of the 19th European symposium on CAPE, 2009

# Life Cycle Impact Assessment

- Selected impact assessment methods

$$\begin{bmatrix} F_{1,1} & \dots & F_{1,n} \\ \dots & \dots & \dots \\ F_{m,1} & \dots & F_{m,n} \end{bmatrix} * \begin{bmatrix} E_1 \\ \dots \\ E_n \end{bmatrix} = \begin{bmatrix} I_1 \\ \dots \\ I_m \end{bmatrix}$$



$$I_{tot} = \sum_{i=1}^m I_i * w_i$$

$E$  : Emission or extractions from LCI

$F$  : Impact factors of the method

$I$  : Impact categories of the method

$n$  : Number of emissions accounted in LCI

$m$  : Number of impact categories of method

$w$  : Weights of the method, for additional weighting step (if applicable)

$I_{tot}$  : Single score of the method (if applicable)

Method	Impact category	Units
Ecoscarcity06	Air emissions	pts
	Surface water emissions	pts
	Groundwater emissions	pts
	Top soil emissions	pts
	Energy resources	pts
	Natural resources	pts
	Deposited waste	pts
Ecoindicator99-(h,a)	Human health	pts
	Ecosystem quality	pts
	Resources	pts
IPCC	Global Warming Potential, 100a	kgCO2-eq

**I 1+2 environmental performance indicators**





# Optimization strategy

- Environomic optimal process design
  - ➔ 2 objectives
    - economic
    - environmental
- Effect of technology and scale
  - 6 scenarios
  - 19-21 decisions variables
    - process scale [5-200 MWth]
    - operating conditions





# Optimization strategy

- Environomic optimal process design
  - ➔ 2 objectives
    - economic → *Biomass profitability*
    - environmental
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# Optimization strategy

- Environomic optimal process design

- ➔ 2 objectives

- economic → *Biomass profitability*

- environmental

*Ecoindicator99-(h,a) (Single score)*

*Ecoscarcity06 (Single score)*

*Global Warming Potential, 100a*

- Effect of technology and scale

- 6 scenarios

- 19-21 decisions variables

- process scale [5-200 MWth]

- operating conditions



# Scenarios characteristics

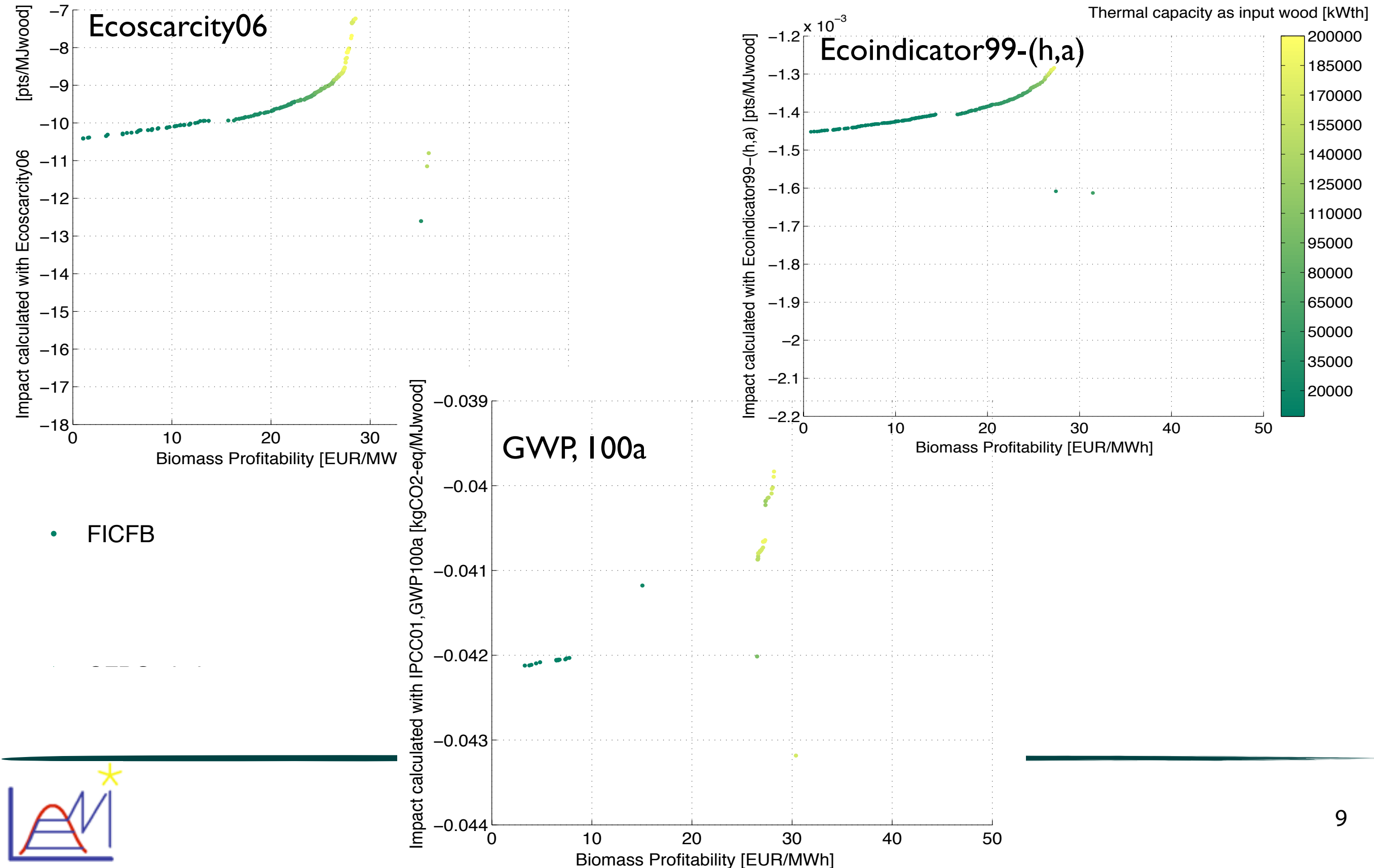
- Choice of technology scenarios for optimisation (I)

	FICFB	FICFB,torr	pFICFB	pFICFB, hcl	CFBO2	CFBO2,hcl
biomass pretreatment	-	torrefaction	-	-	-	-
gasification technology	indirect, H2O	indirect,H2O	indirect,H2O	indirect,H2O	direct,O2	direct,O2
gasification pressure	atm.	atm.	1-30 bar	1-30 bar	1-30 bar	1-30 bar
gas cleaning	cold	cold	cold	hot	cold	hot
SNG upgrade	membranes	membranes	membranes	membranes	membranes	membranes

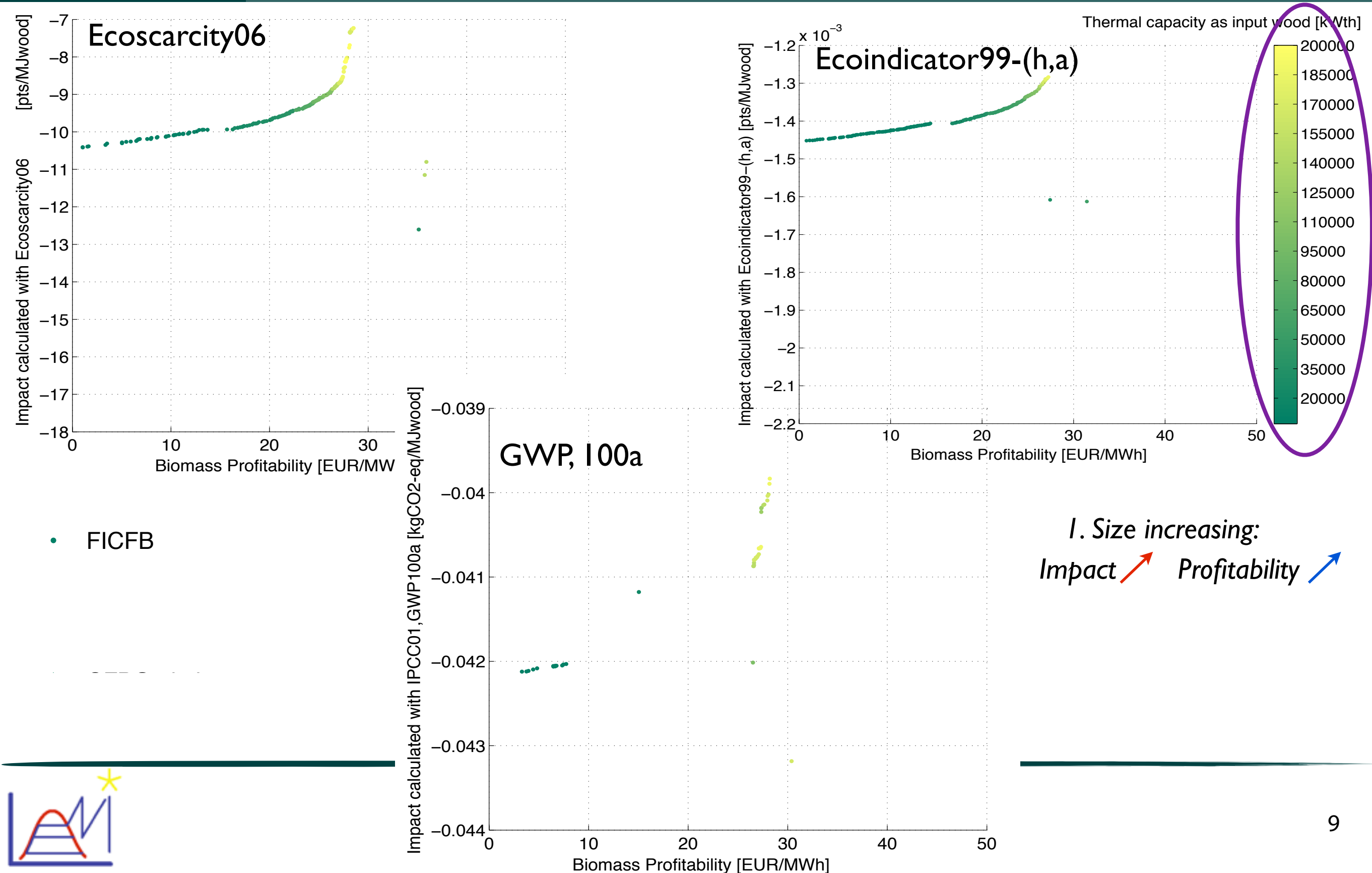
(I) M. Gassner and F. Maréchal, *Thermo-economic process model for thermochemical production of Synthetic Natural Gas (SNG) from lignocellulosic biomass*, Biomass and Bioenergy 33, pp 1587-1604, 2009



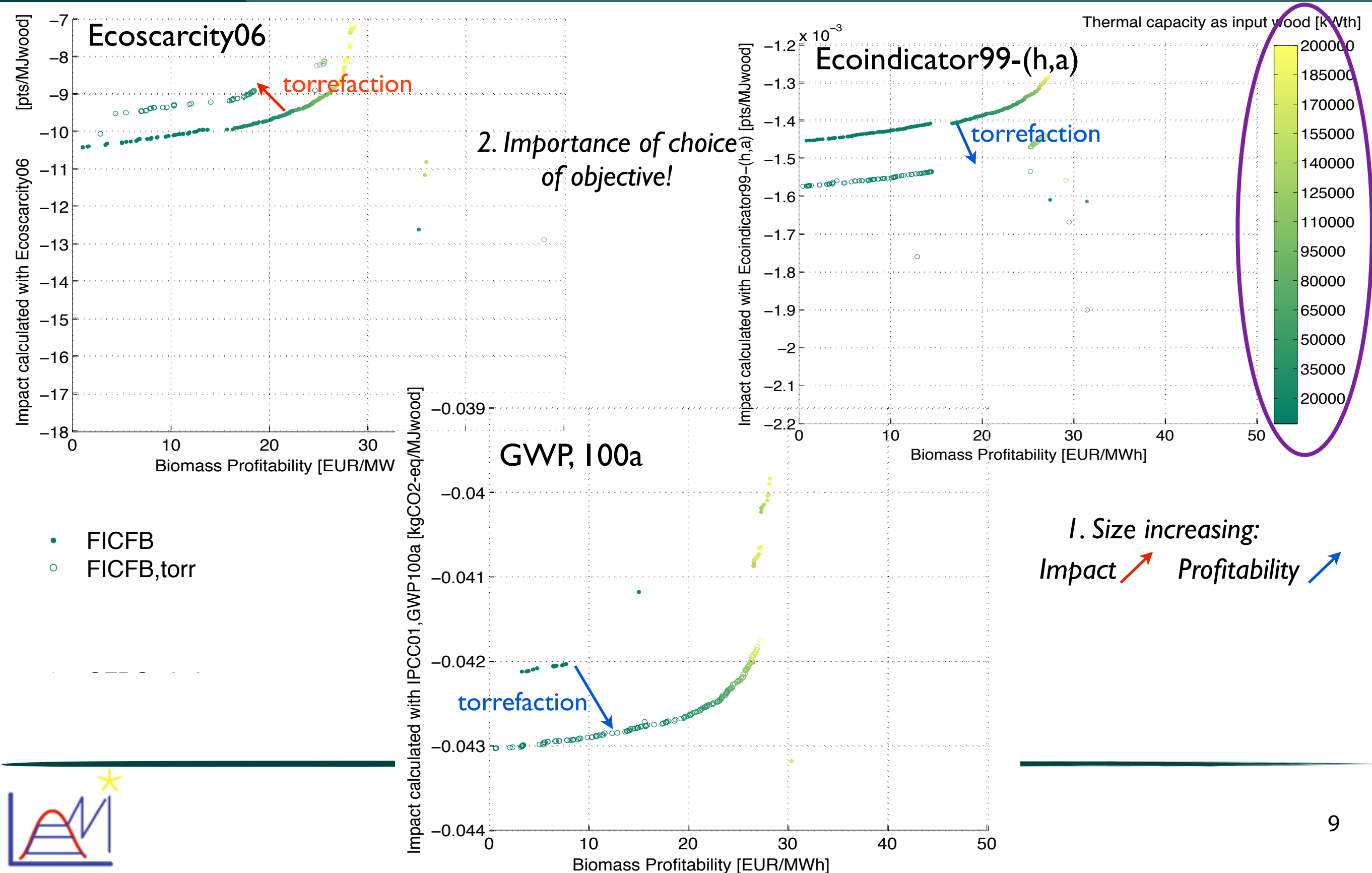
# Scenarios comparison



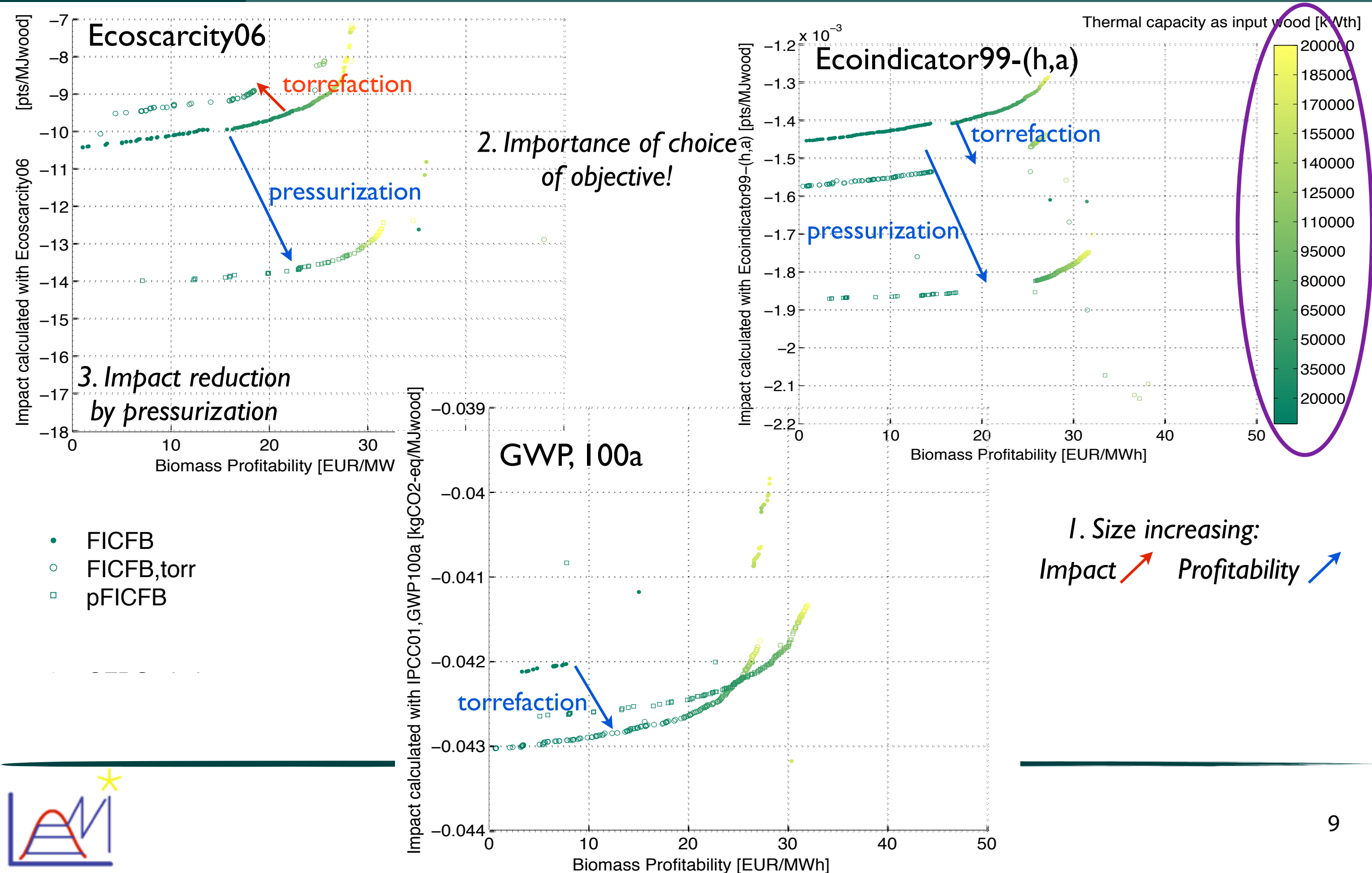
# Scenarios comparison



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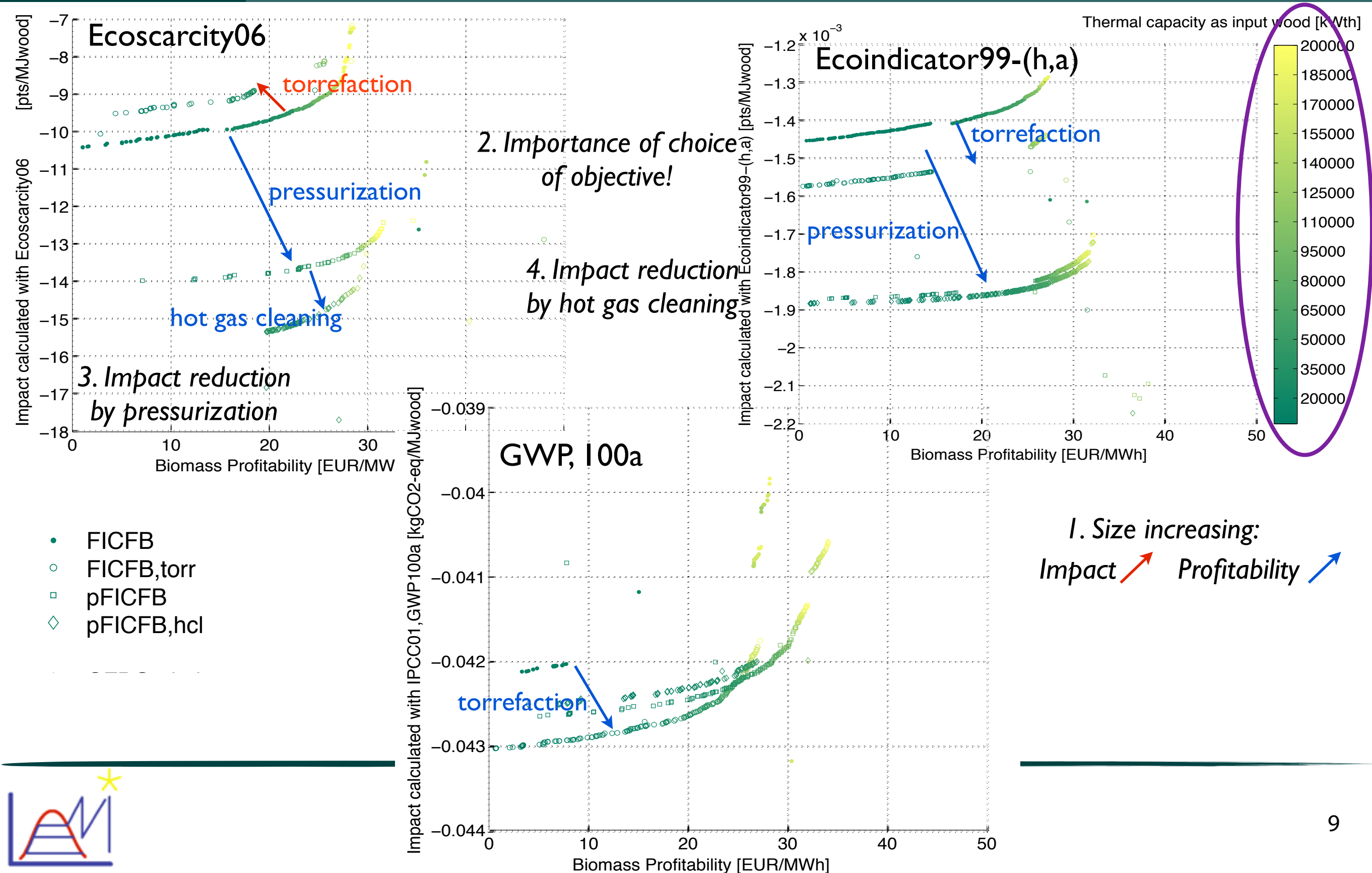


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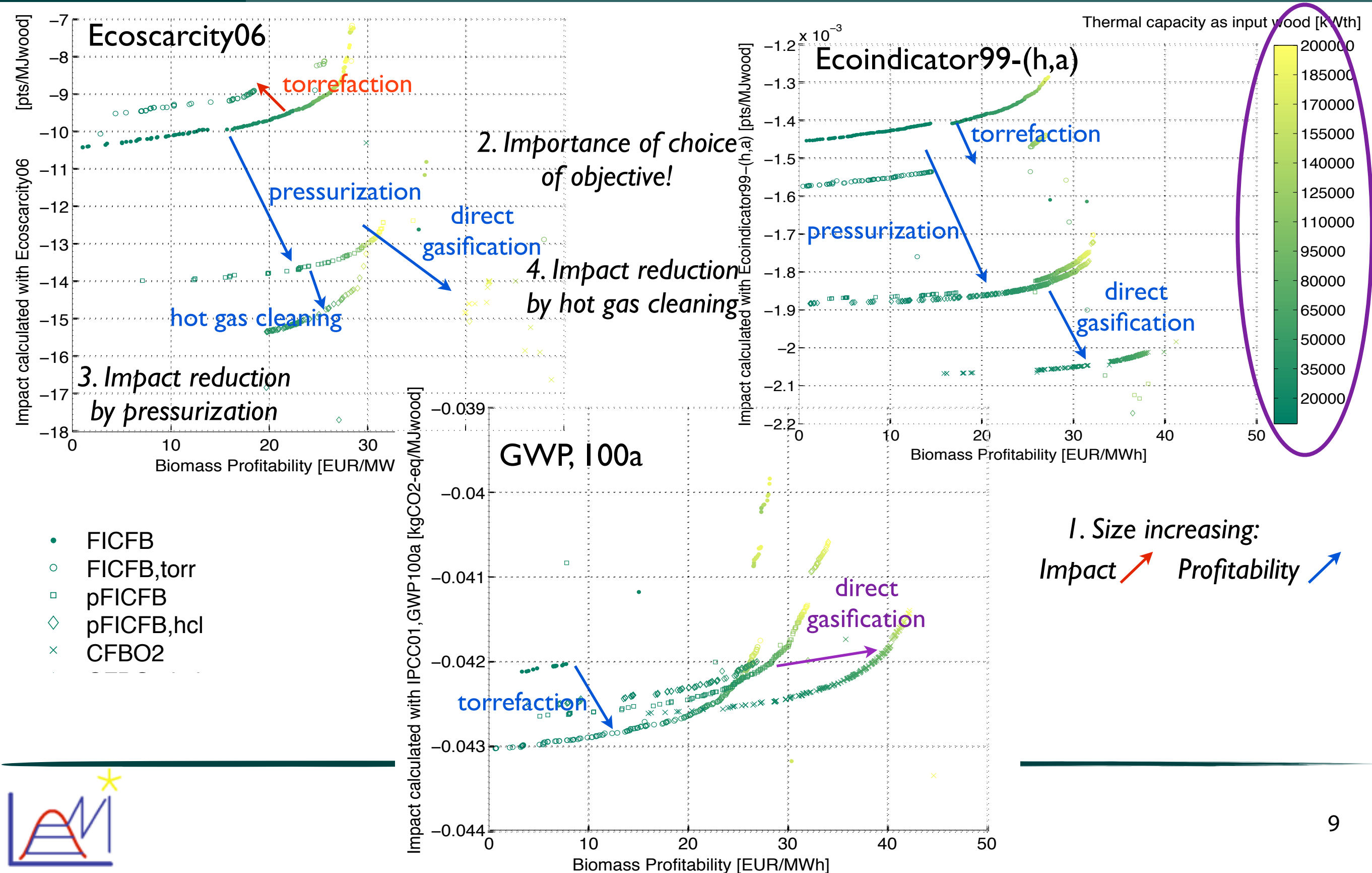




