IAEE SESSION 7A: CLIMATE VII
POTENTIAL AND COSTS FOR CO_2 MITIGATION FOR REFINERIES IN EU-28 FOR 2050

Fraunhofer Institute for Systems and Innovation Research ISI

Source: EPA

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Motivation

- The European Council's reconfirmation of the EU objective of GHG mitigation by **80-95%** until 2050 compared to 1990
- In EU emissions trading system (EU ETS), the refinery sector has 130 installations emit 130 Mt in 2015: **25%** of emissions accounted for by industrial activities in the EU ETS
- Yet, comprehensive analysis on energy demand, CO_2 emissions, CO_2 mitigation potential and costs has not been studied for the European refinery sector at the plant level.

European Commission. (2011). *Communication from the commission to the European Parliament, the council, the European economy and social committee and the committee of the regions: A roadmap for moving to a competitive low carbon economy in 2050* (COM (2011)). Brussels: European Union: European Commission

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Research Questions

1. What is EU Refineries' status-quo in terms of production, energy demand and CO_2 emission on site-level?
2. How could the energy demand and CO_2 emission of the EU refineries change, driven by the production projection until 2050 under various scenarios?
3. What are the potential and costs for the EU refineries to reduce CO_2 emissions by employing energy saving options under various diffusion conditions?

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Methodology

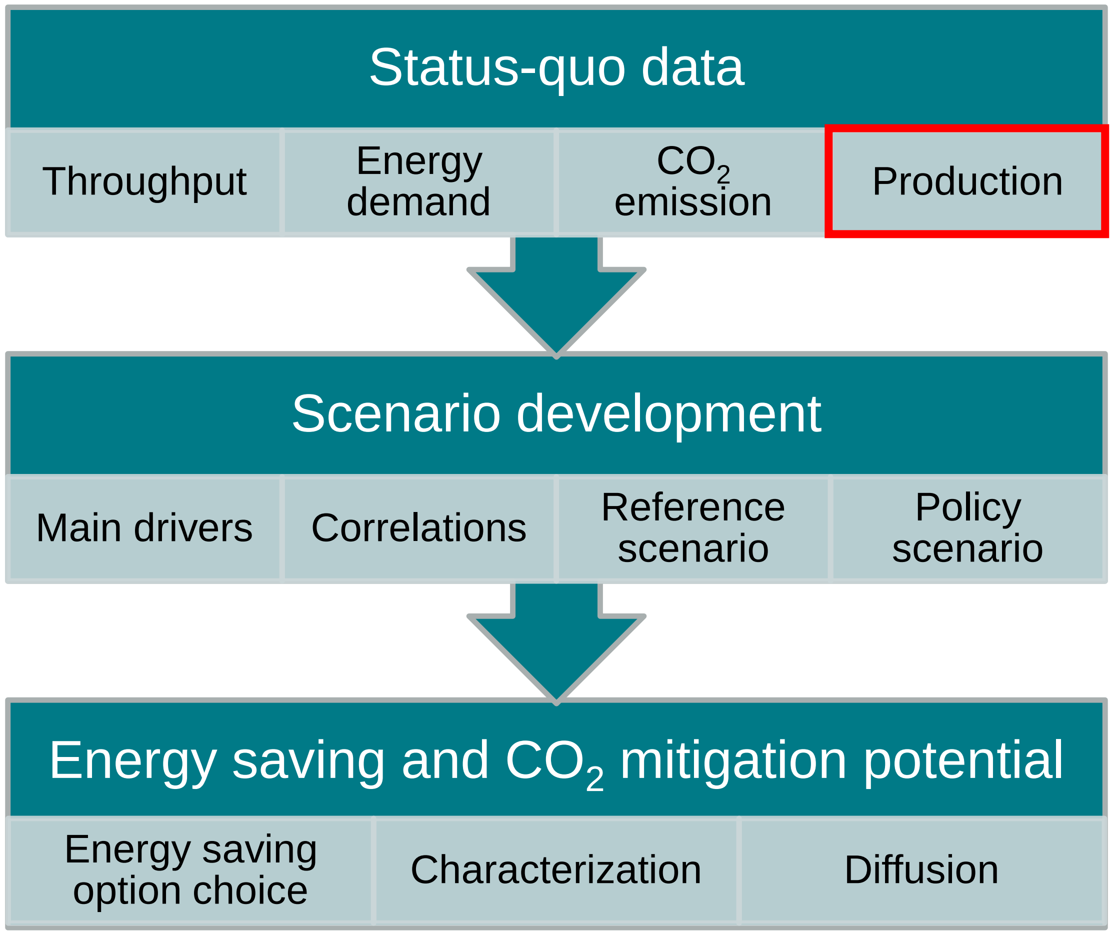

Figure 1. Research methodology based on bottom-up approach.