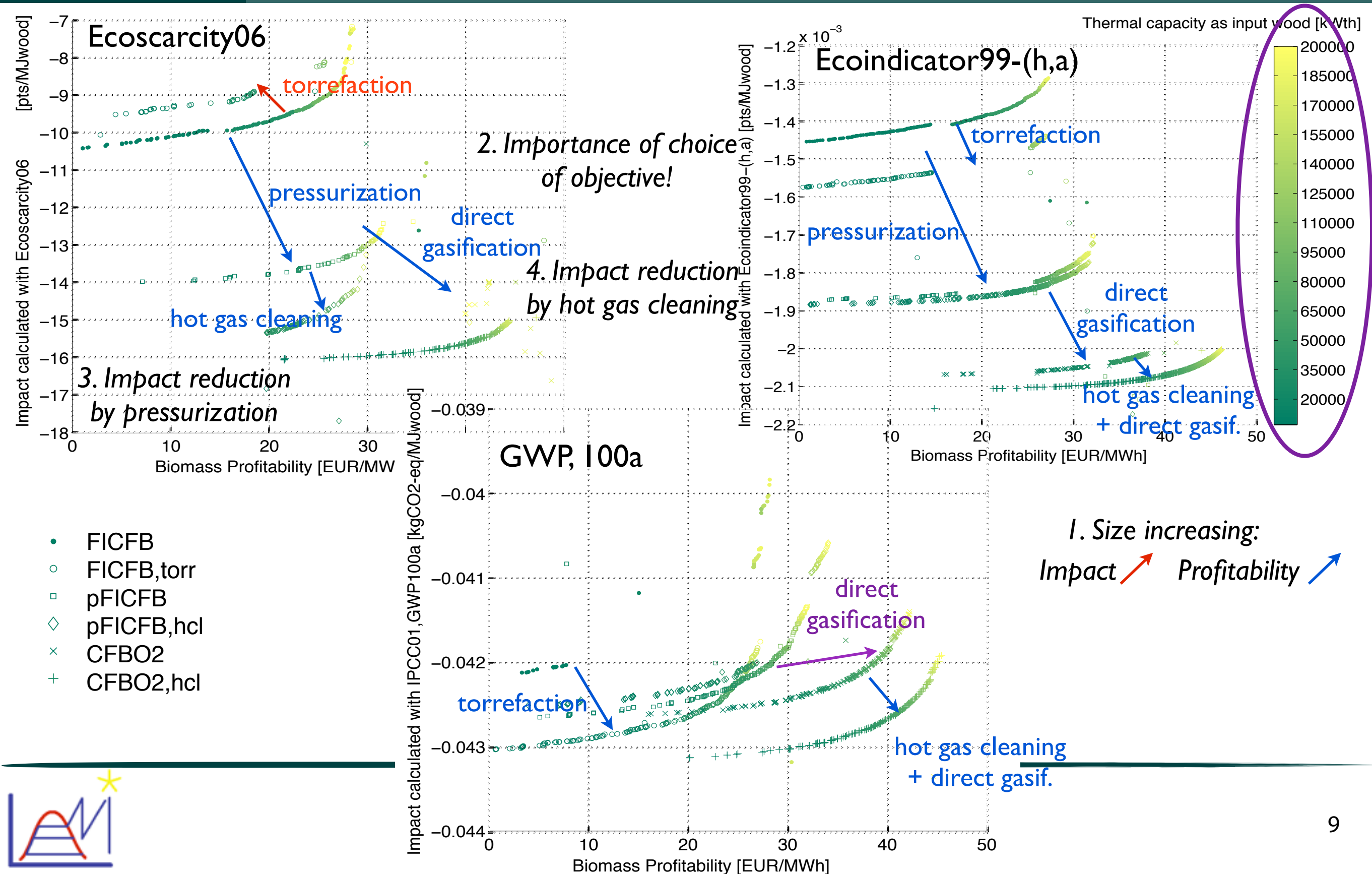
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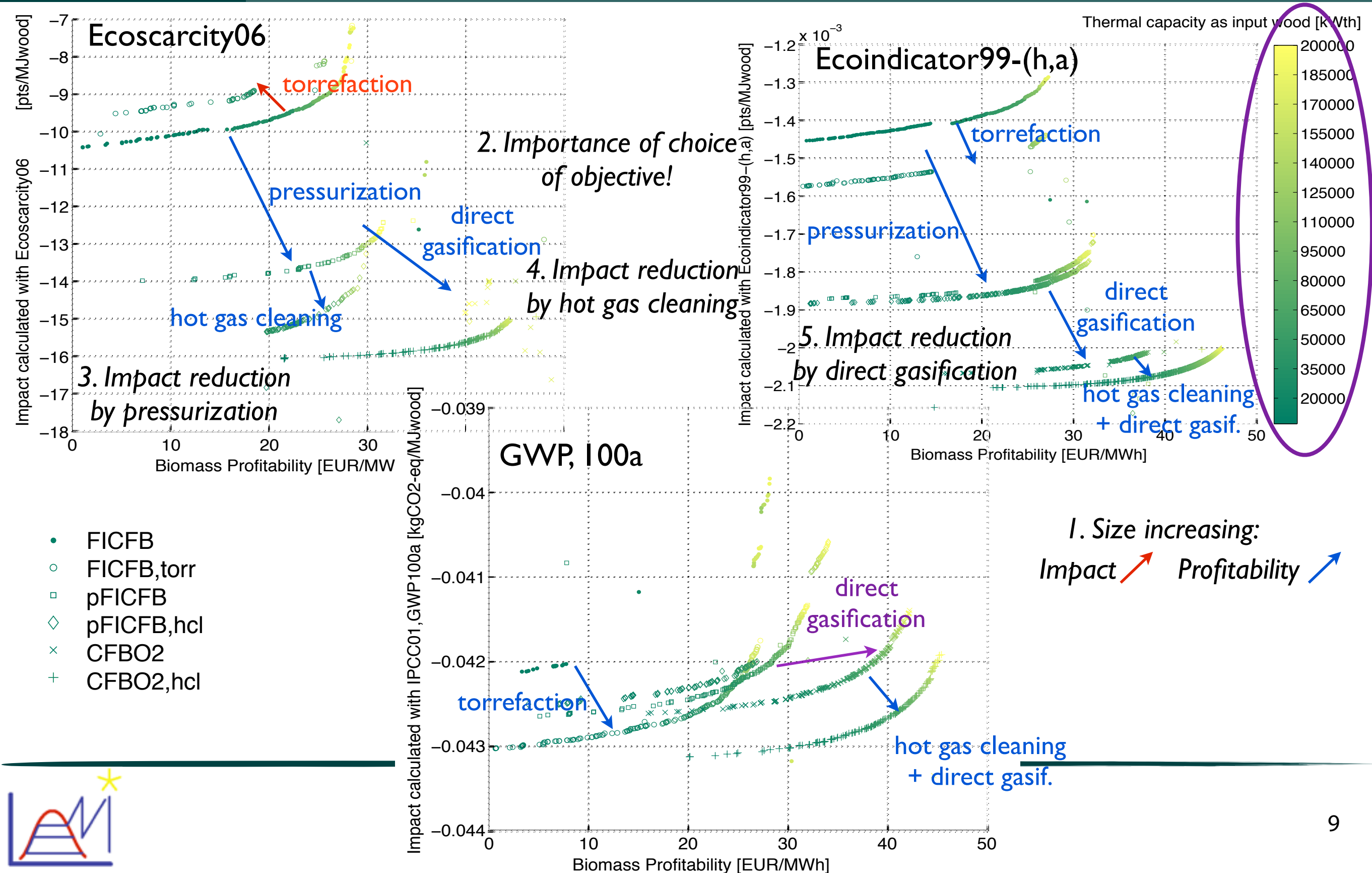
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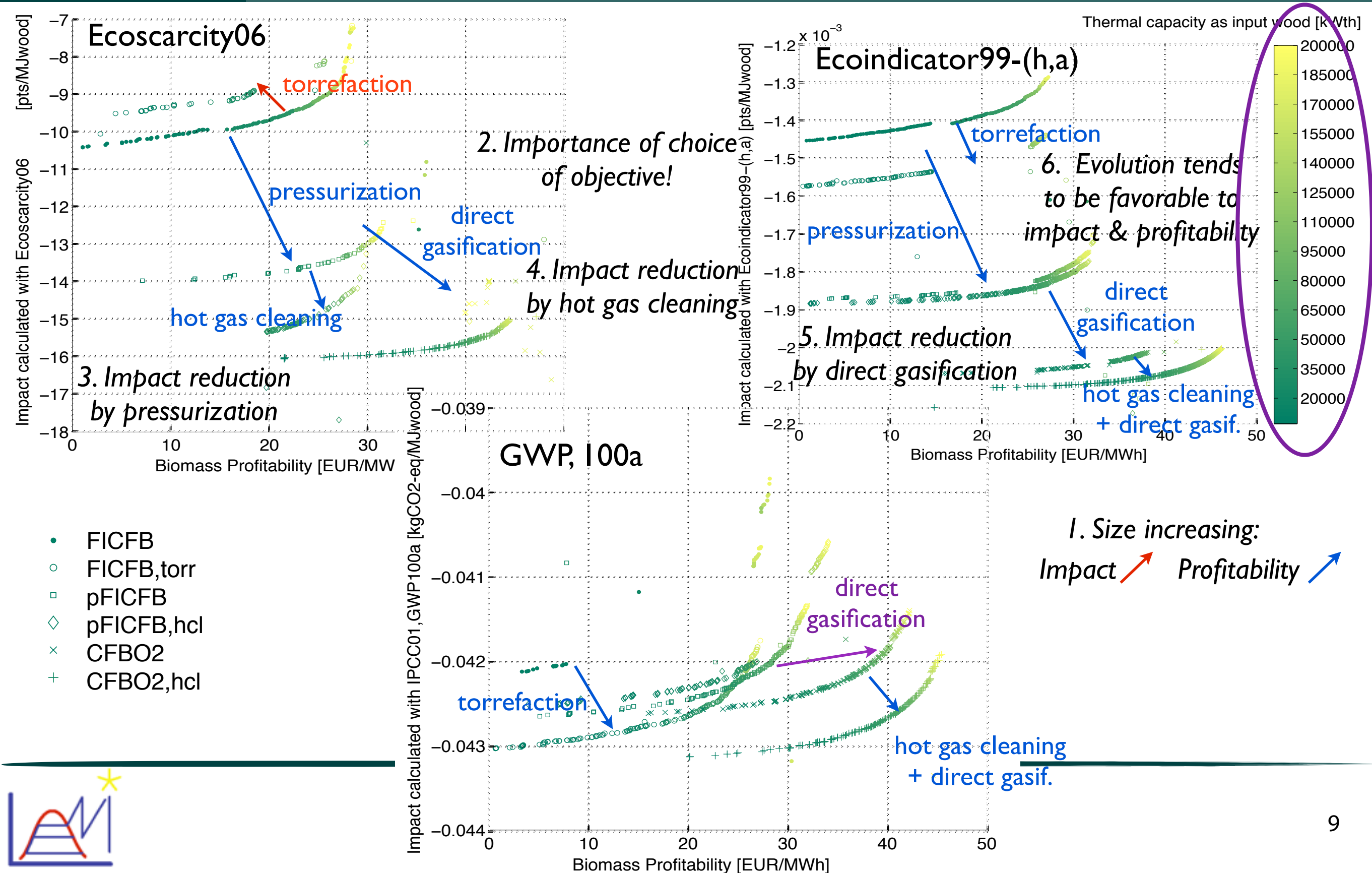


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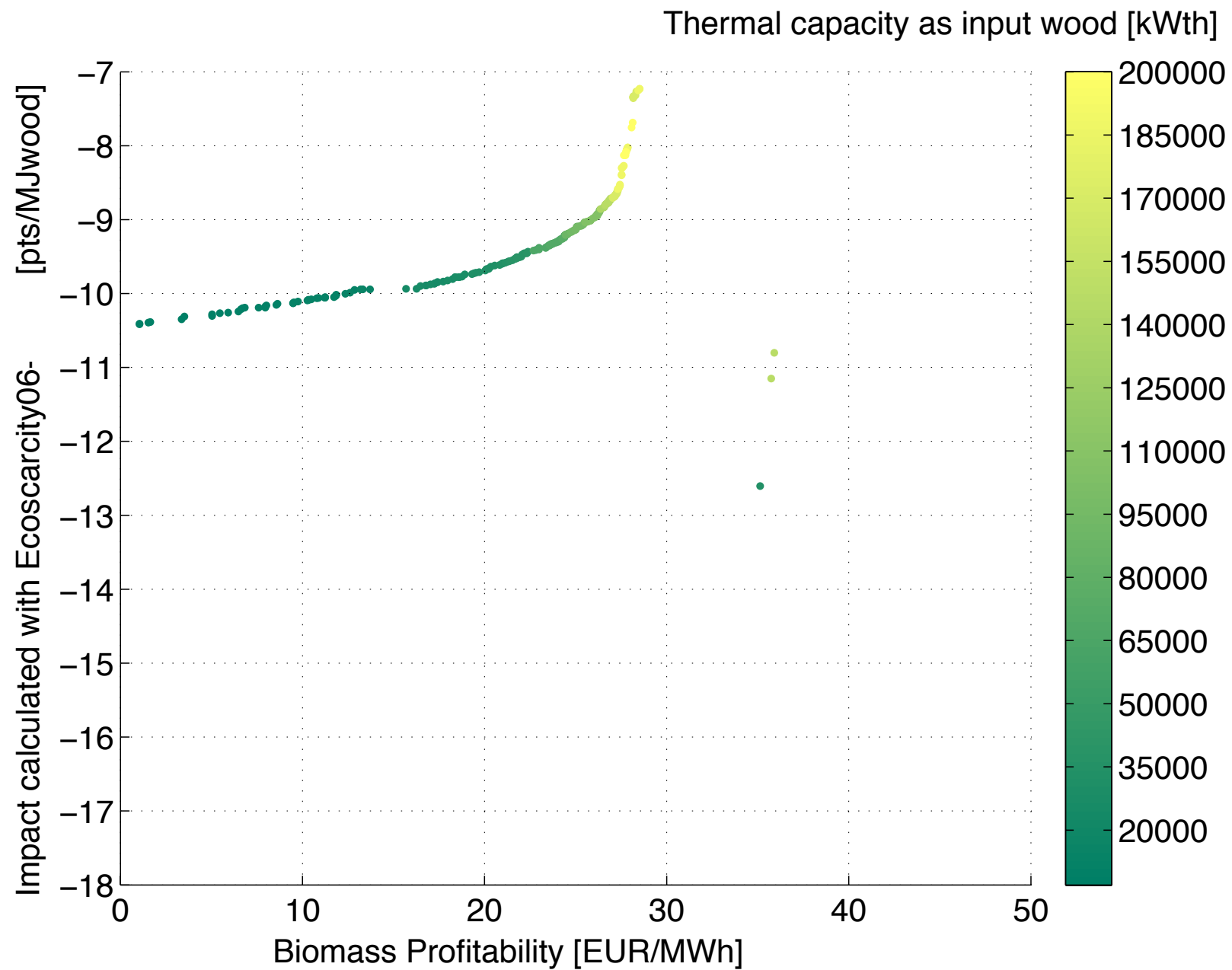


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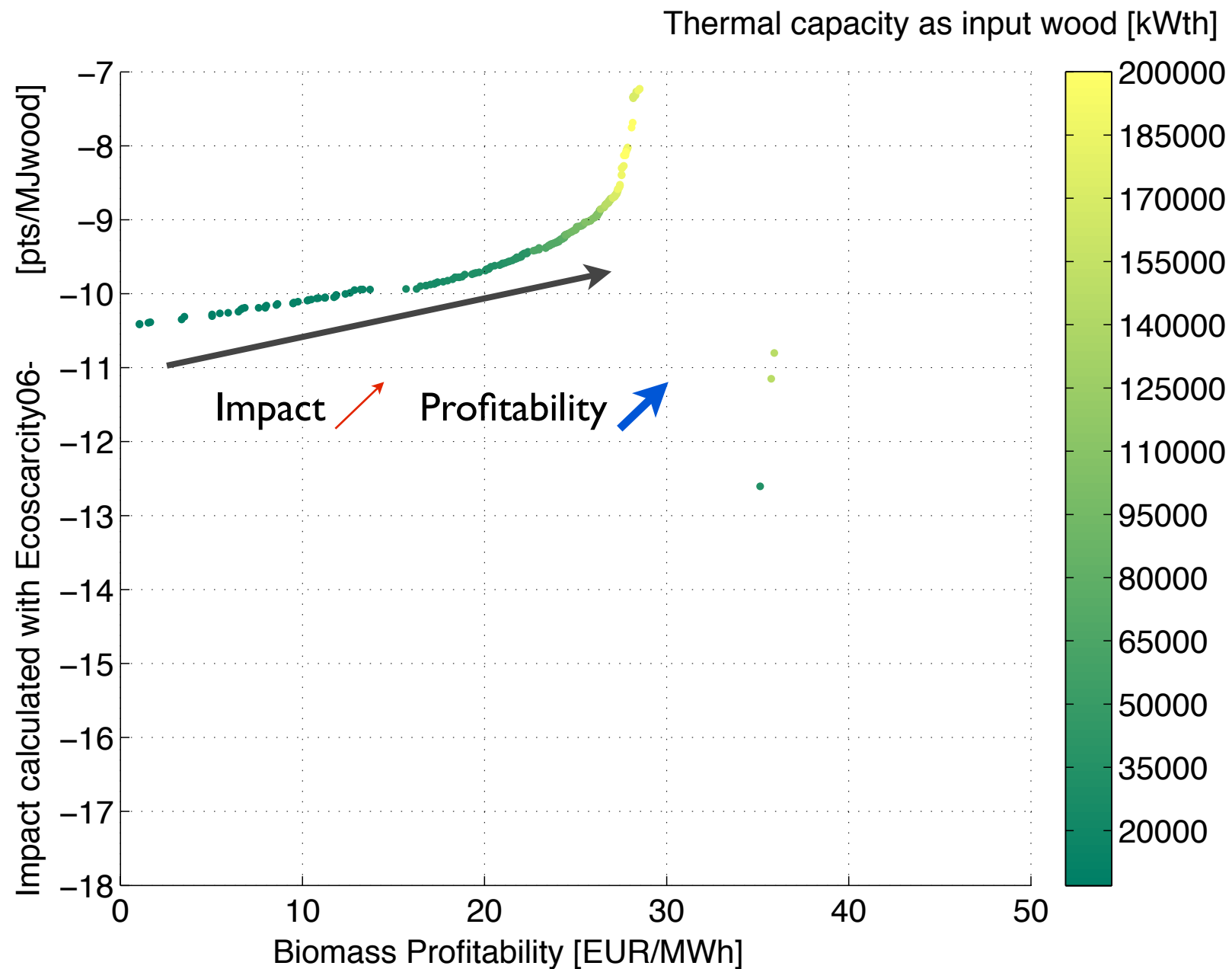
# Optimal process scale

- Example with FICFB scenario (indirect gasif., atm pressure)



# Optimal process scale

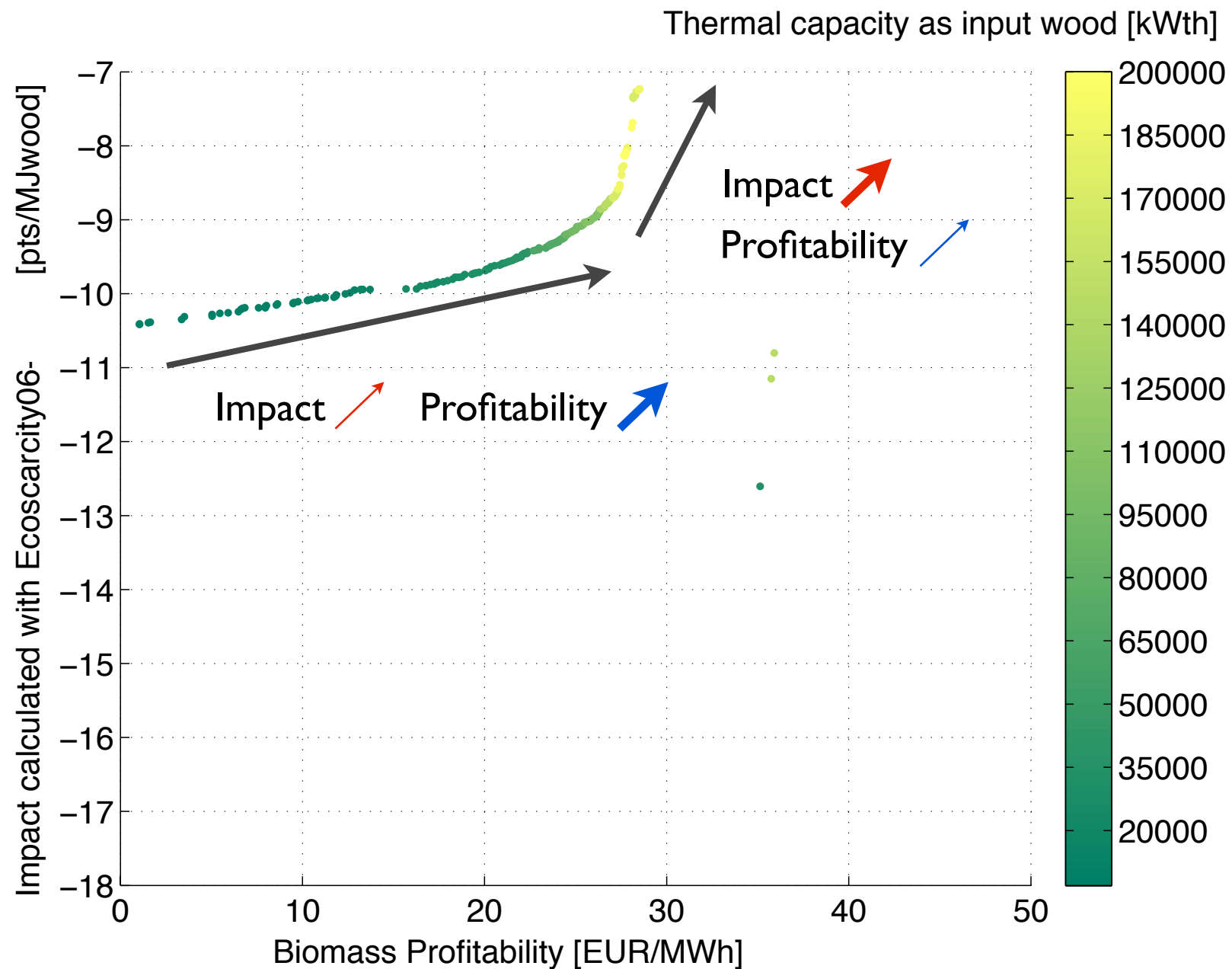
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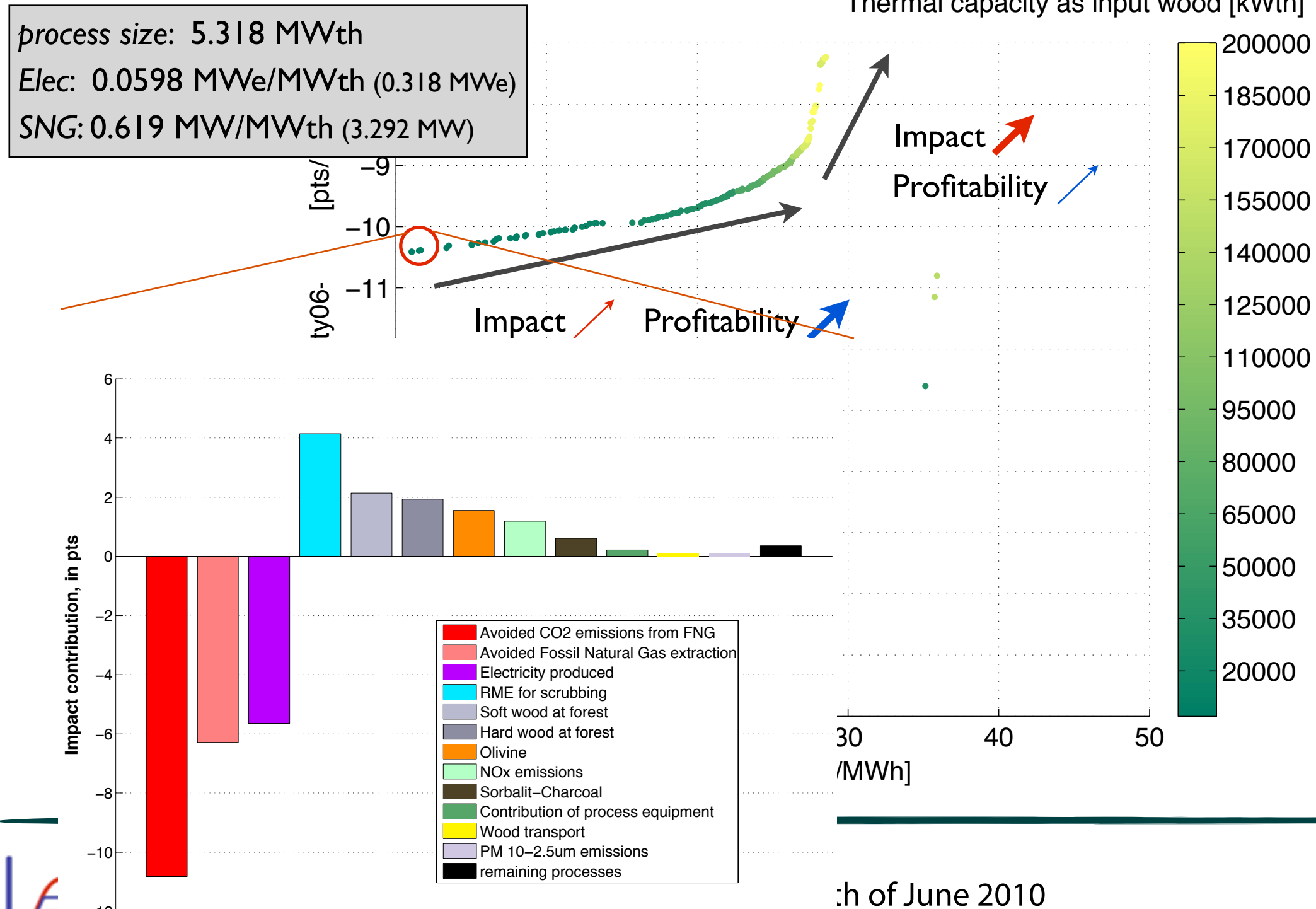
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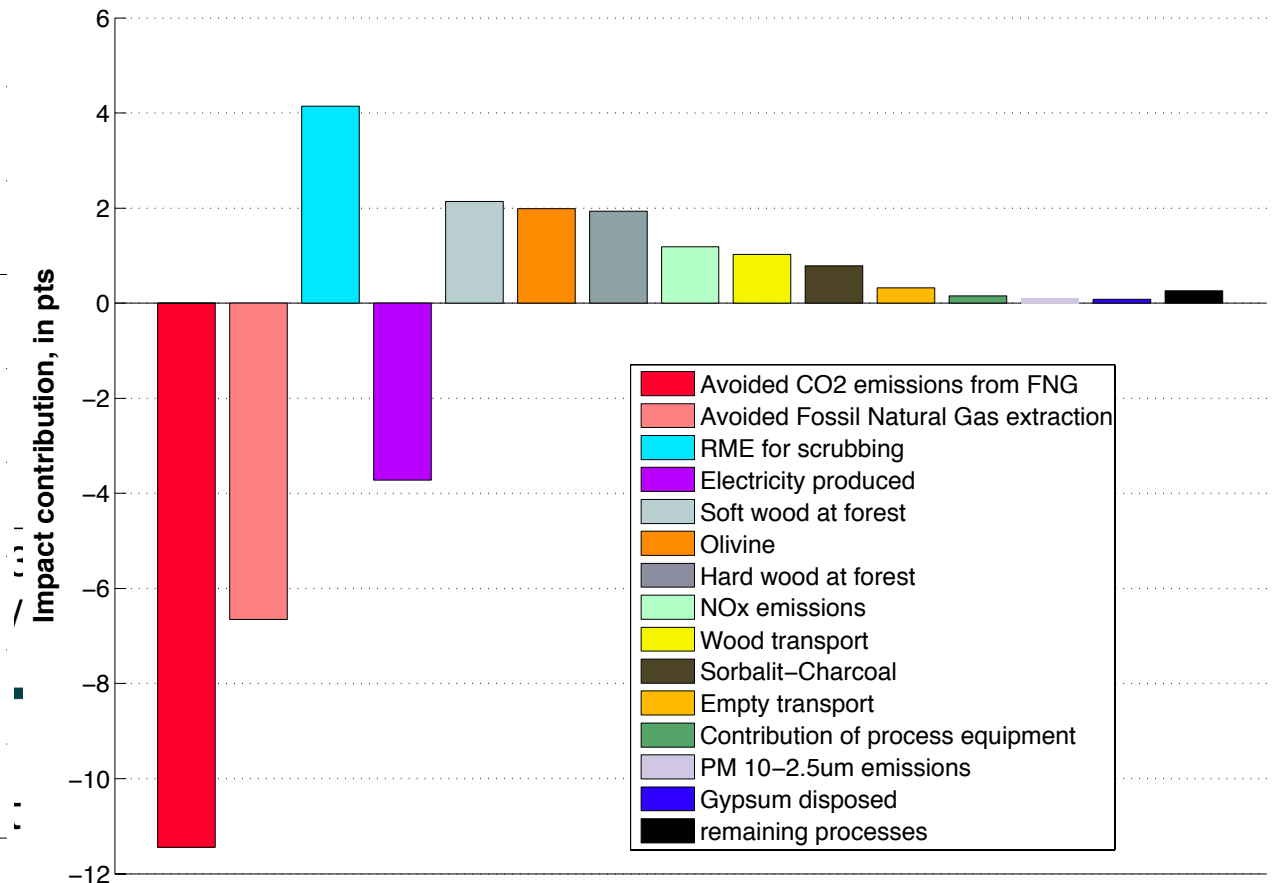
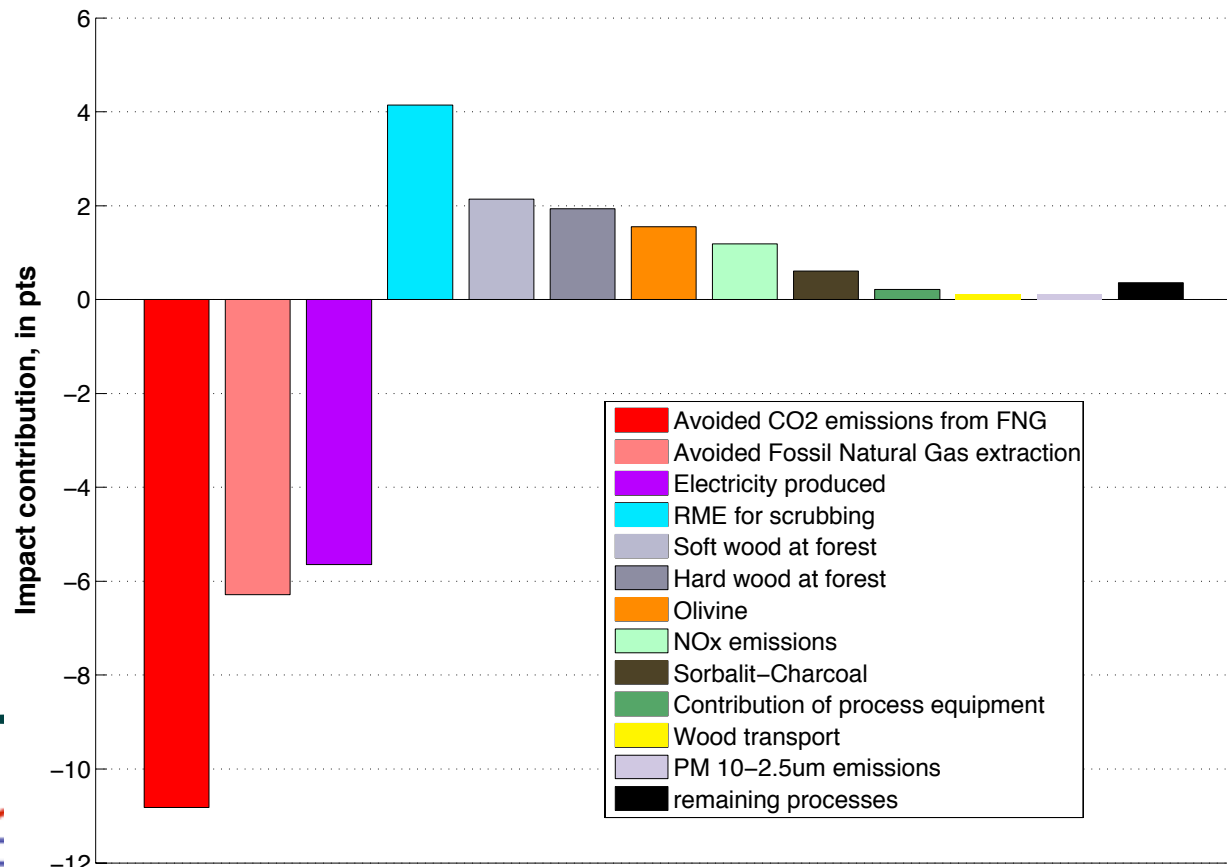
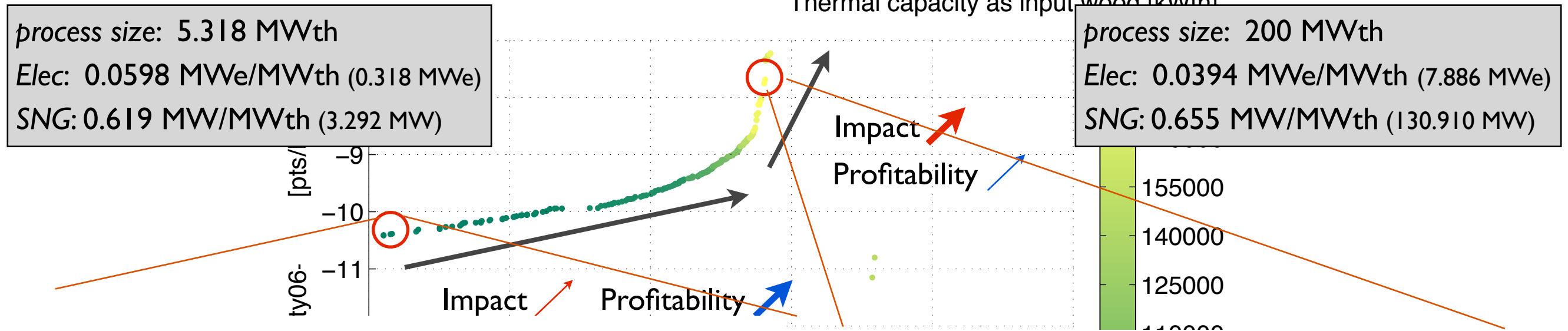
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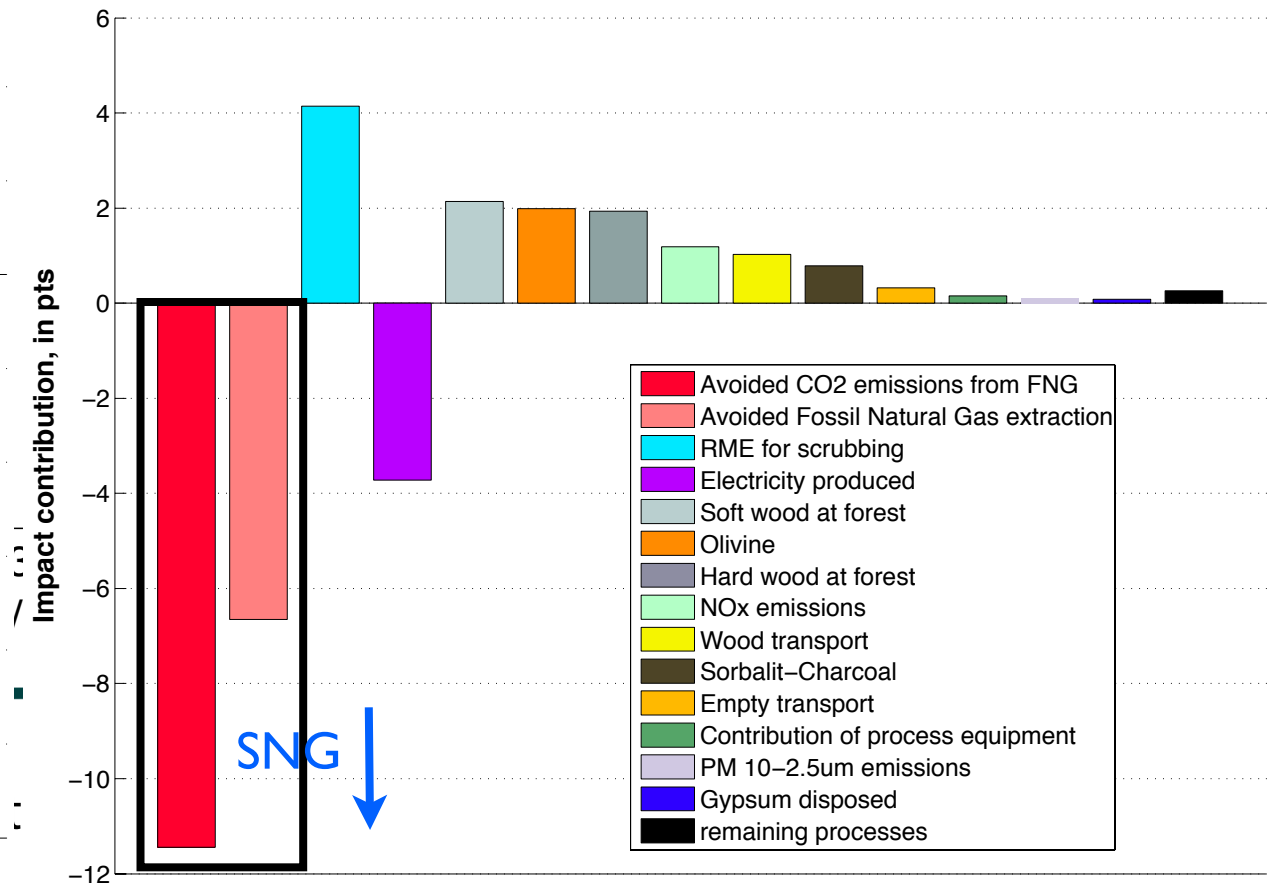
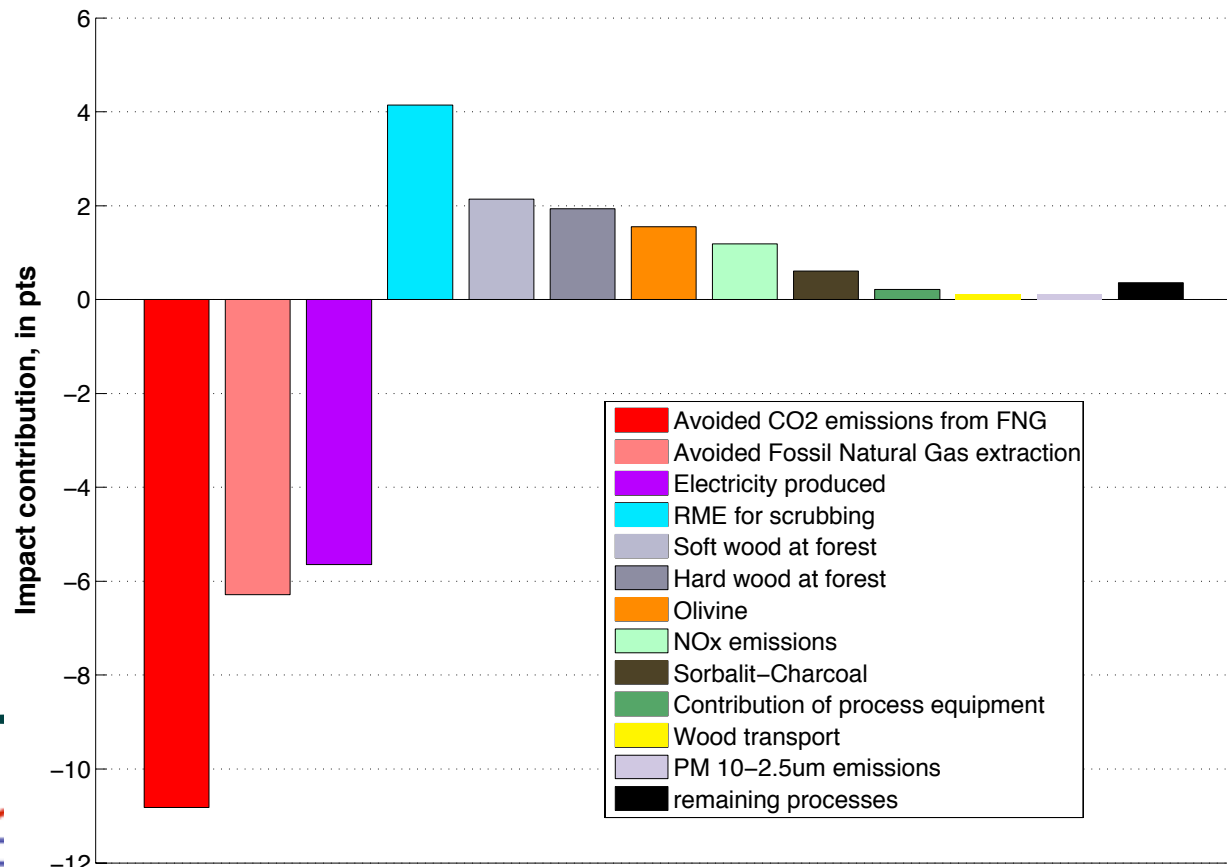
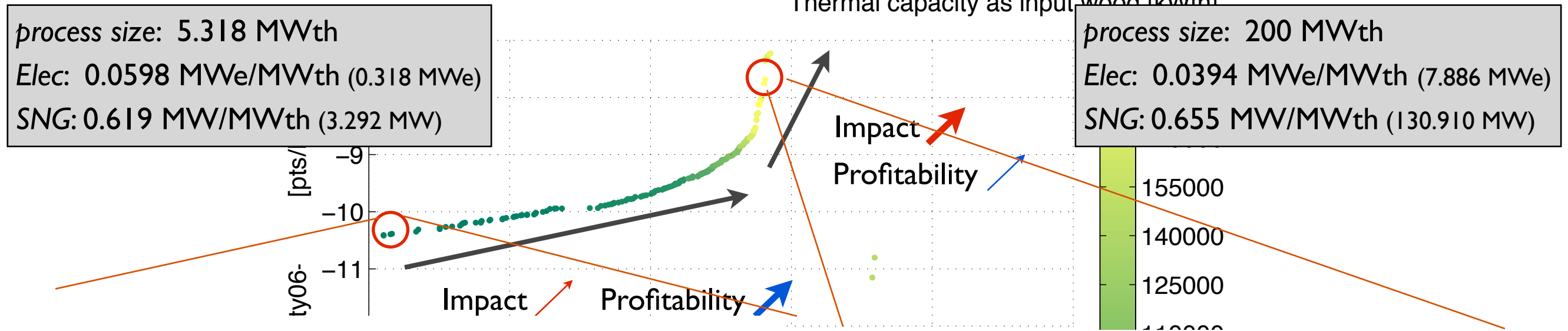
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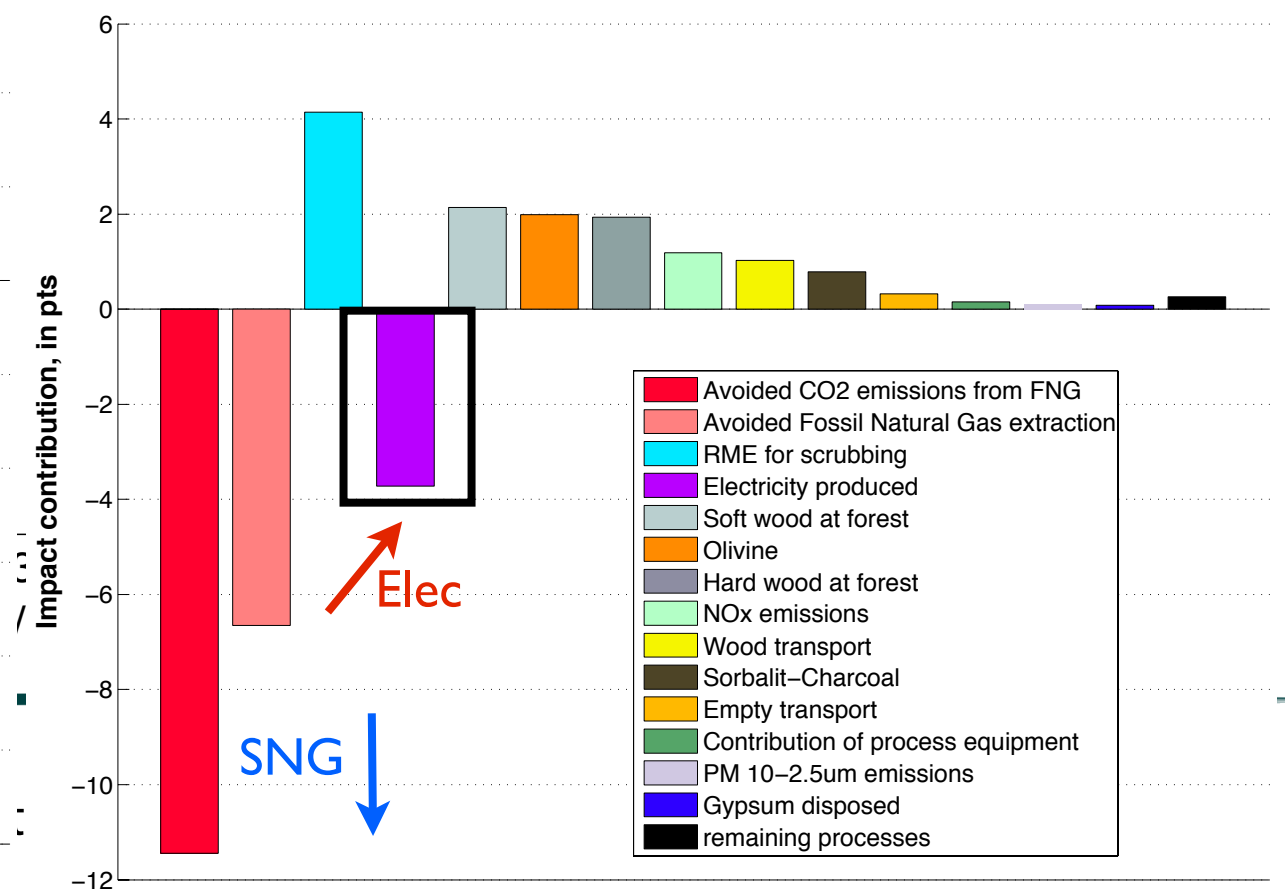
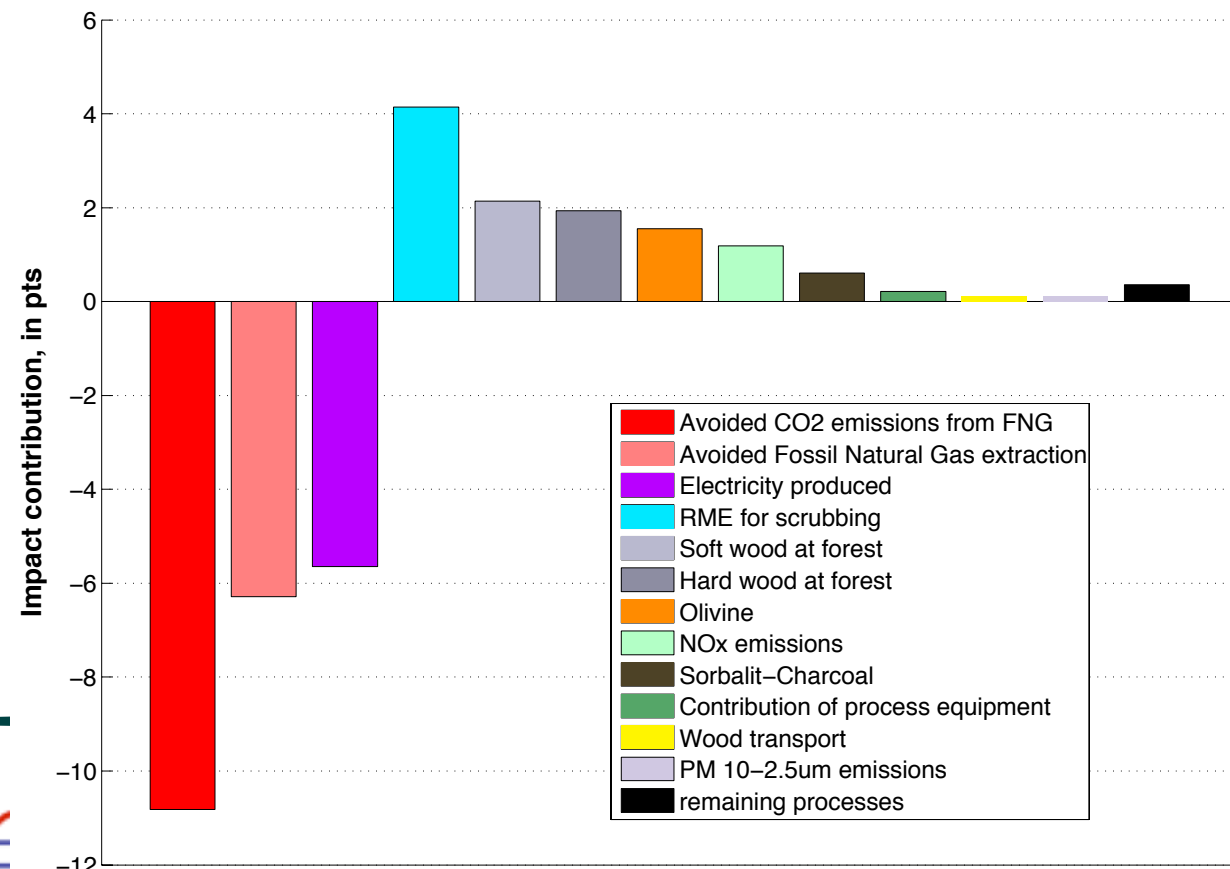
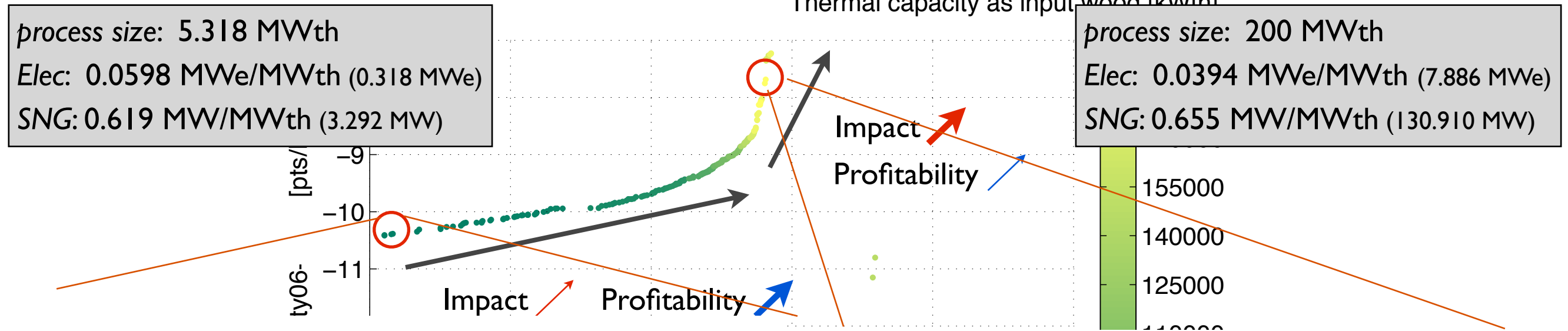
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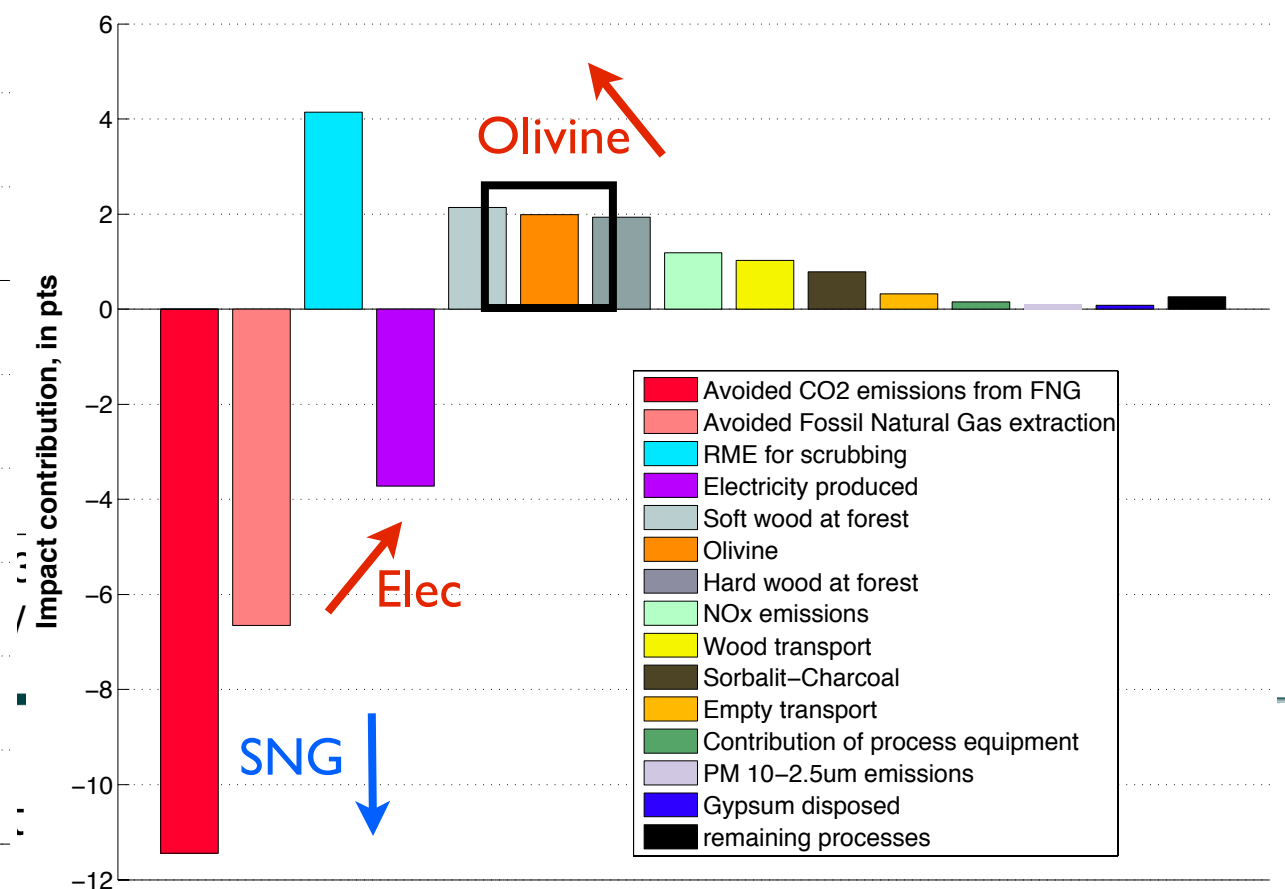
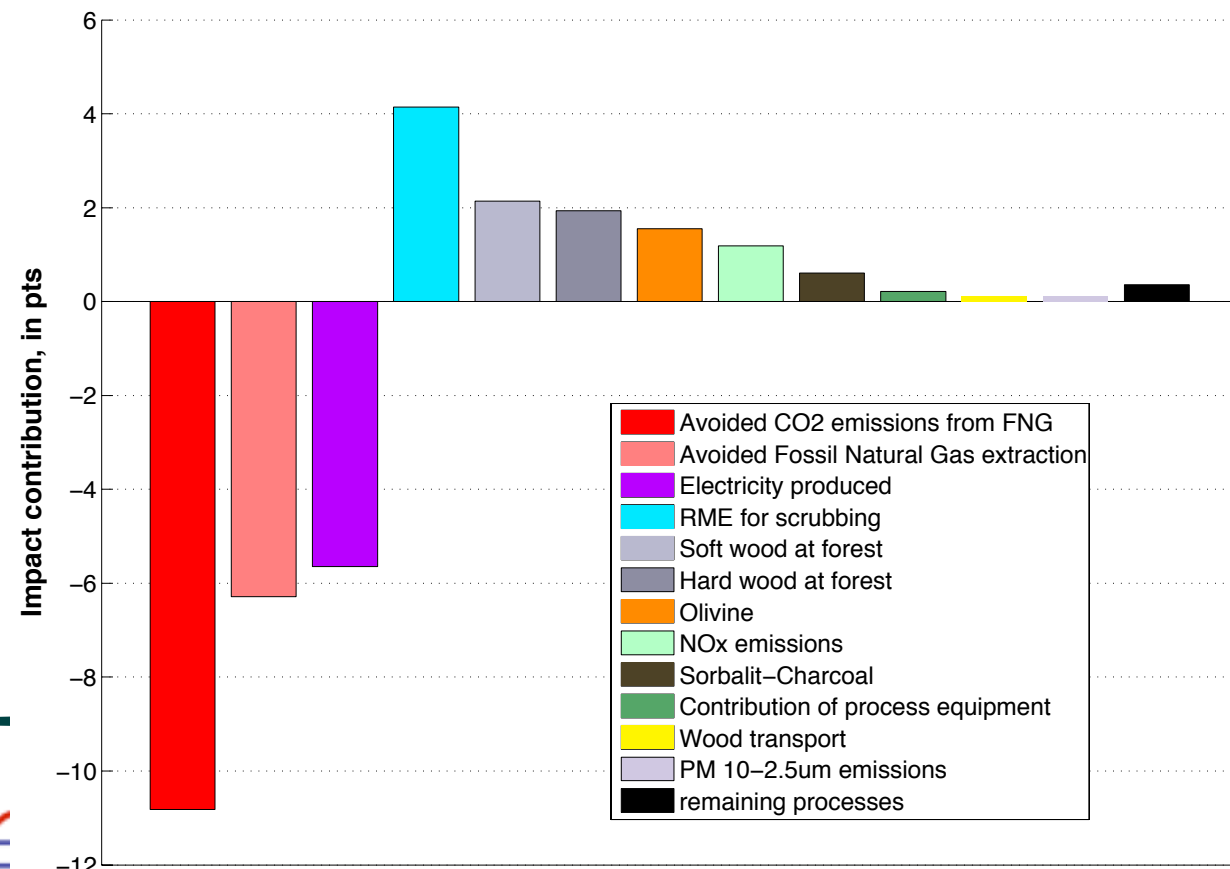
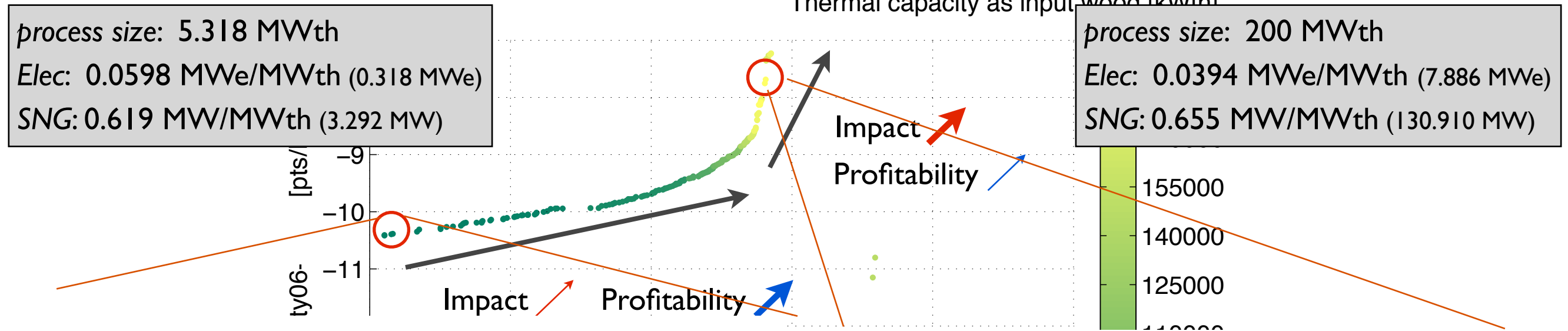
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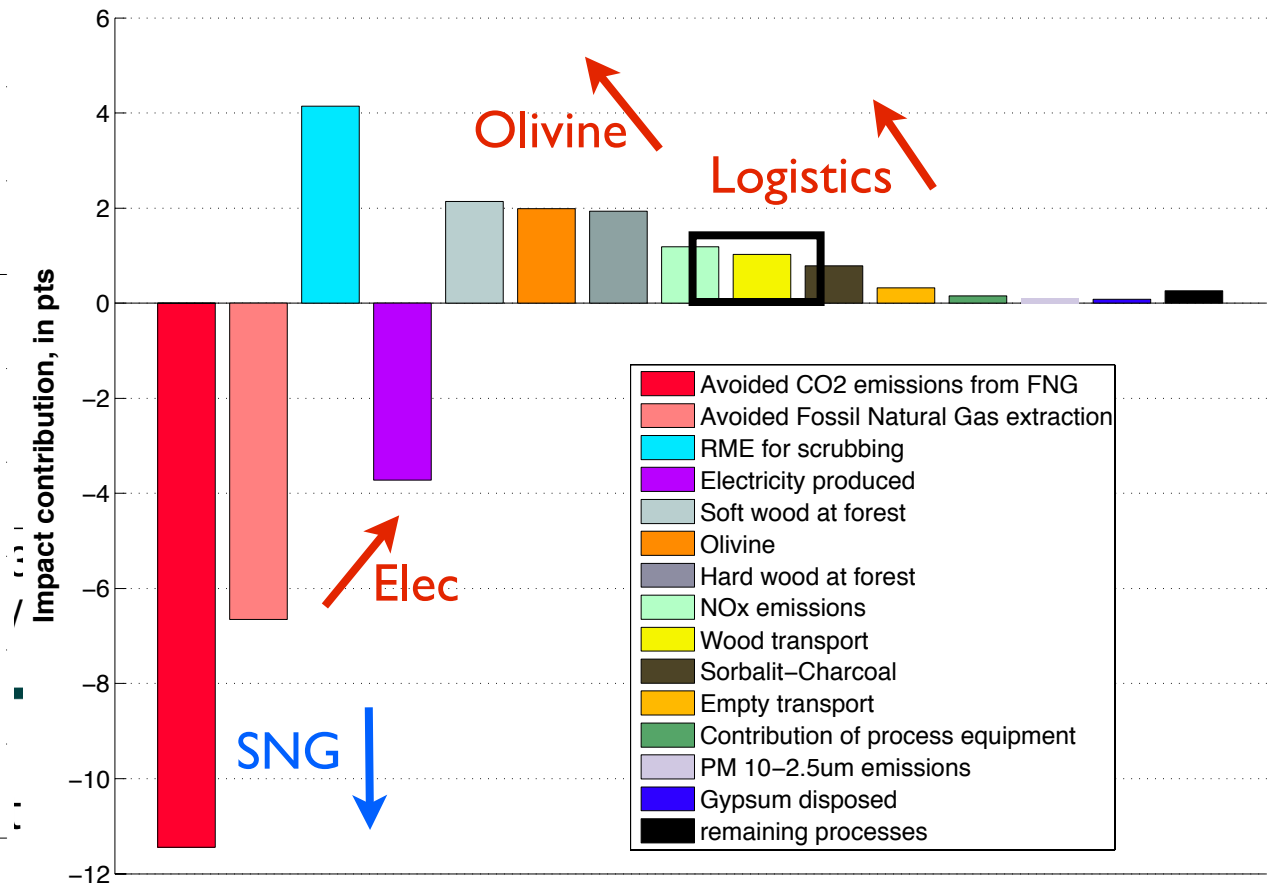
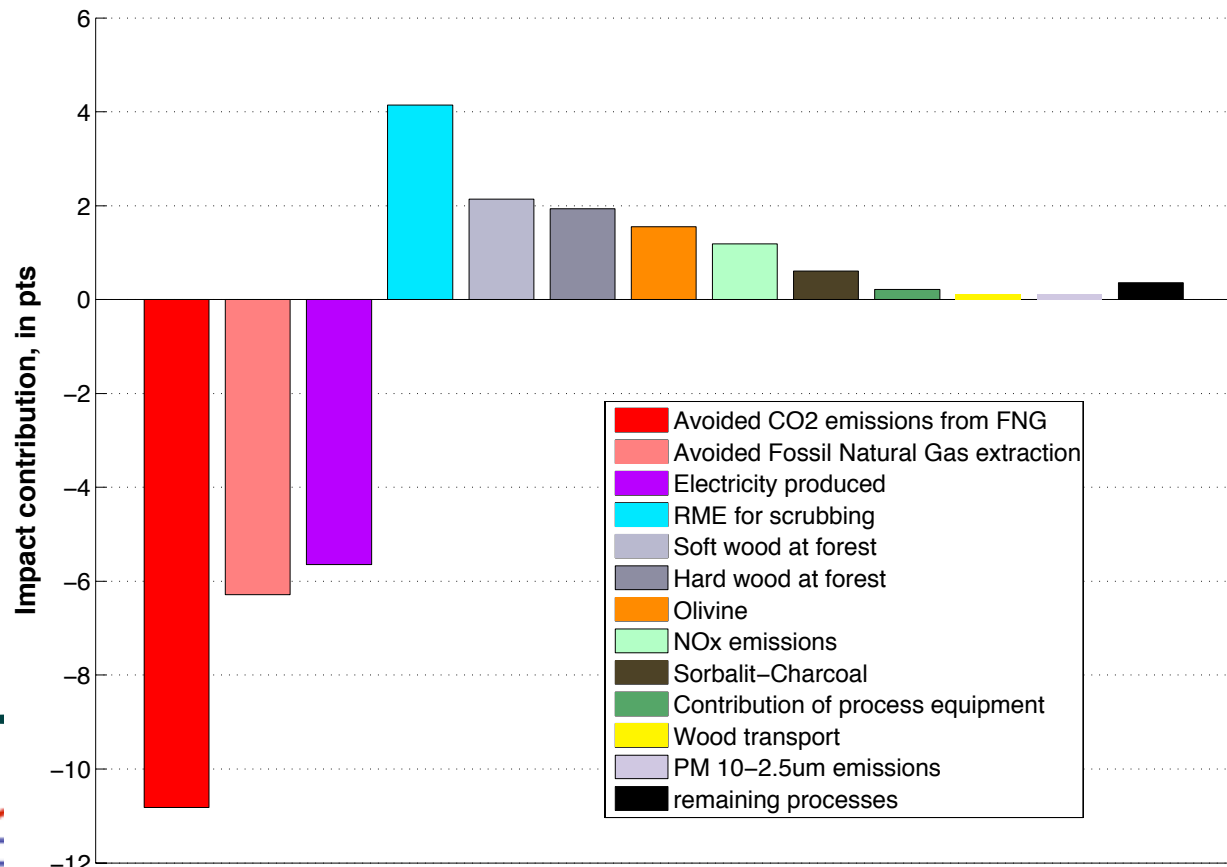
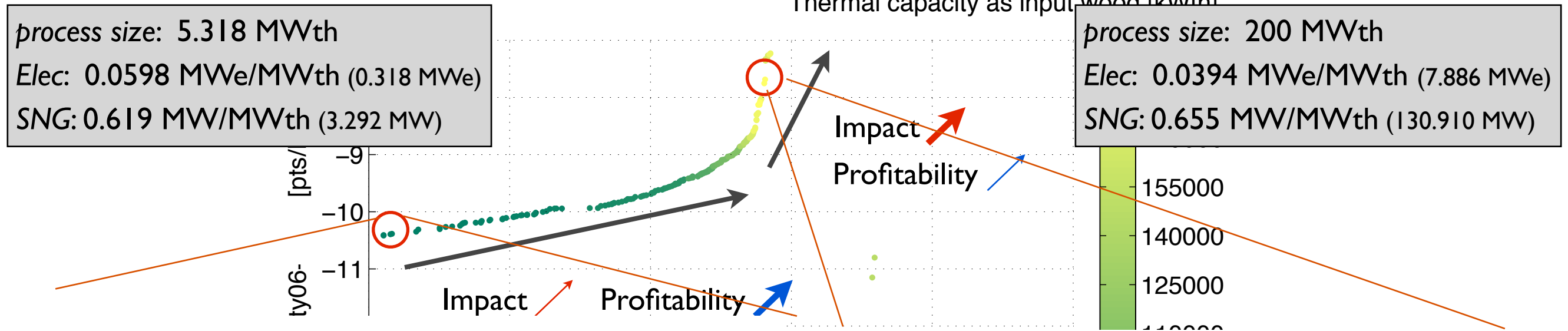
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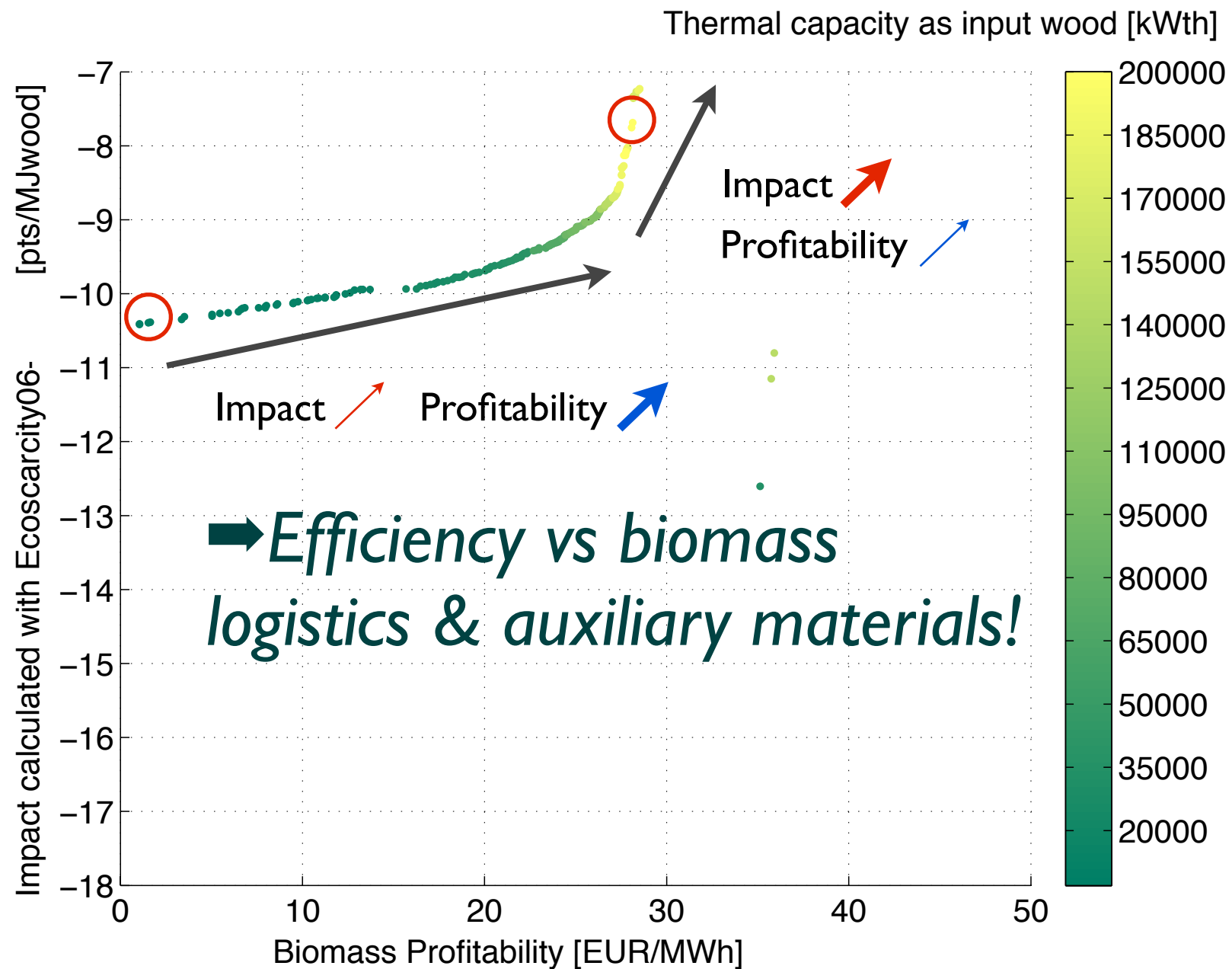
- Example with FICFB scenario (indirect gasif., atm pressure)