Methodology - Status-Quo Data: Categorization

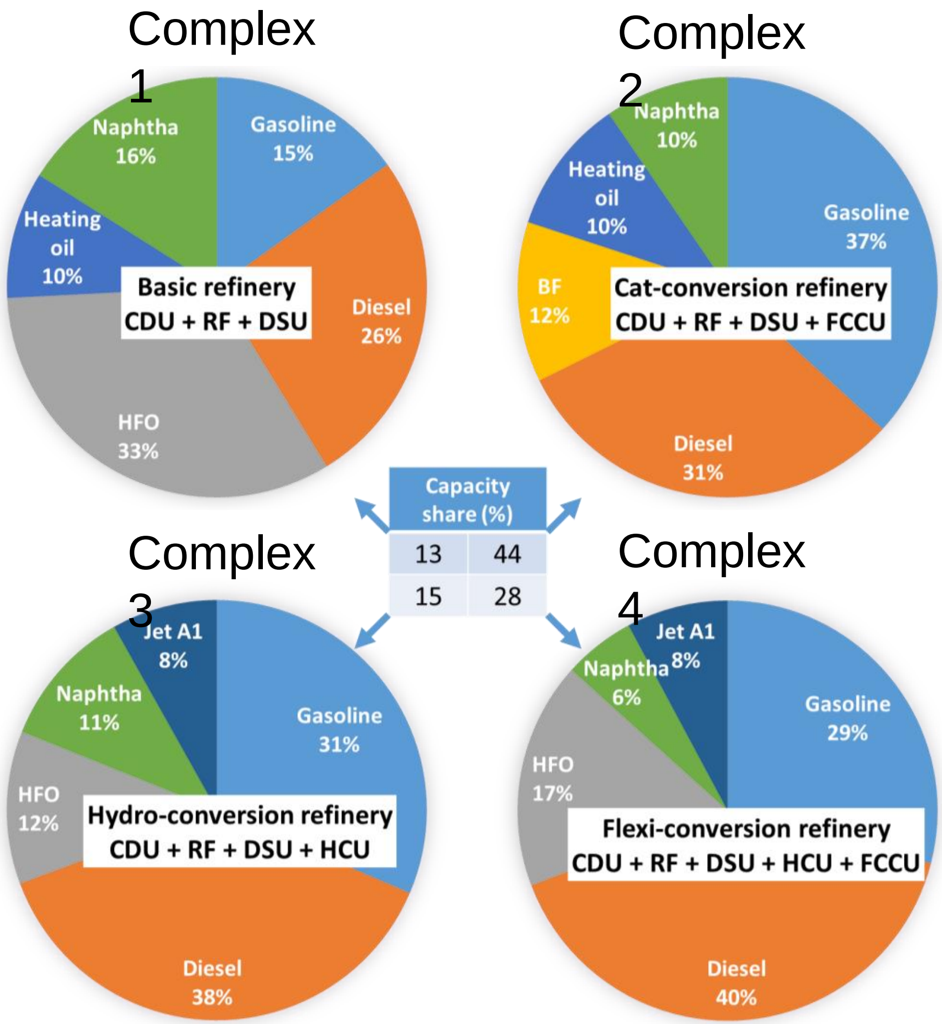

Figure 2. capacity share, process configuration and product slates of categories.

Note: CDU- Crude Distillate Unit, RF- Reforming unit, DSU- Desulfurization unit, FCCU- Fluid catalytic cracking unit, HCU- Hydrocracking unit.

Reinaud, J. (2005). The European refinery industry under the EU emissions trading scheme: Competitiveness, trade flows and investment inplications. *IEA information paper, Paris*.

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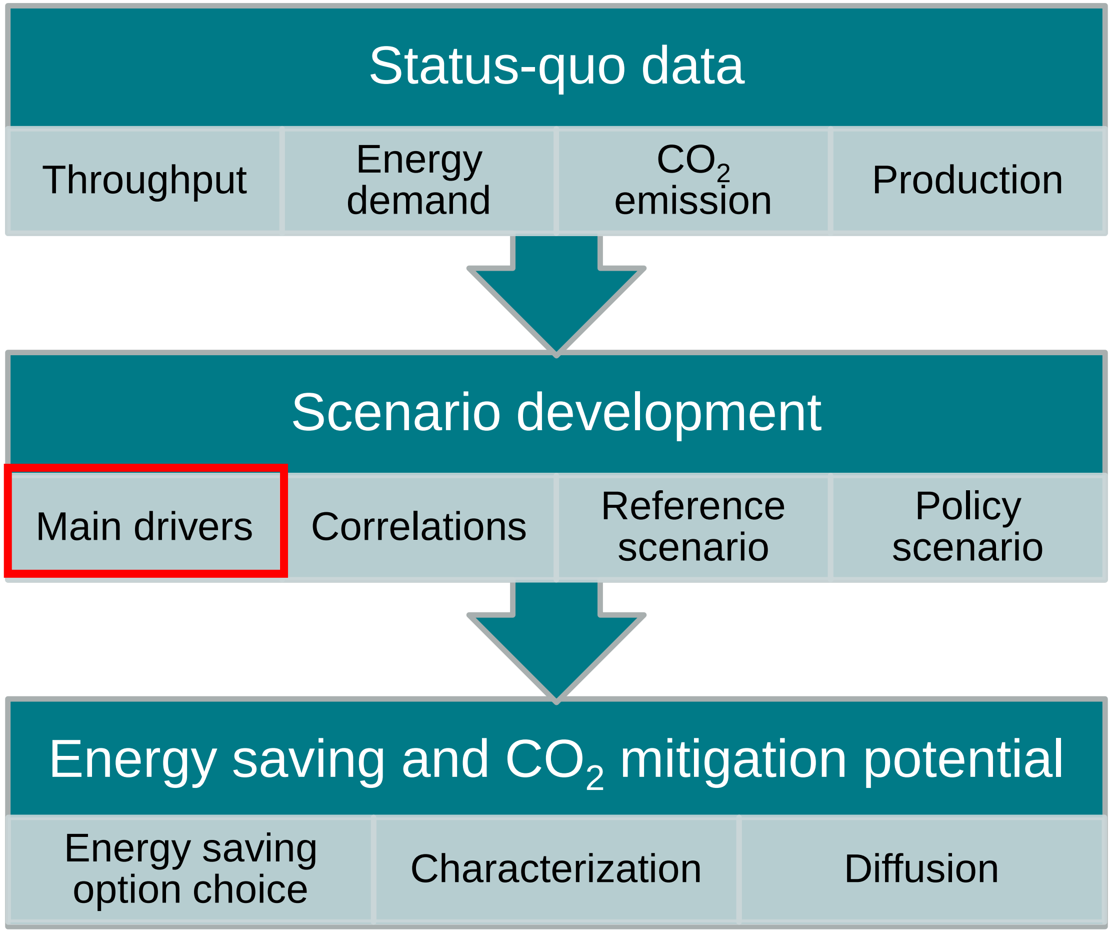
Methodology