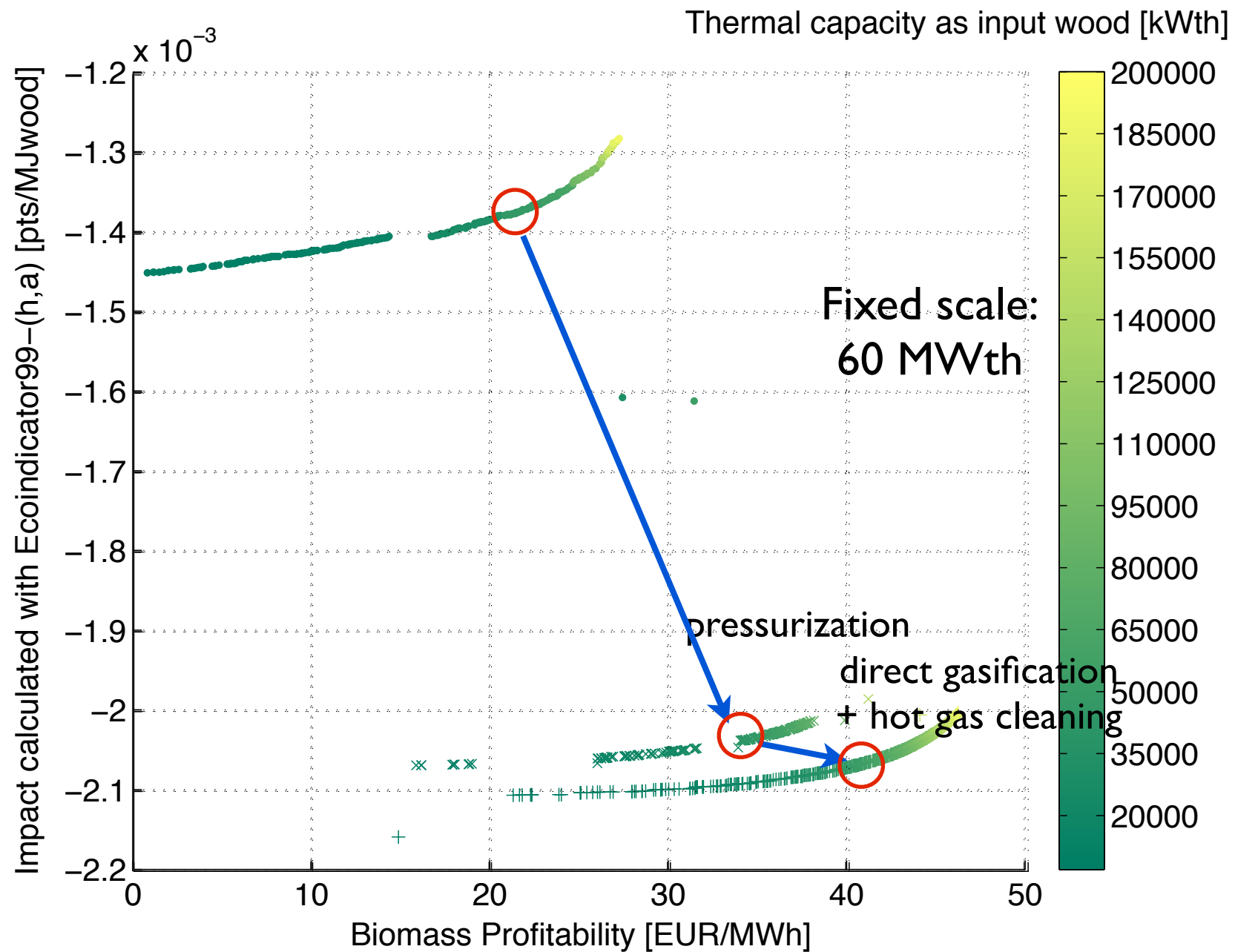
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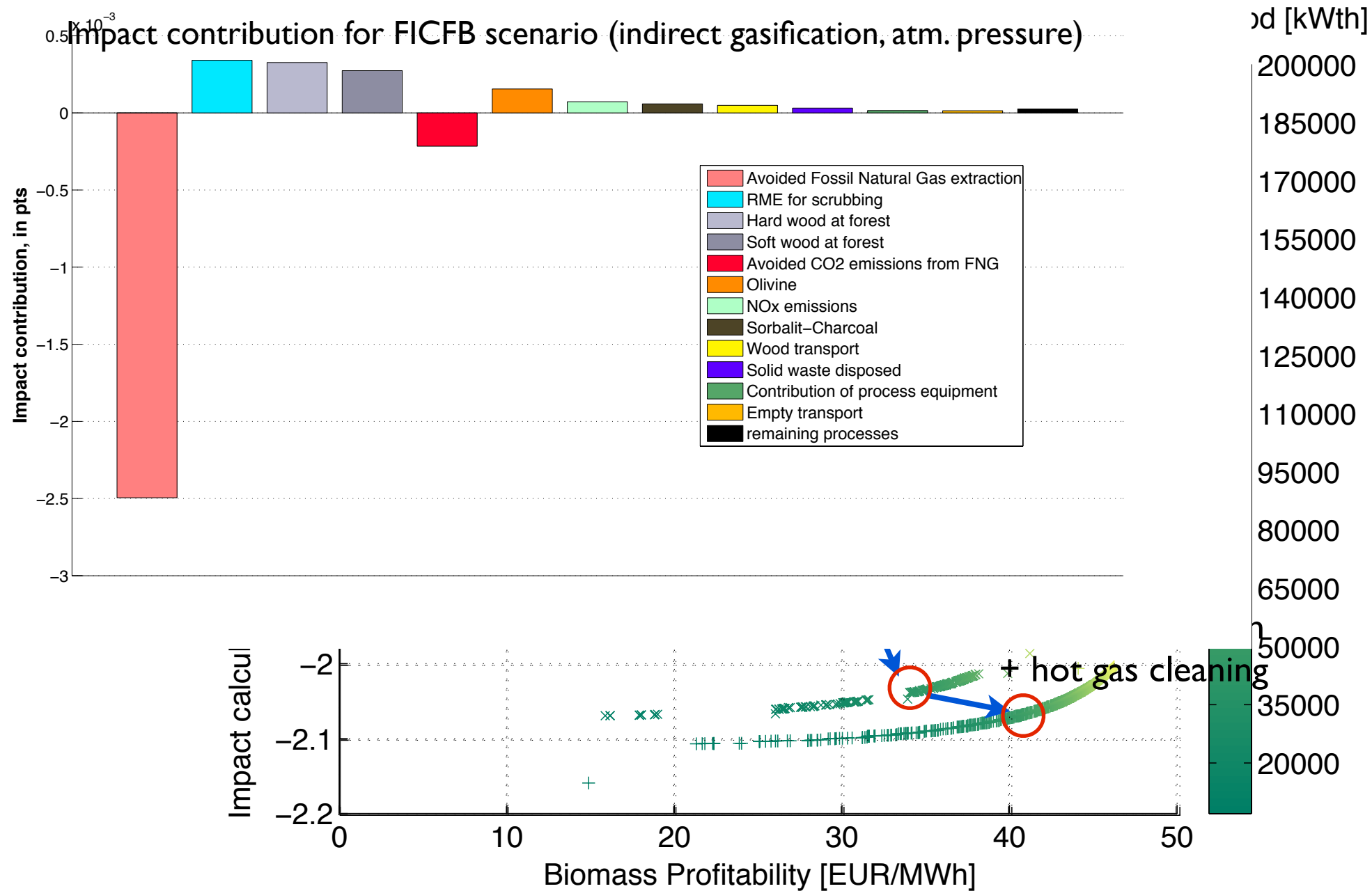
# Environomic design