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Methodology- Main Drivers

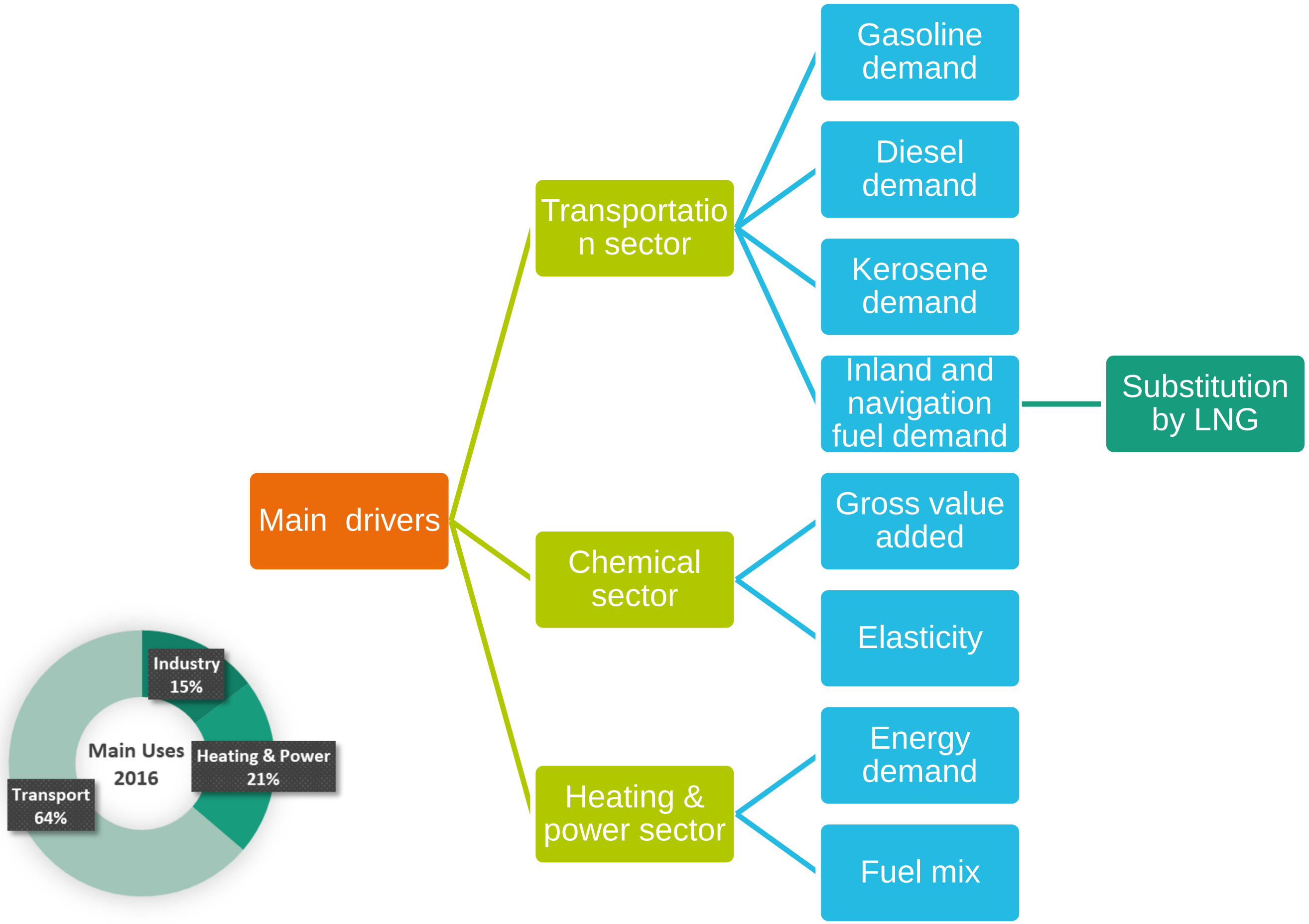
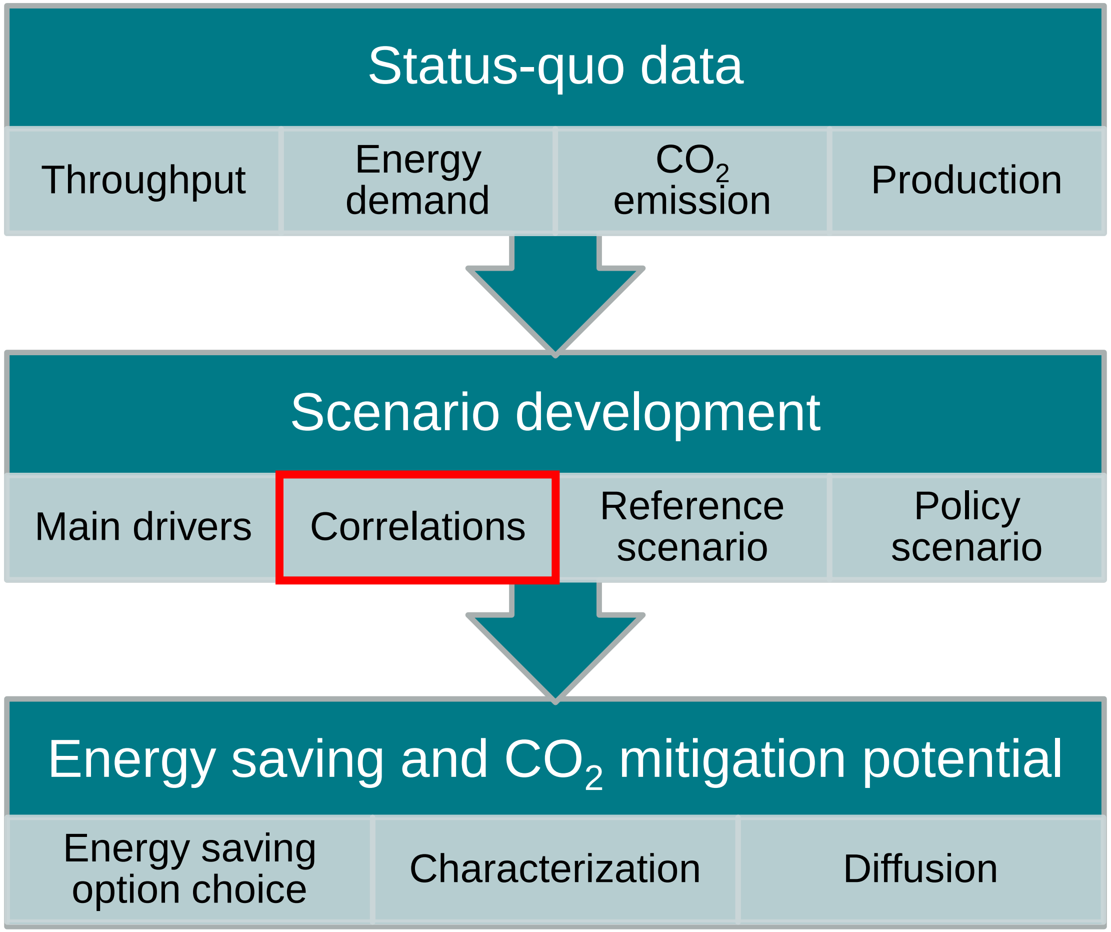