- Effect of technology evolution



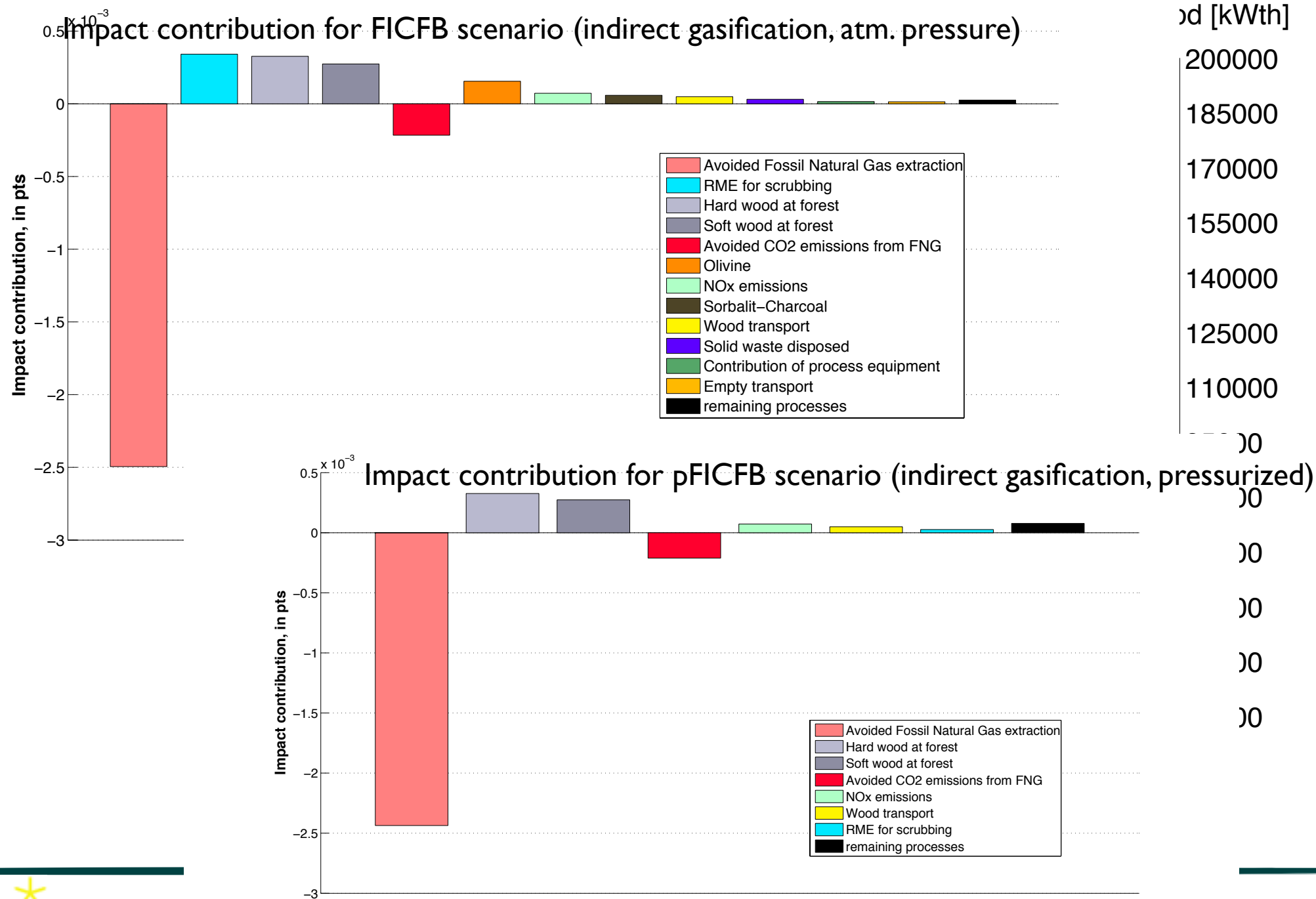
# Environomic design

## • Effect of technology evolution



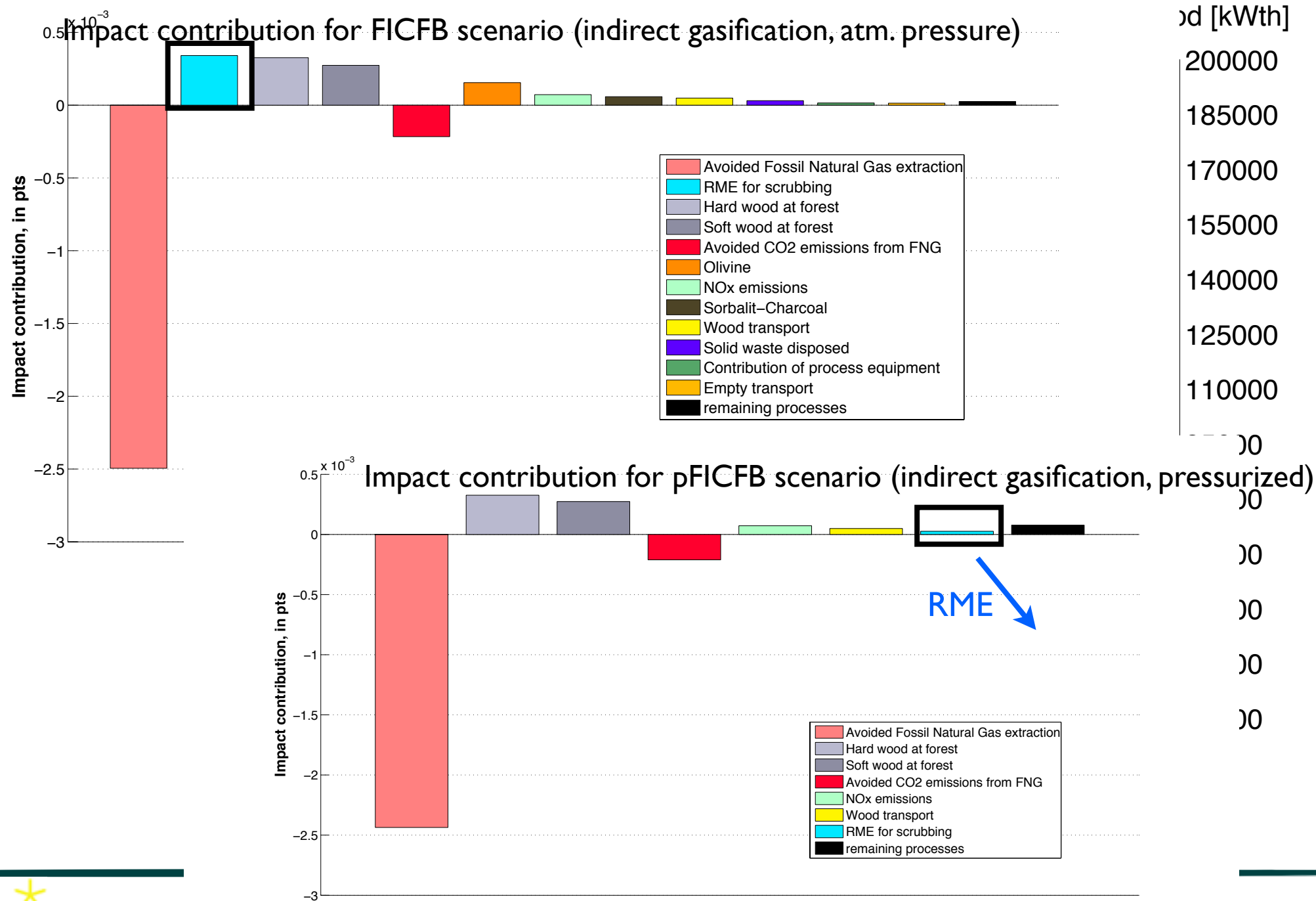
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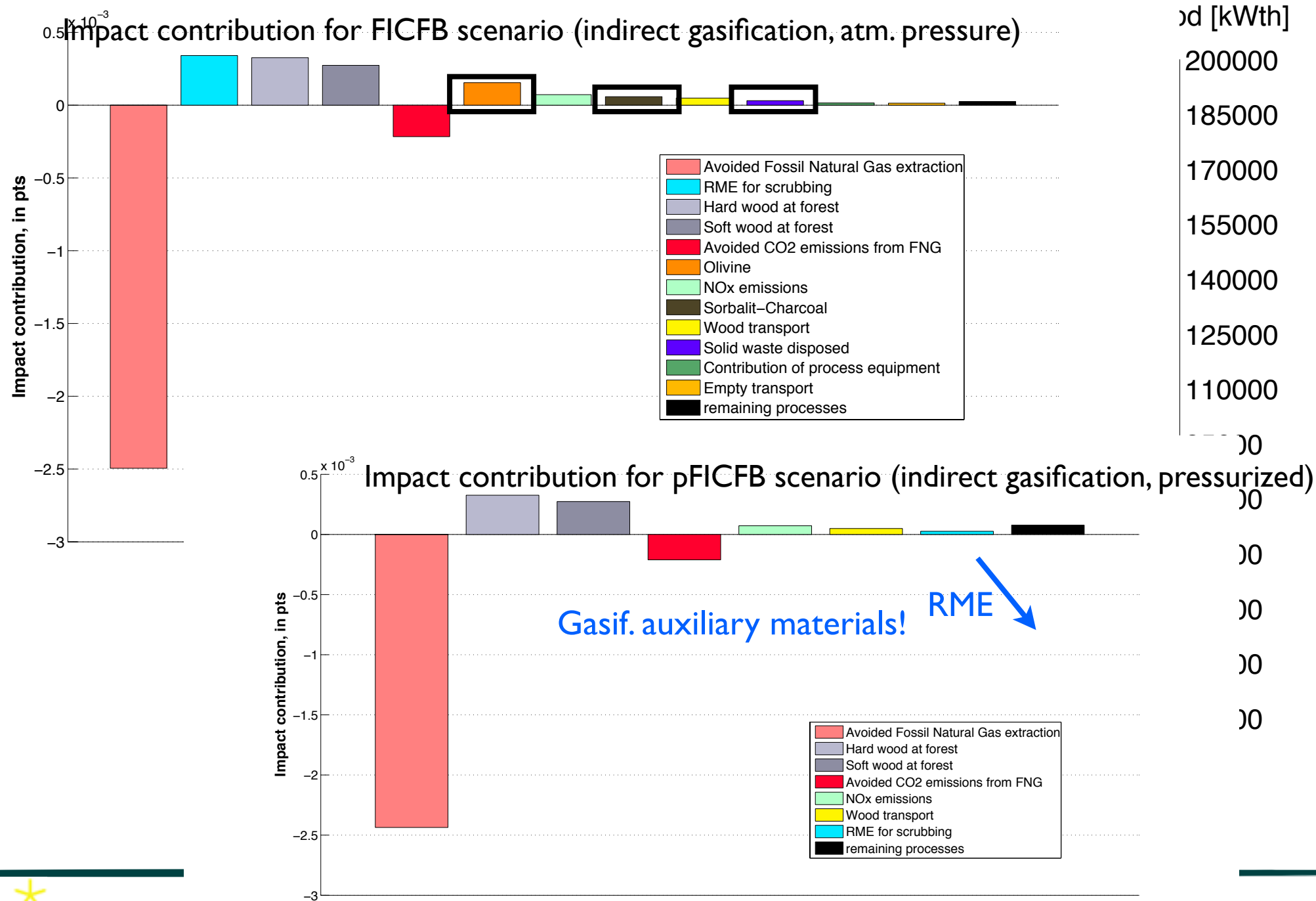
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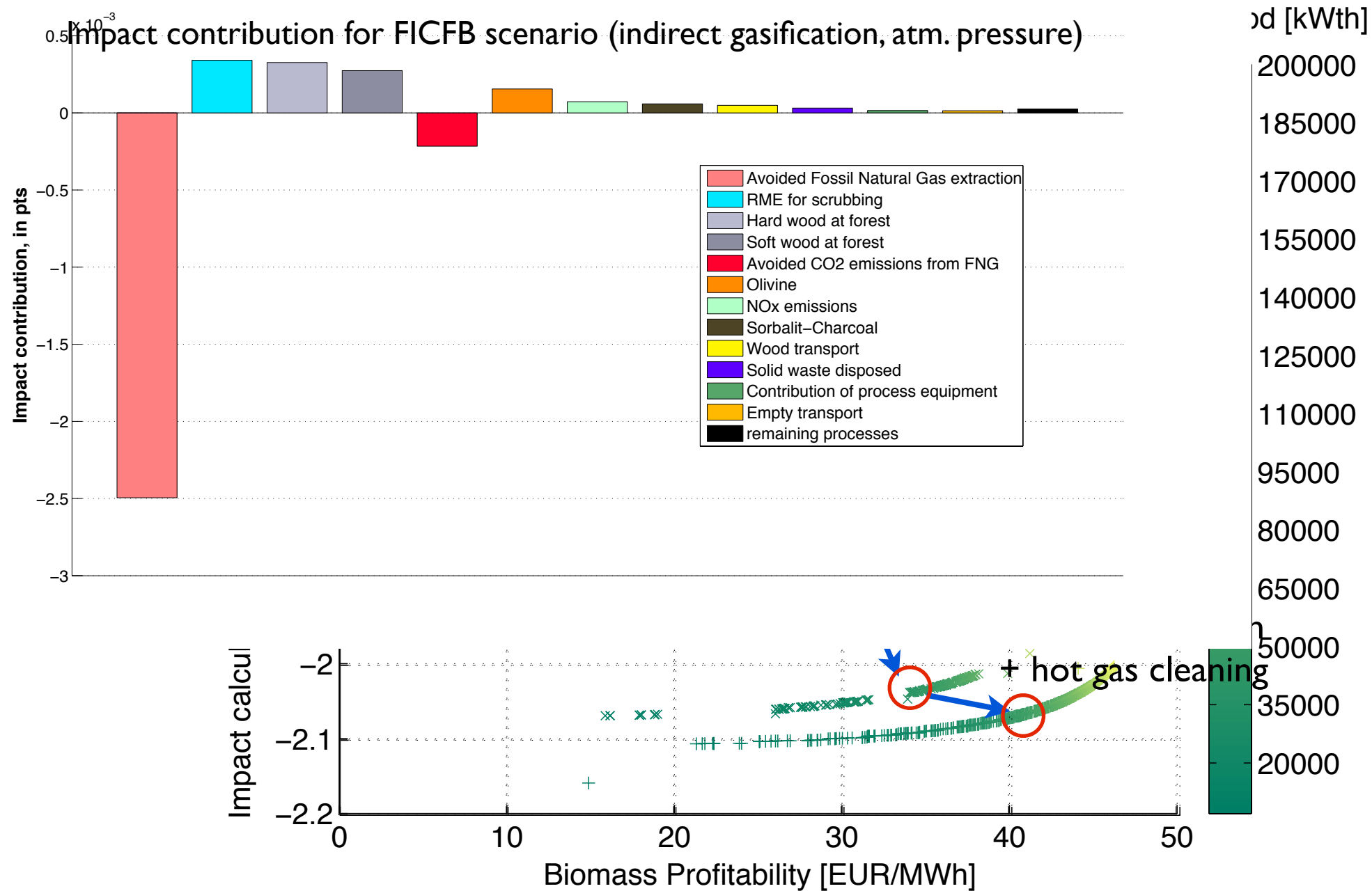
# Environomic design

## • Effect of technology evolution



# Environomic design

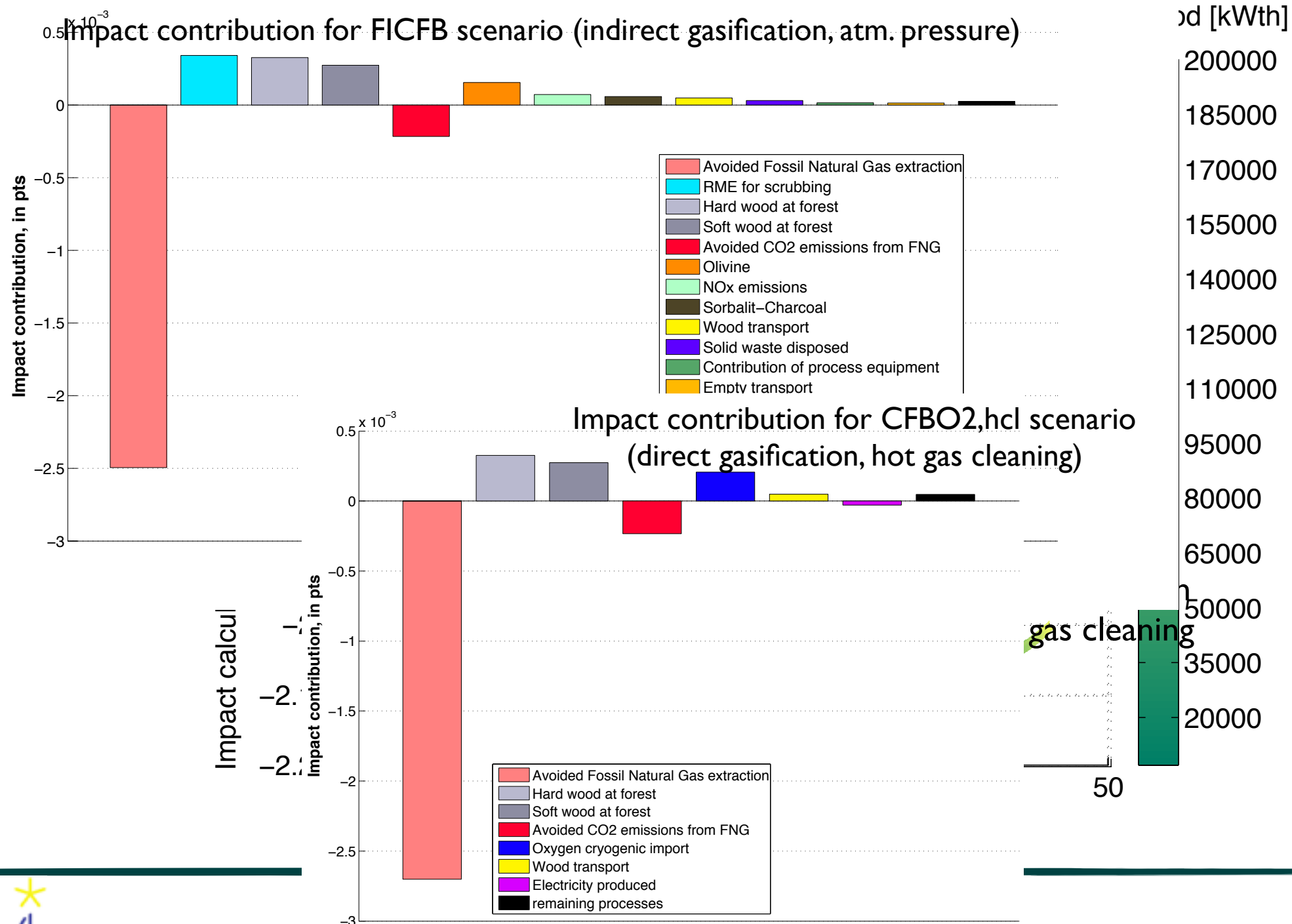
## • Effect of technology evolution





# Environomic design

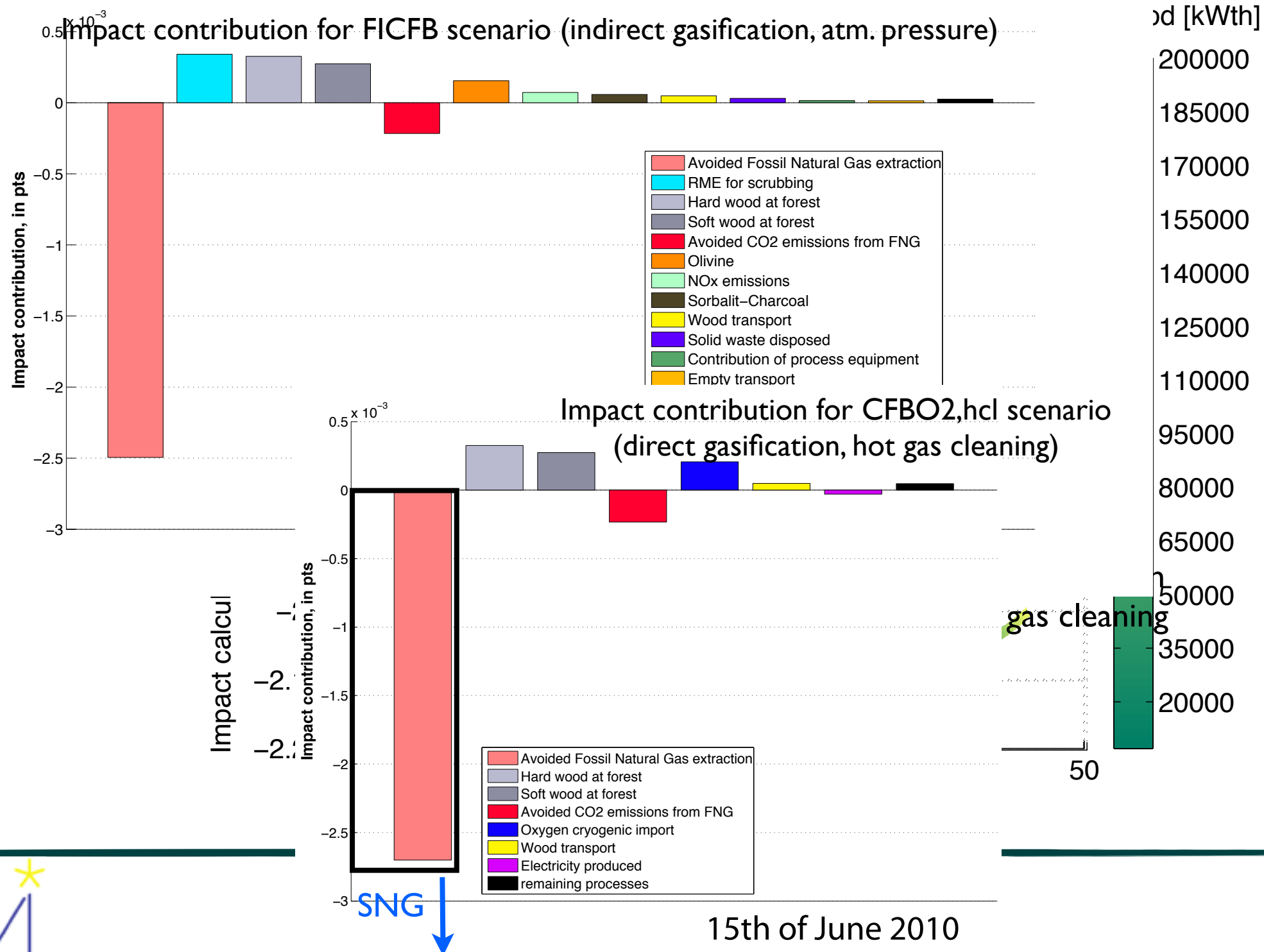
## • Effect of technology evolution



15th of June 2010

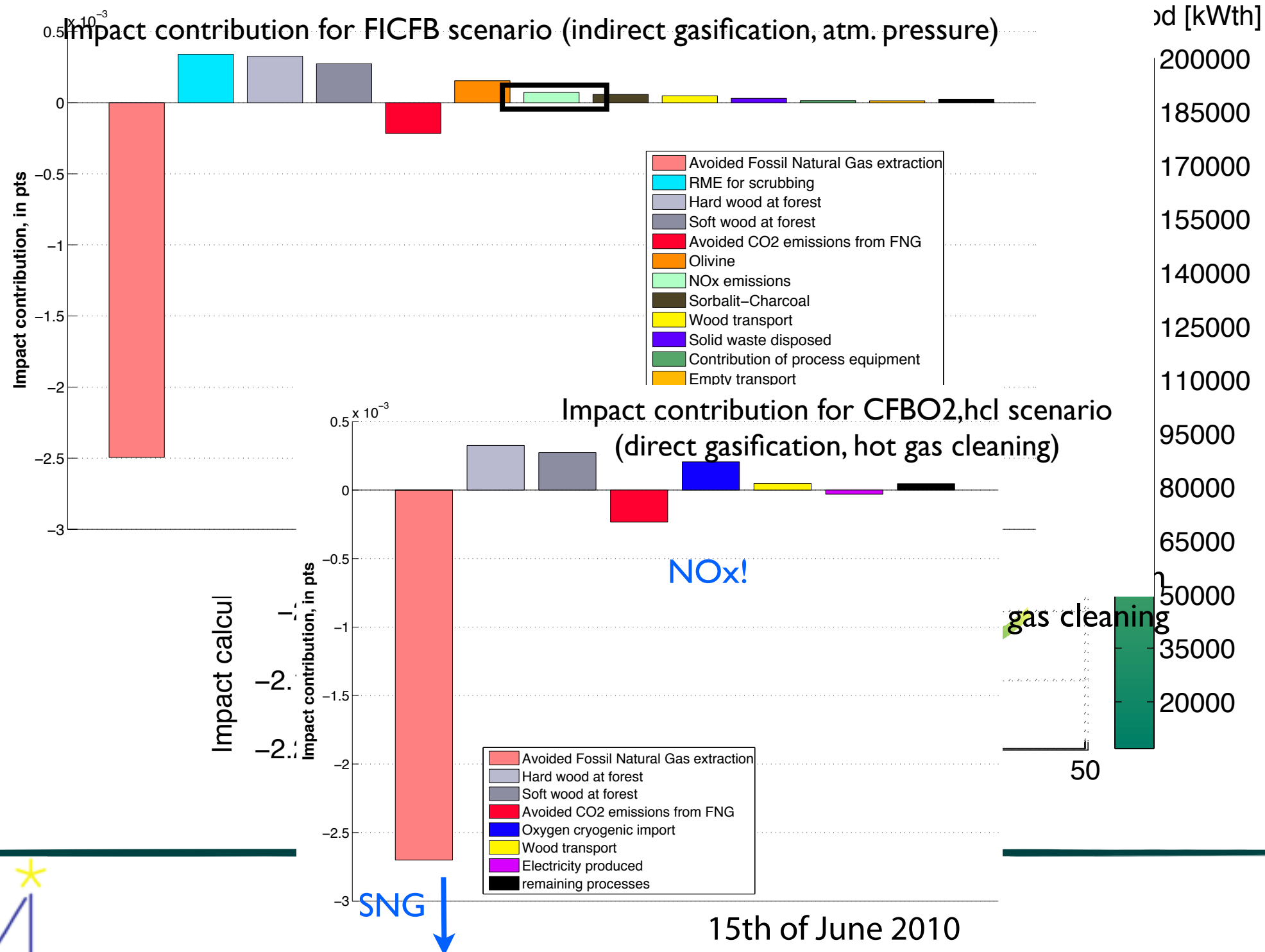
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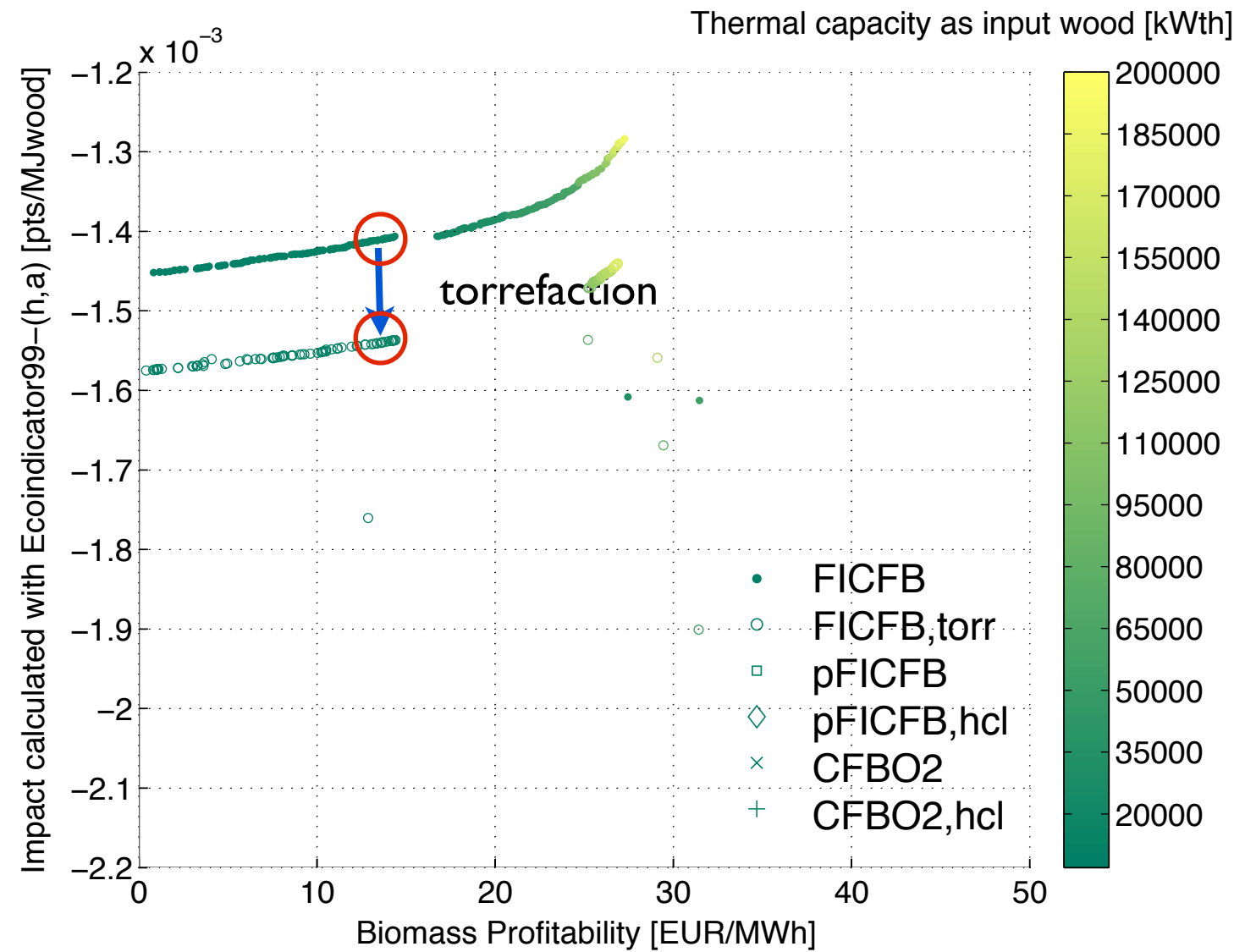
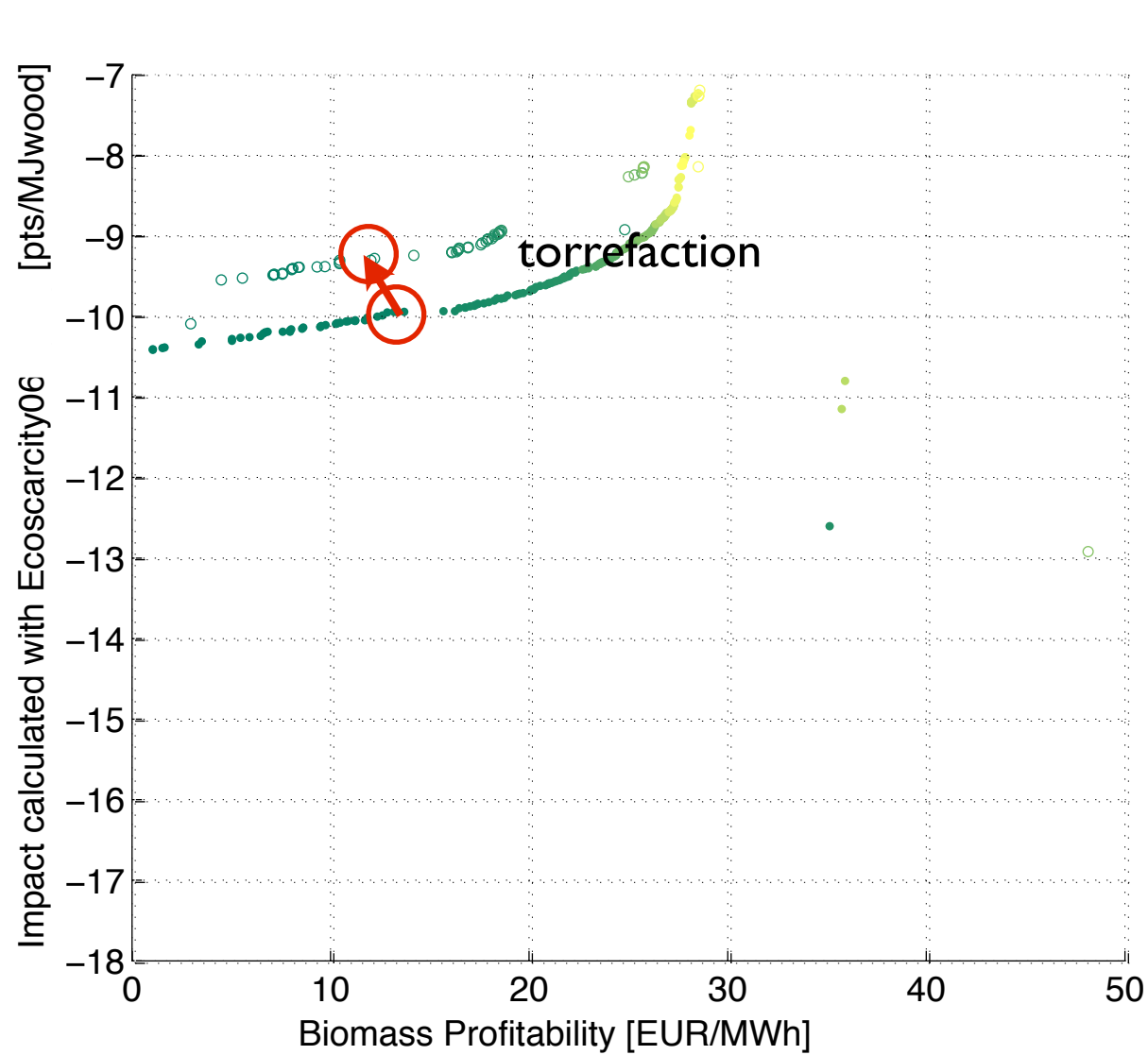
# Environomic design

## • Effect of technology evolution



# Environomic design

- Choice of environmental objective

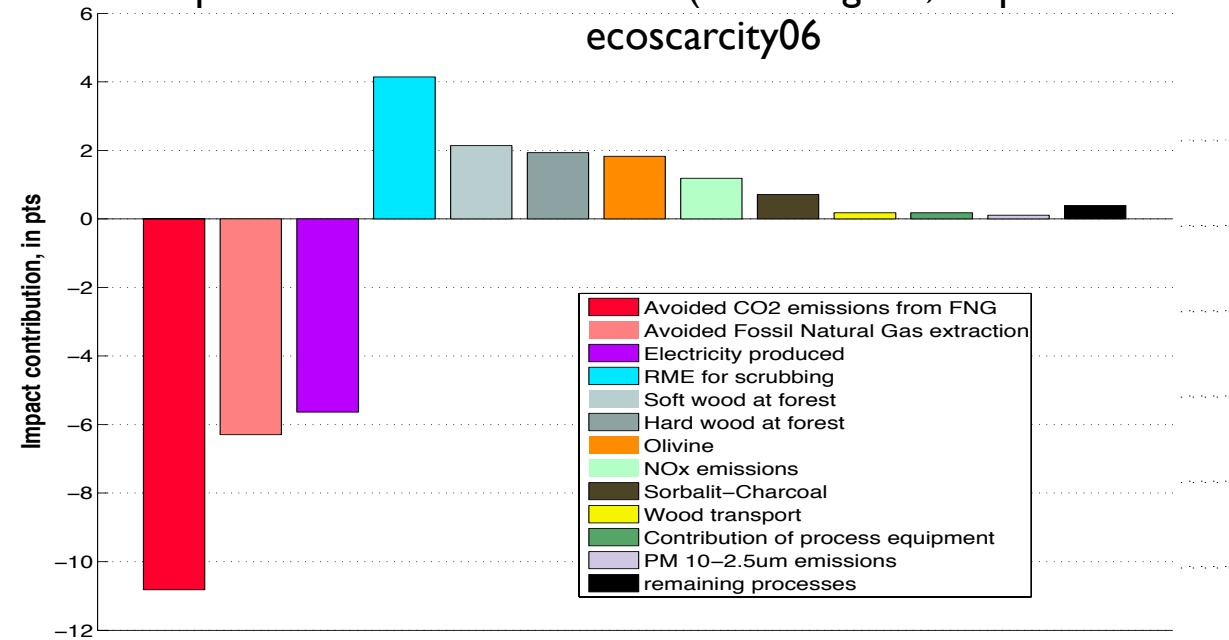


# Environomic design

## Choice of environmental objective

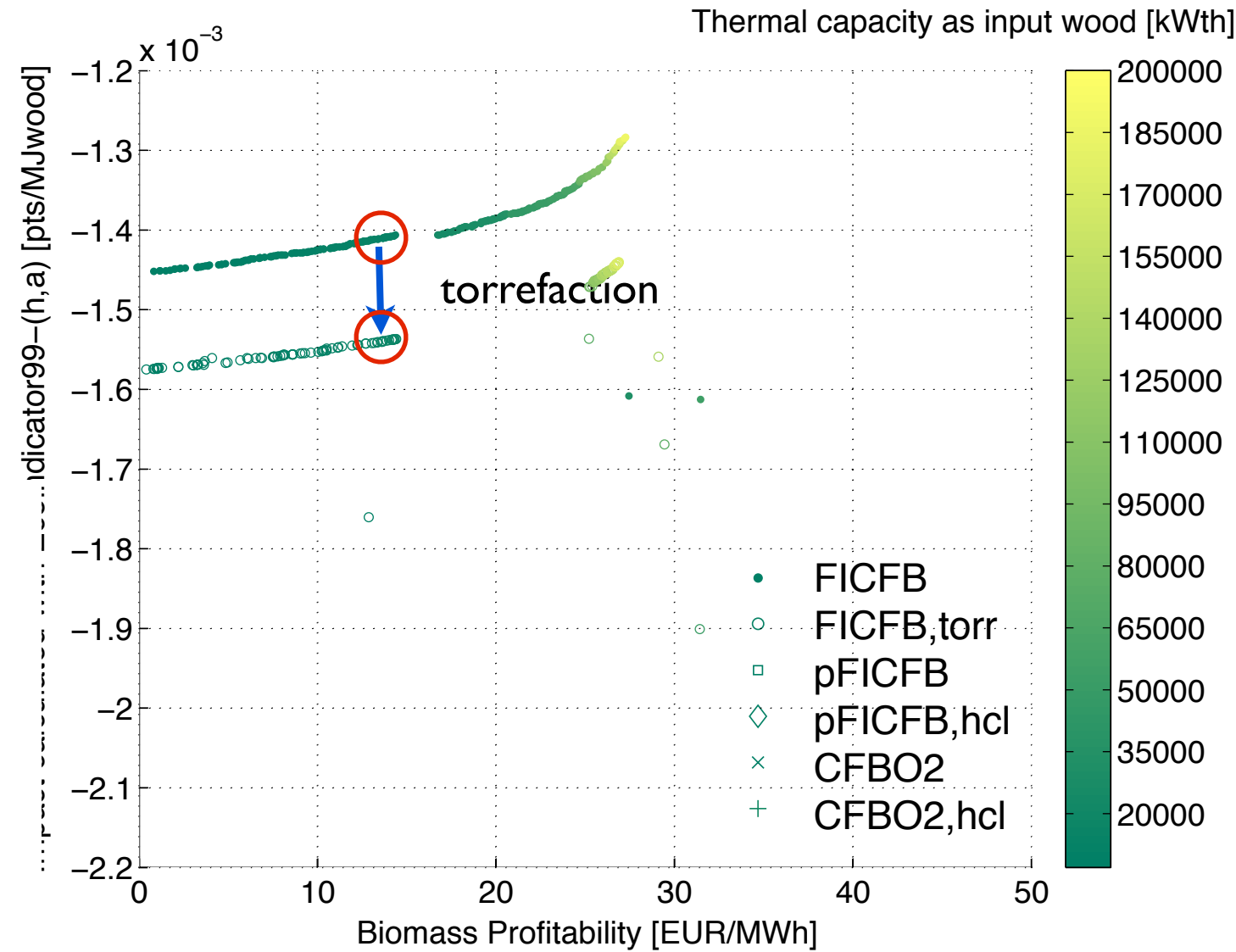
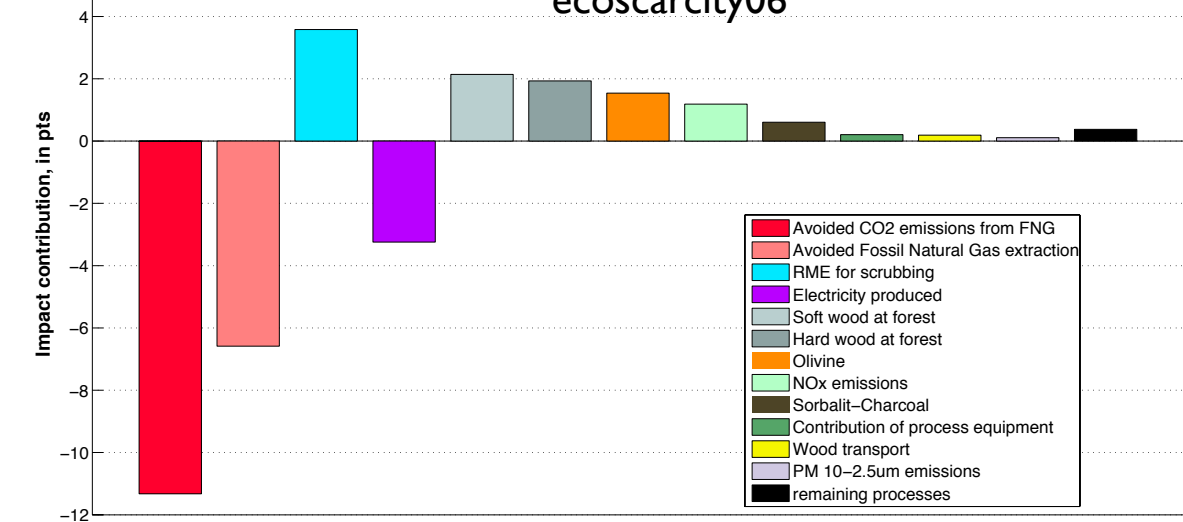
impact contribution for FICFB (indirect gasif., no pretreatment)

ecoscarcity06



impact contribution for FICFB,tor (indirect gasif, torrefaction)

ecoscarcity06

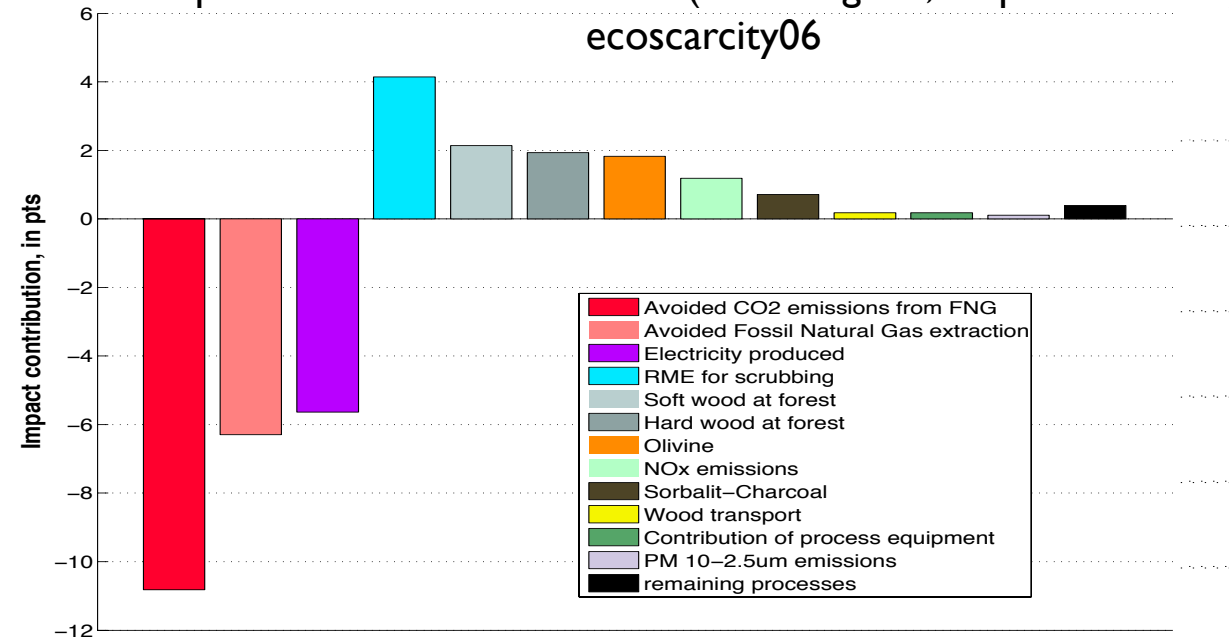


# Environomic design

## Choice of environmental objective

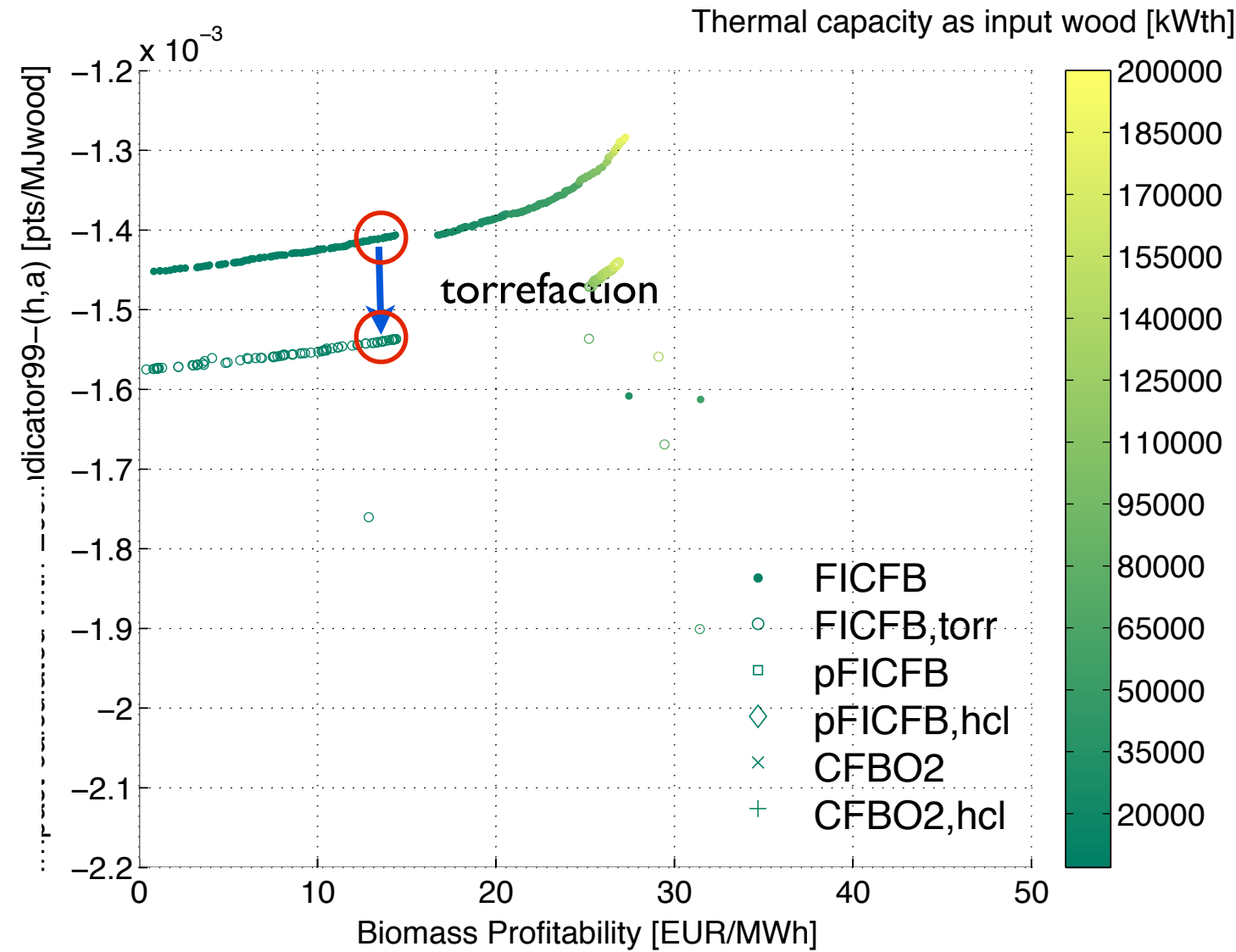
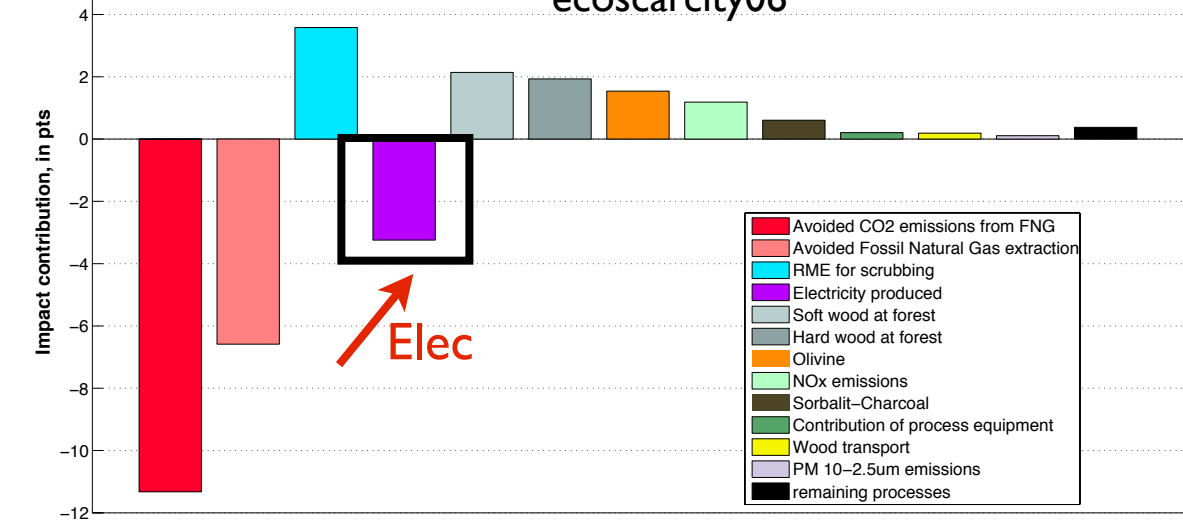
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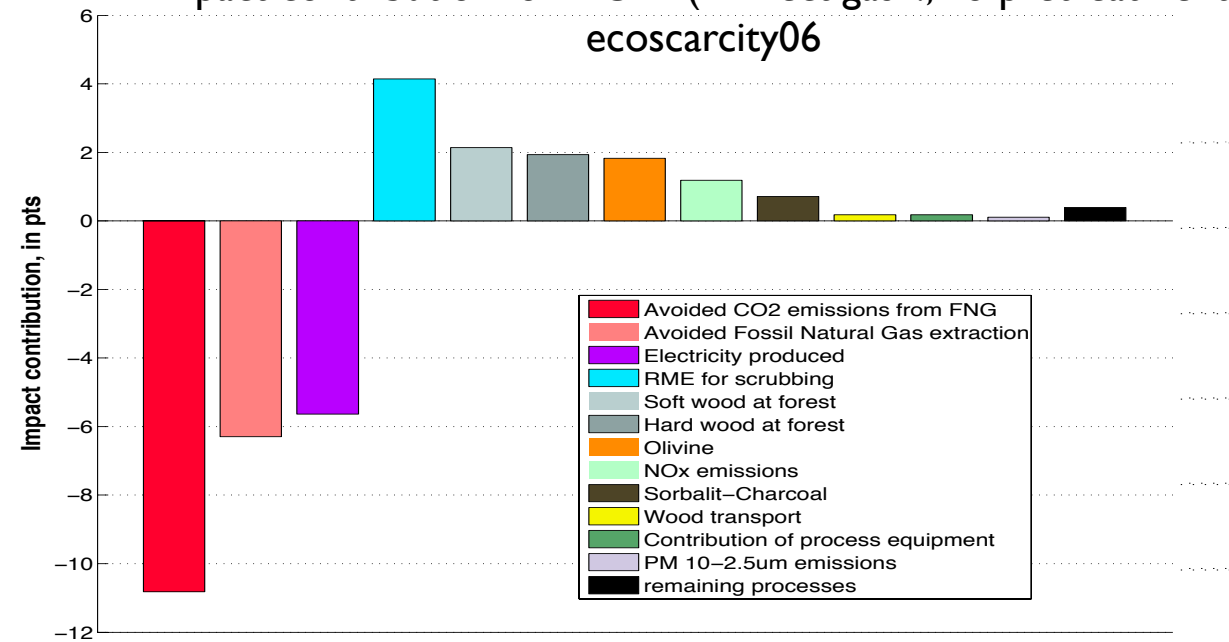
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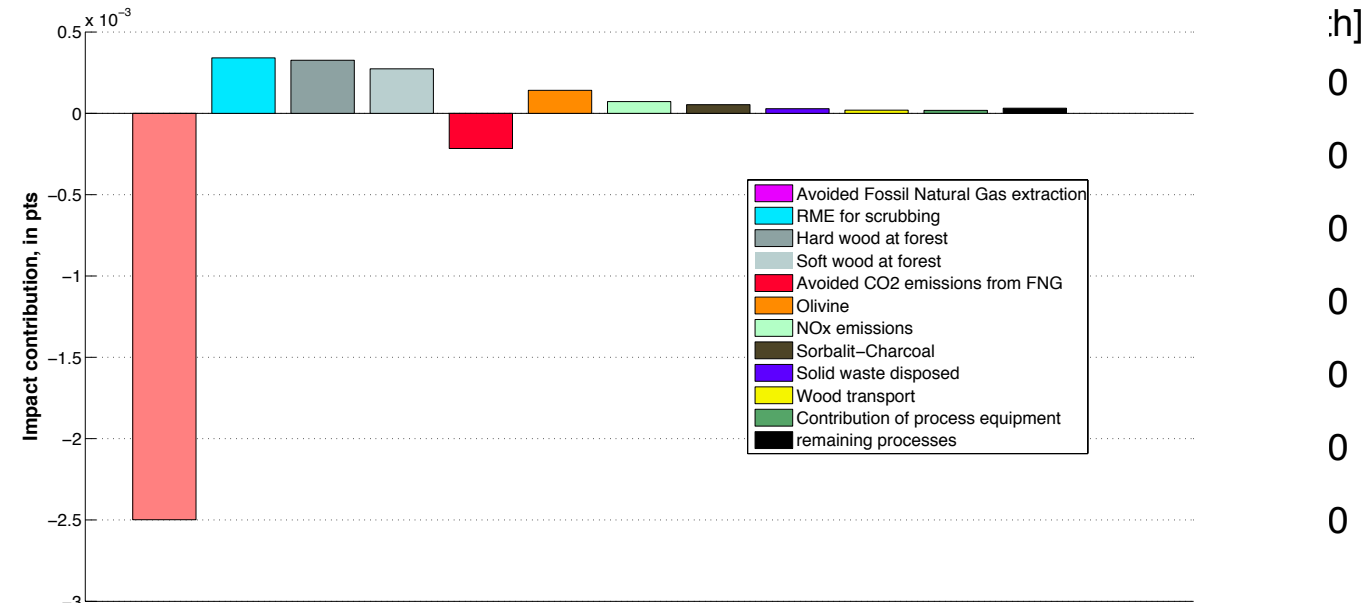
# Environomic design

## Choice of environmental objective

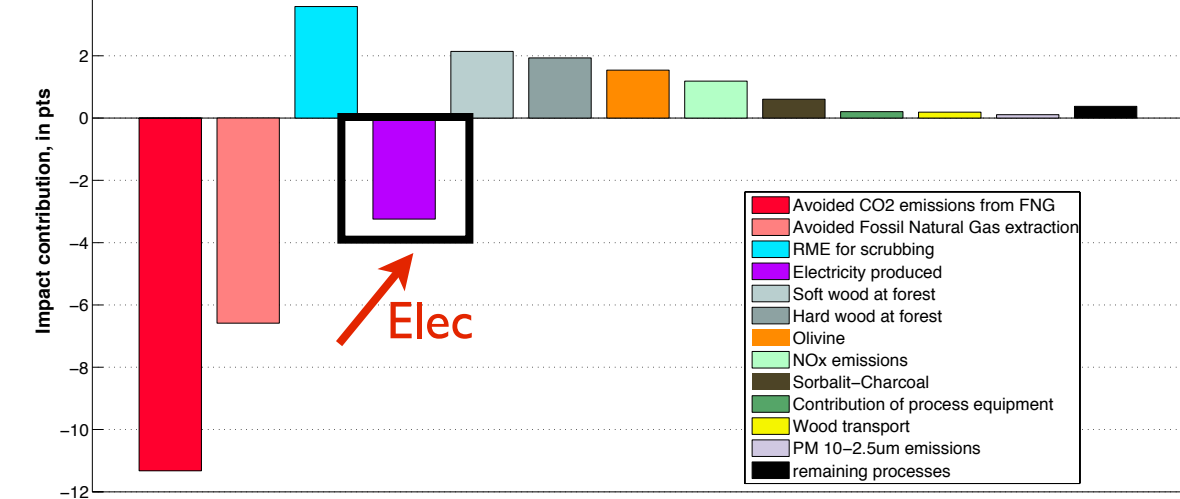
impact contribution for FICFB (indirect gasif., no pretreatment)  
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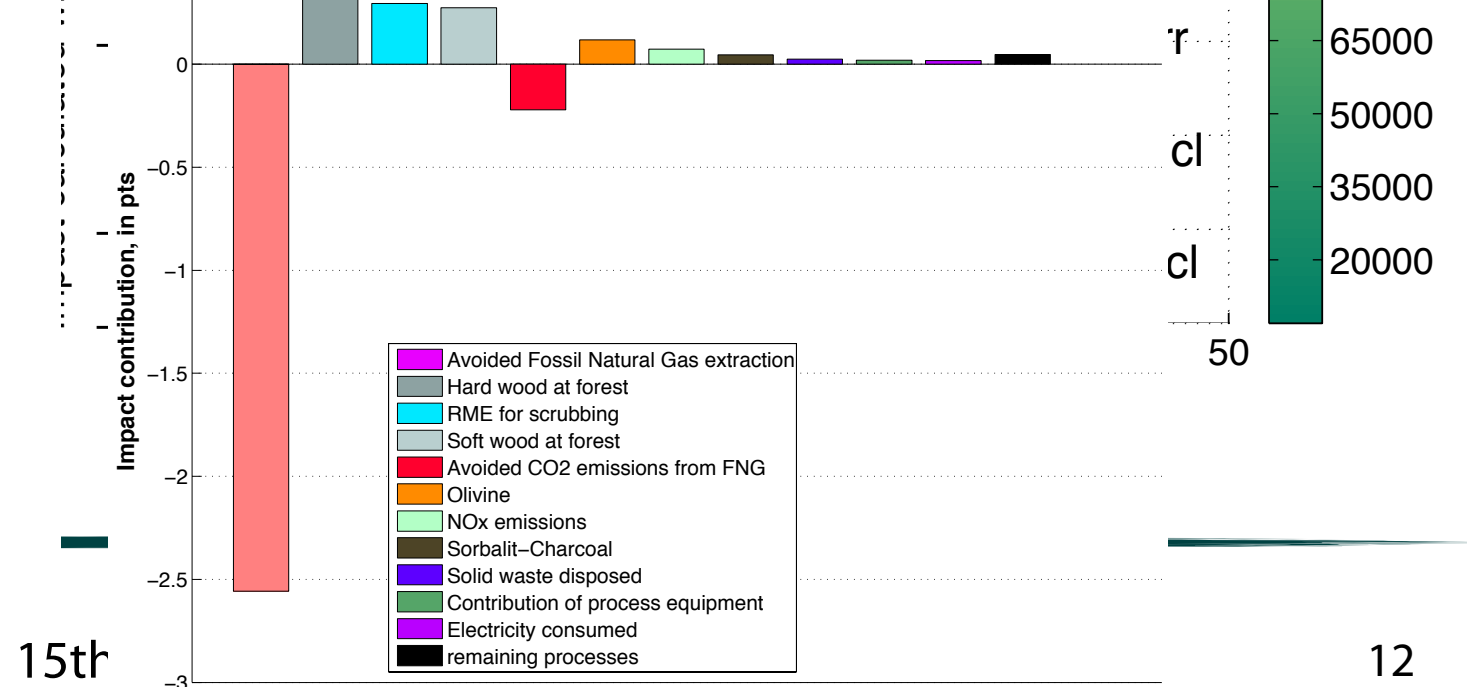
impact contribution for FICFB (indirect gasif, no pretreatment)  
ecoindicator99-(h,a)



impact contribution for FICFB,tor (indirect gasif, torrefaction)  
ecoscarcity06



impact contribution for FICFB,tor (indirect gasification, torrefaction)  
ecoindicator99-(h,a)

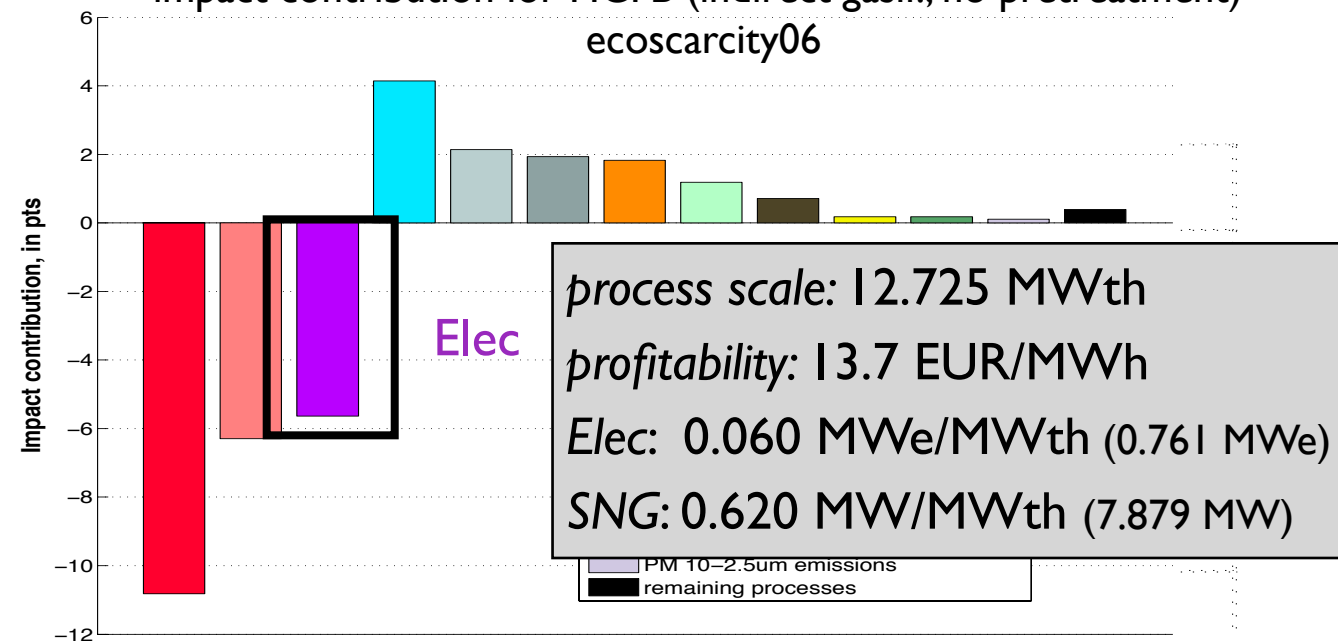




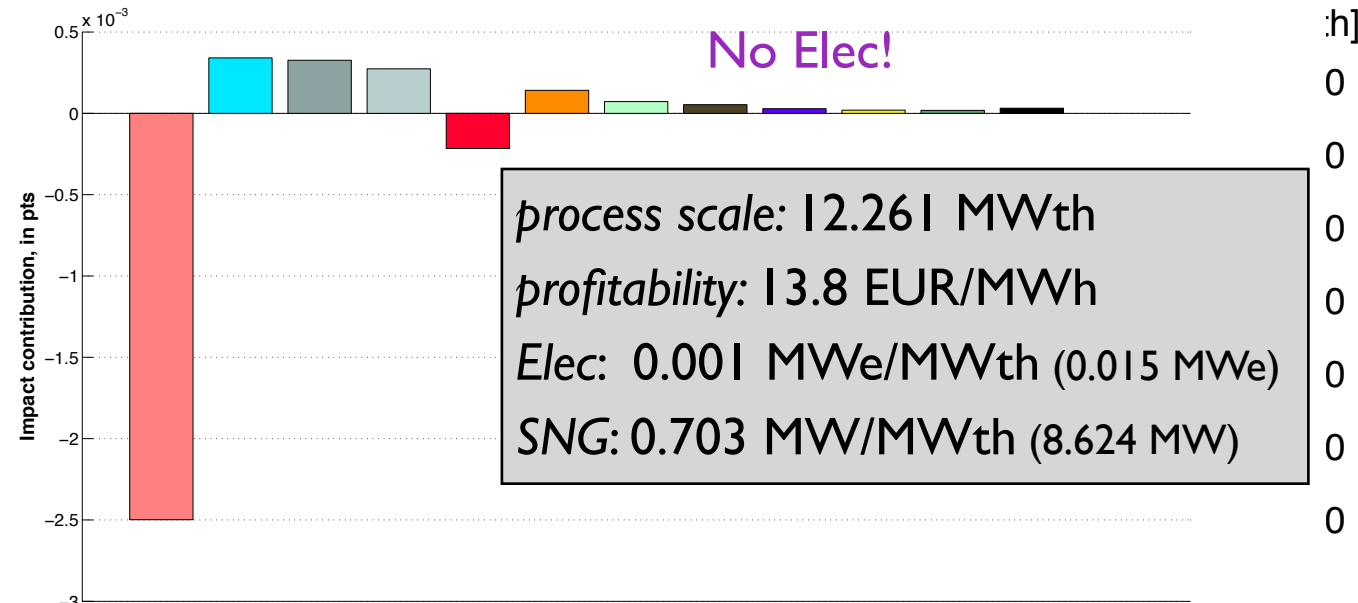
# Environomic design

## Choice of environmental objective

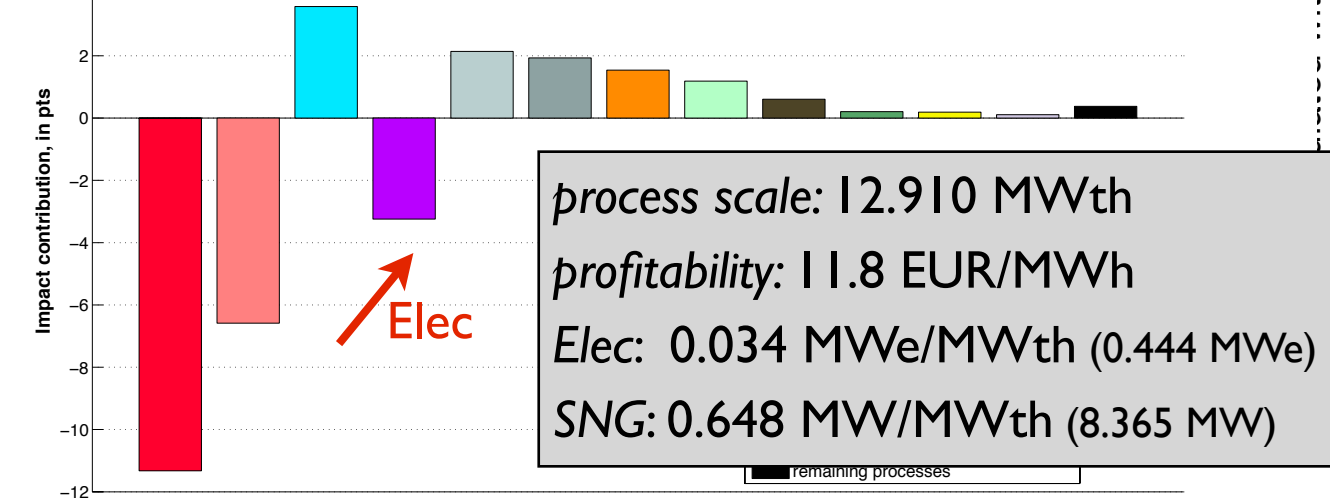
impact contribution for FICFB (indirect gasif., no pretreatment)  
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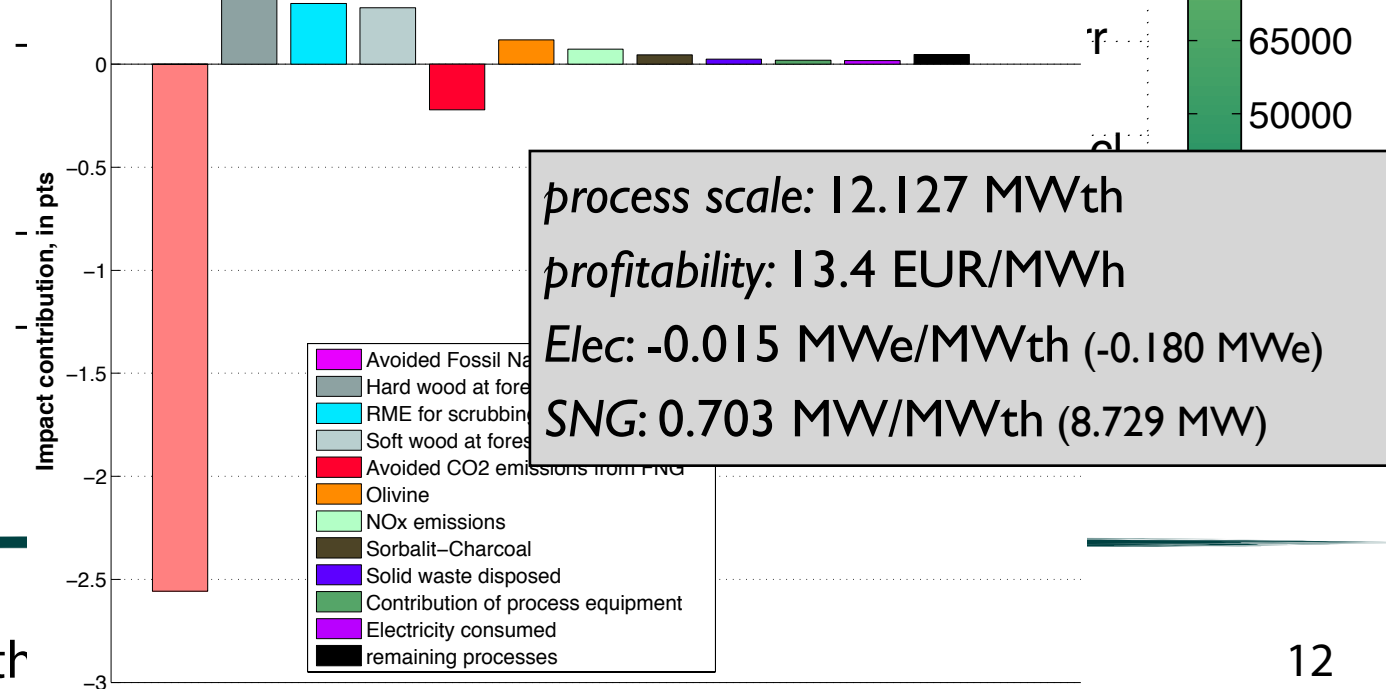
impact contribution for FICFB (indirect gasif, no pretreatment)  
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impact contribution for FICFB,tor (indirect gasif, torrefaction)  
ecoscarcity06



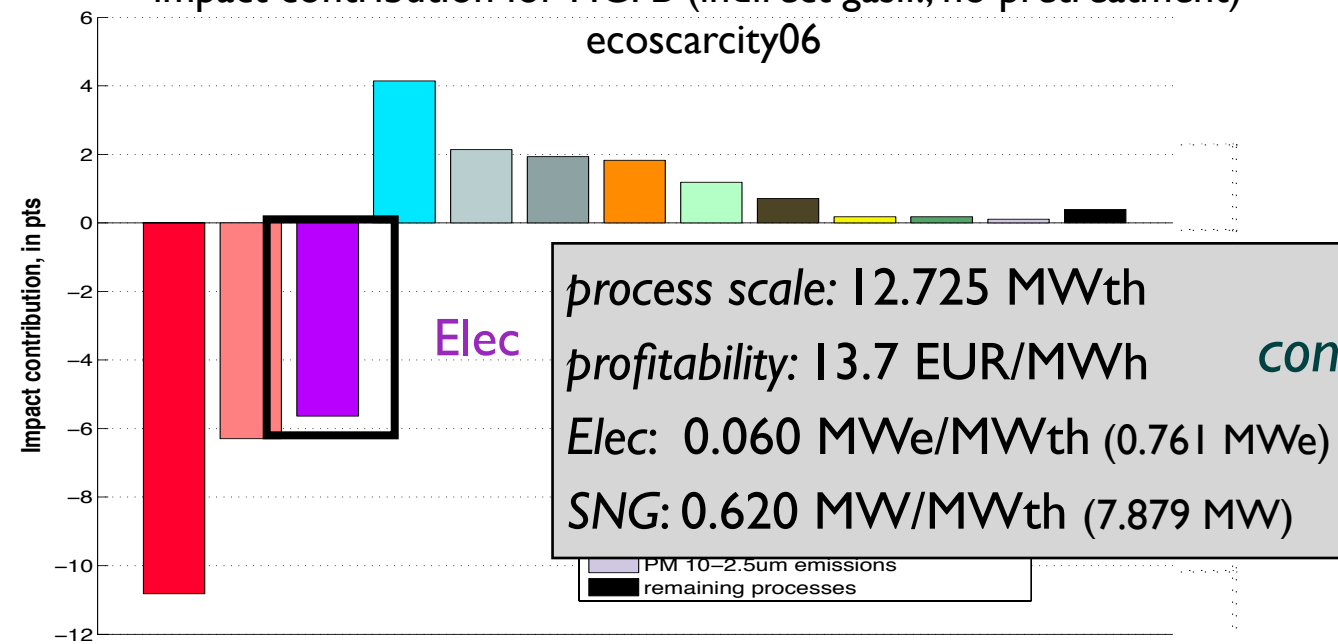
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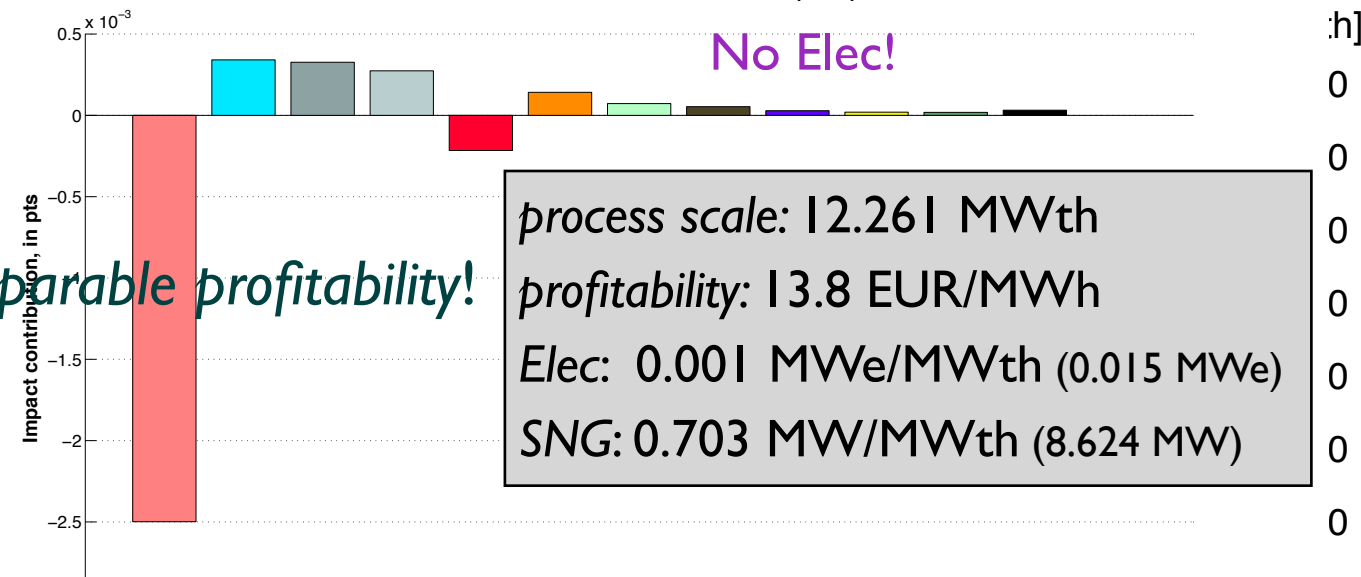
# Environomic design

## Choice of environmental objective

impact contribution for FICFB (indirect gasif., no pretreatment)  
ecoscarcity06

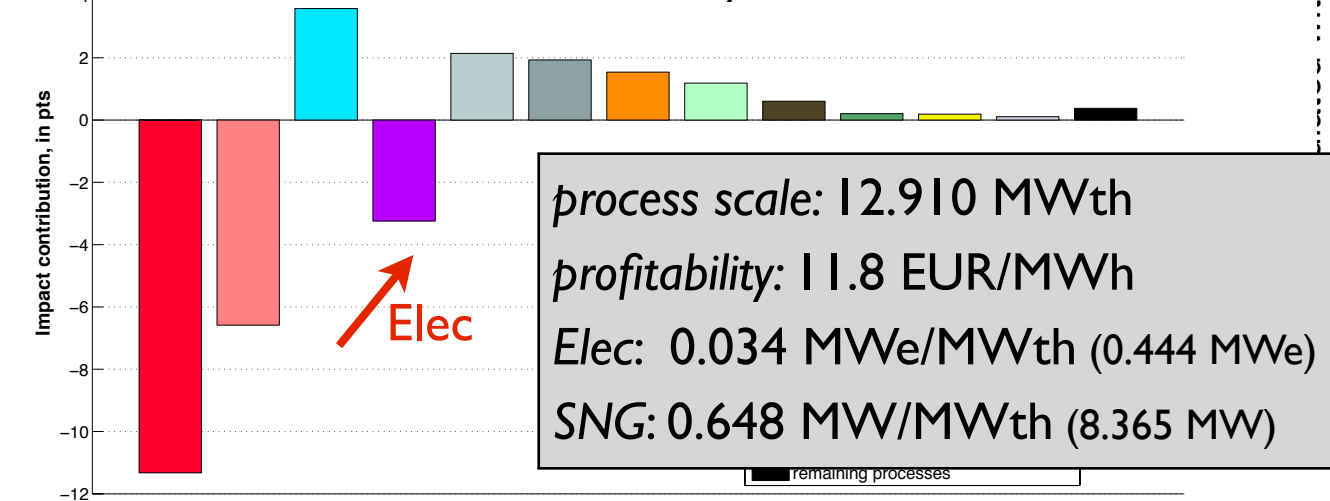


impact contribution for FICFB (indirect gasif., no pretreatment)  
ecoindicator99-(h,a)

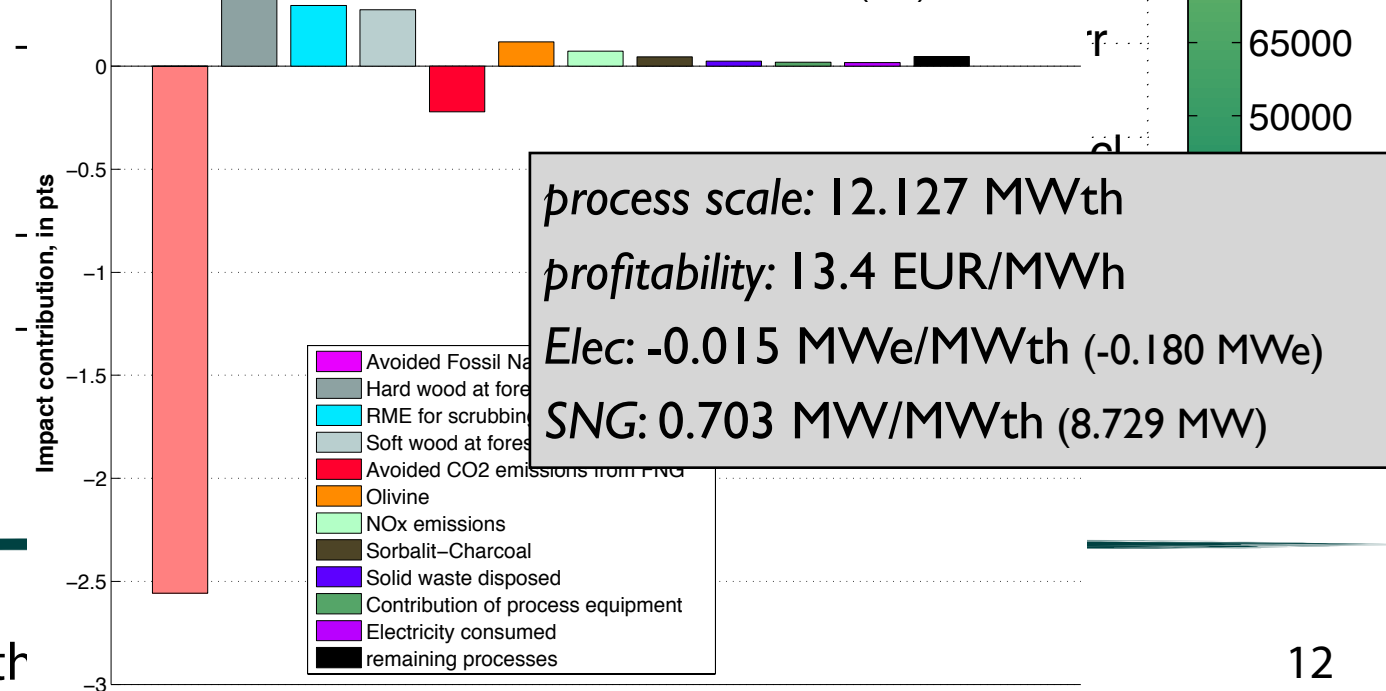


comparable profitability!

impact contribution for FICFB,tor (indirect gasif, torrefaction)  
ecoscarcity06

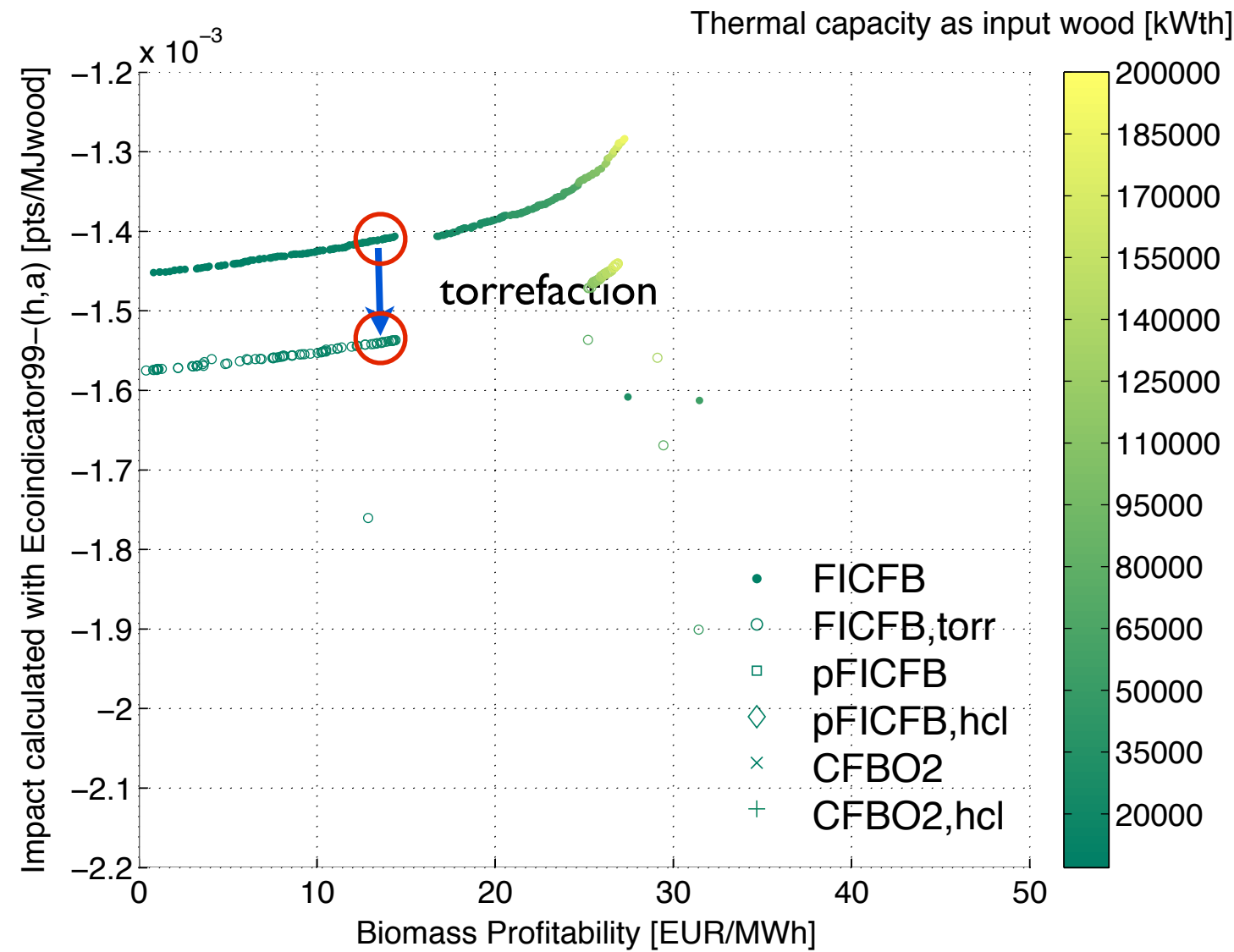
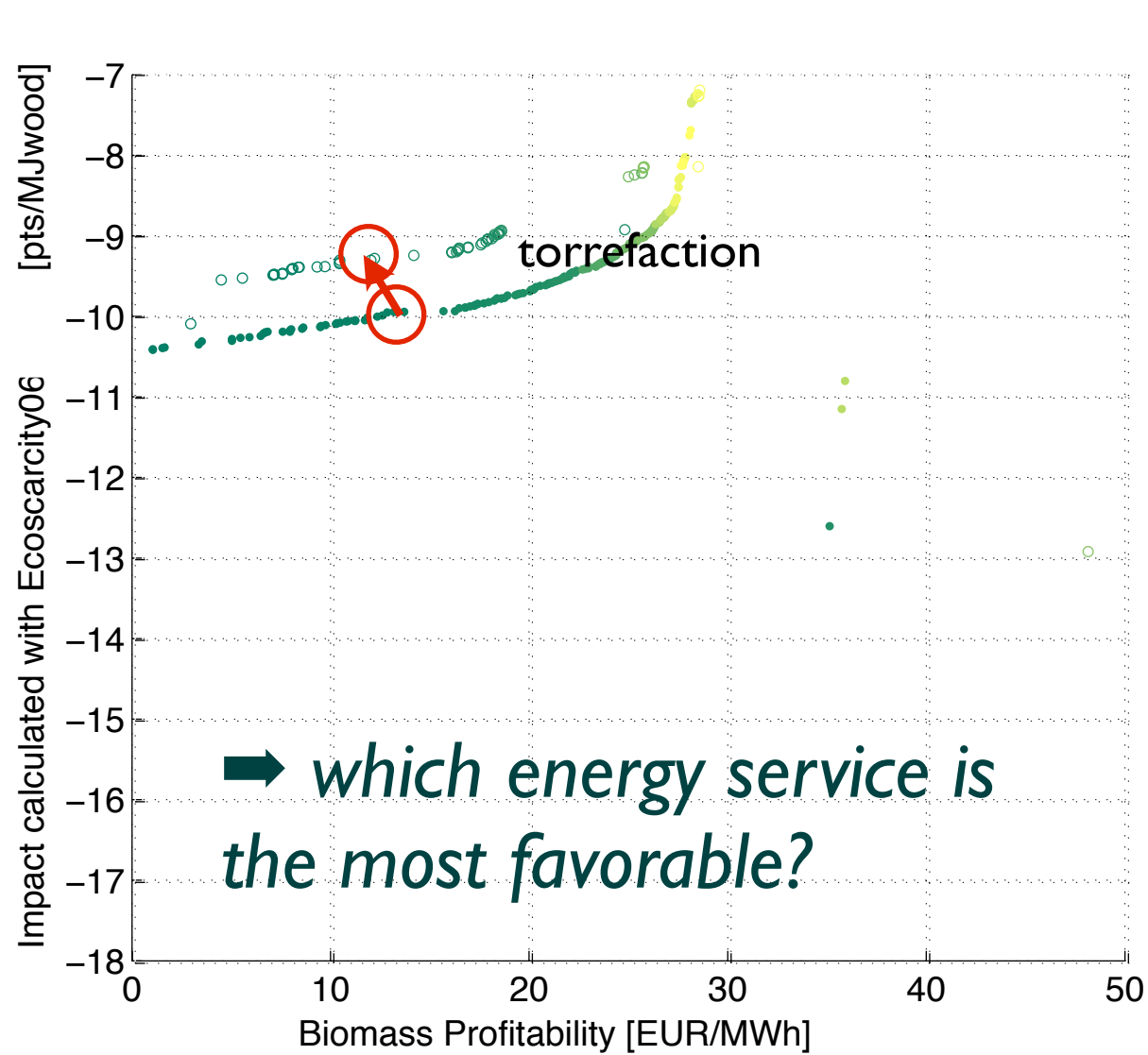


impact contribution for FICFB,tor (indirect gasification, torrefaction)  
ecoindicator99-(h,a)



# Environomic design

- Choice of environmental objective



# Change in optimization strategy

- Polygeneration effects
- Influence of environmental objective on optimal process design
  - ➔ 3 objectives
    - SNG
    - Electricity
    - Environmental impact
  - FICFB scenario
    - Fixed scale (20 MWth)
    - operating conditions



# Change in optimization strategy

- Polygeneration effects
- Influence of environmental objective on optimal process design

## ➔ 3 objectives

- SNG
- Electricity
- Environmental impact

*Ecoindicator99-(h,a) (Single score)*

*Ecoscarcity06 (Single score)*

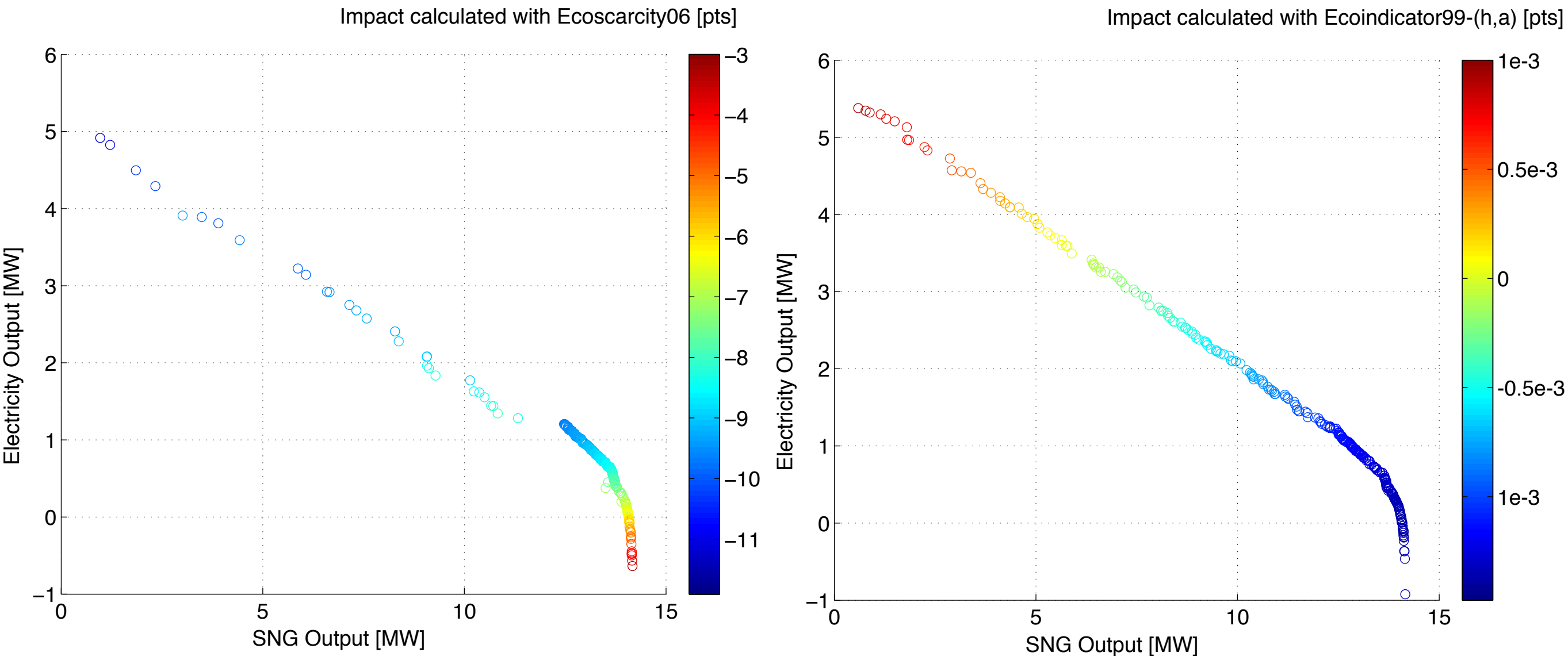
- FICFB scenario

- Fixed scale (20 MWth)
- operating conditions



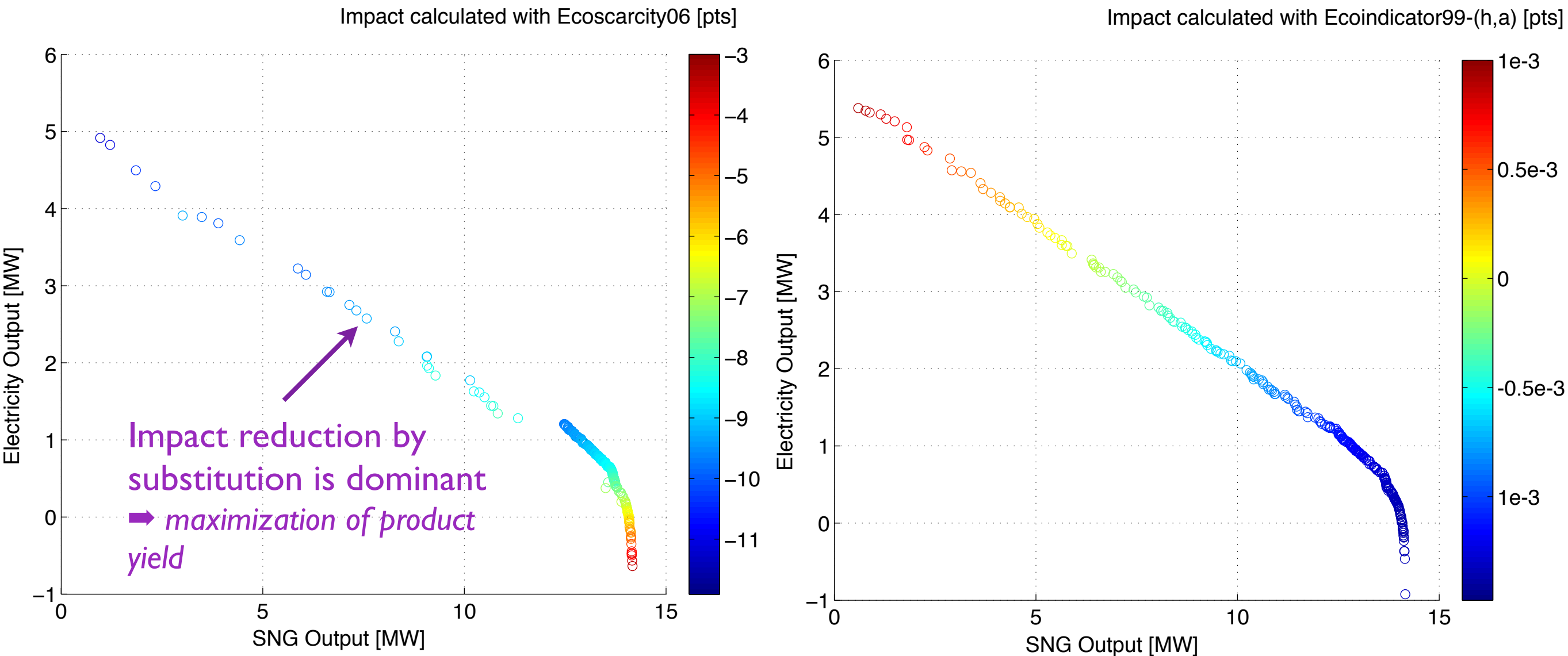
# Environomic design

- Influence of polygeneration and objective function



# Environomic design

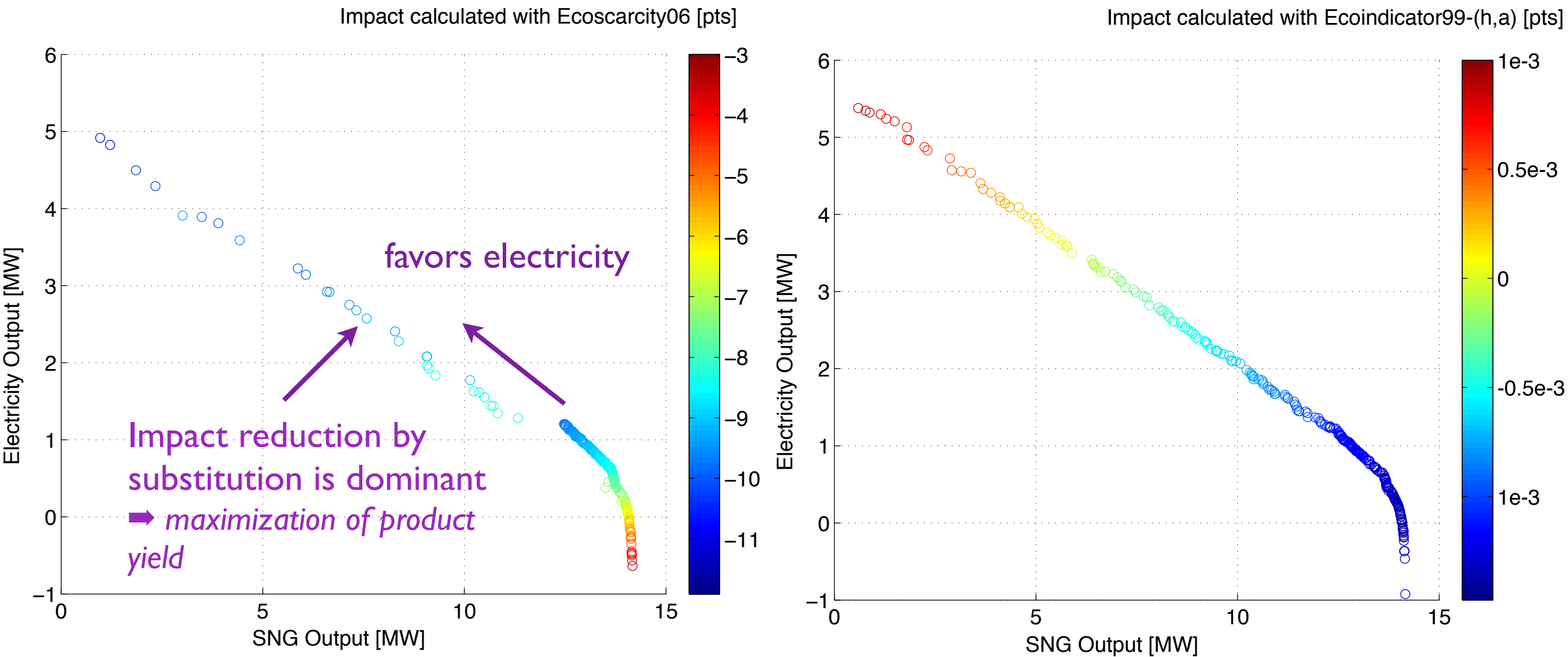
- Influence of polygeneration and objective function





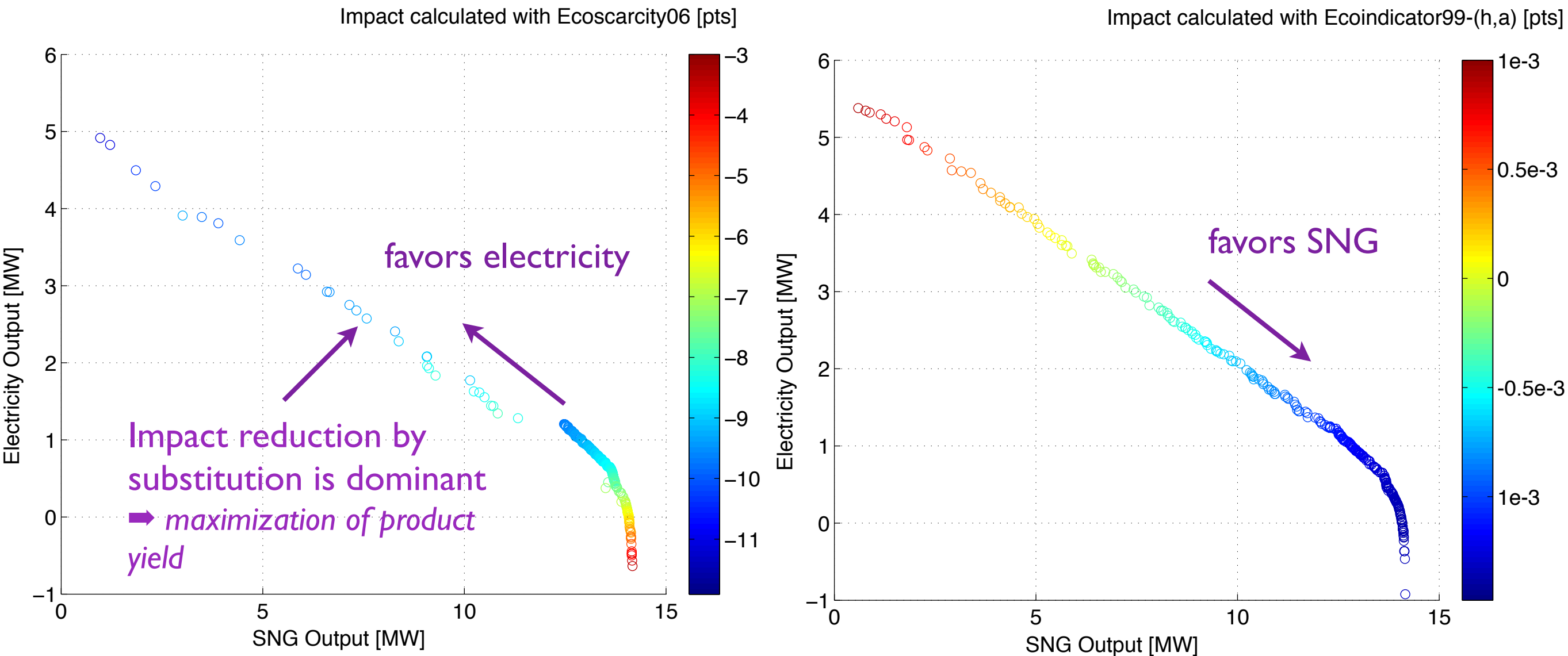
# Environomic design

- Influence of polygeneration and objective function



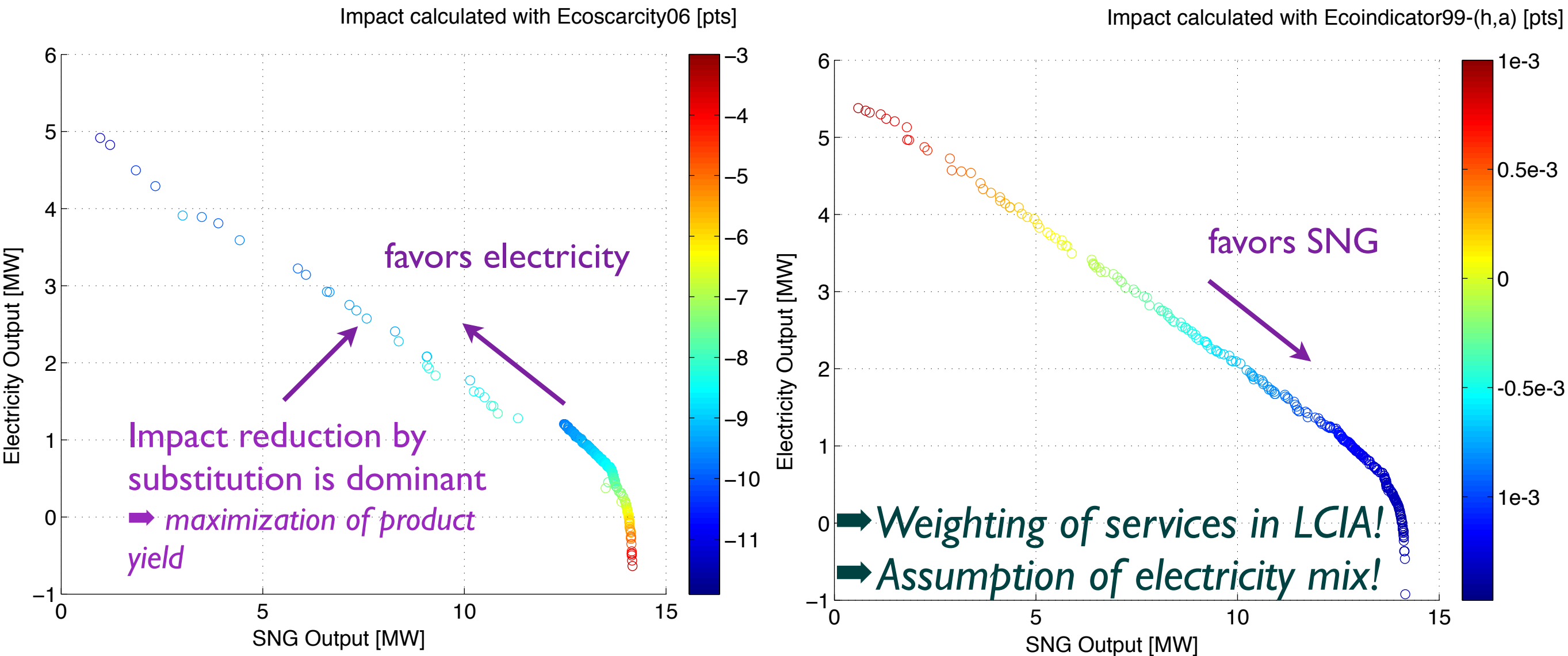
# Environomic design

- Influence of polygeneration and objective function



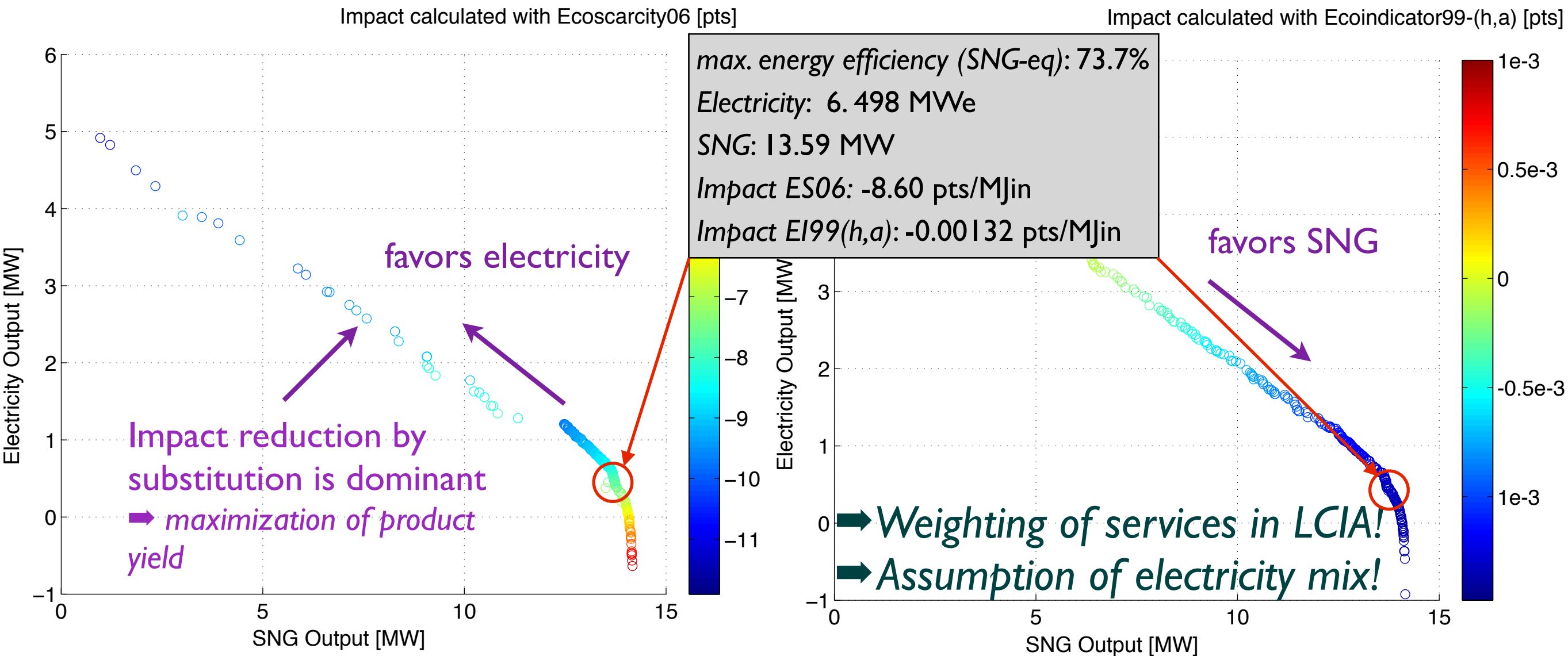
# Environomic design

- Influence of polygeneration and objective function



# Environomic design

## • Influence of polygeneration and objective function



# Conclusions

- Inclusion of environmental impacts in process design by LCA
- Environomic optimization of SNG production
  - Process scale
    - Trade-off between efficiency and auxiliary materials & logistics
  - Process efficiency
    - Key-point for impact reduction
    - ▶ Not assimilable to environmental impacts for multi-service process!
  - Choice of environmental objective function
    - Influences strongly optimal environomic process design!



Thank you for your attention!

contact: [leda.gerber@epfl.ch](mailto:leda.gerber@epfl.ch)