Figure 3. Main driver definition by main uses of the refinery products.

Vita, A. de, Tasios, N., Evangelopoulou, S., Forsell, N., Fragiadakis, K., Fragkos, P.,. . . Zampara, M. (2016). *EU reference scenario 2016: Energy, transport and GHG emissions : trends to 2050*. Luxembourg: Publications Office

Chan, Y., Kantamaneni, R., & Allington, M. (2015). Study on energy efficiency and energy saving potential in industry from possible policy mechanisms. *ICF Consulting Limited, London. Tratto il giorno*, *6*(08), 2016.

Methodology



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Methodology-Correlations

Table 2. Main driver correlations to the refinery products.

Product	Main use	Main driver
LPG	Industry, heating and power	Gross value added (GVA), elasticity, Energy demand and fuel mix
Naphtha	Industry	GVA, elasticity
Gasoline	Transportation	Gasoline demand
Jet A1	Transportation	Kerosene demand
Diesel	Transportation	Diesel demand
Heating Oil	Heating & power	Energy demand, fuel mix of residential sector
HFO (Low sulfur and high sulfur)	Heating & power	Energy demand, fuel mix of residential sector
Bunker (Low sulfur and high sulfur)	Transportation	Energy demand from inland navigation, fuel substitution by LNG
Bitumen, sulfur, coke	Industry	Proportional production linked to gasoline

Vita, A. de, Tasios, N., Evangelopoulou, S., Forsell, N., Fragiadakis, K., Fragkos, P.,. . . Zampara, M. (2016). *EU reference scenario 2016: Energy, transport and GHG emissions : trends to 2050*. Luxembourg: Publications Office

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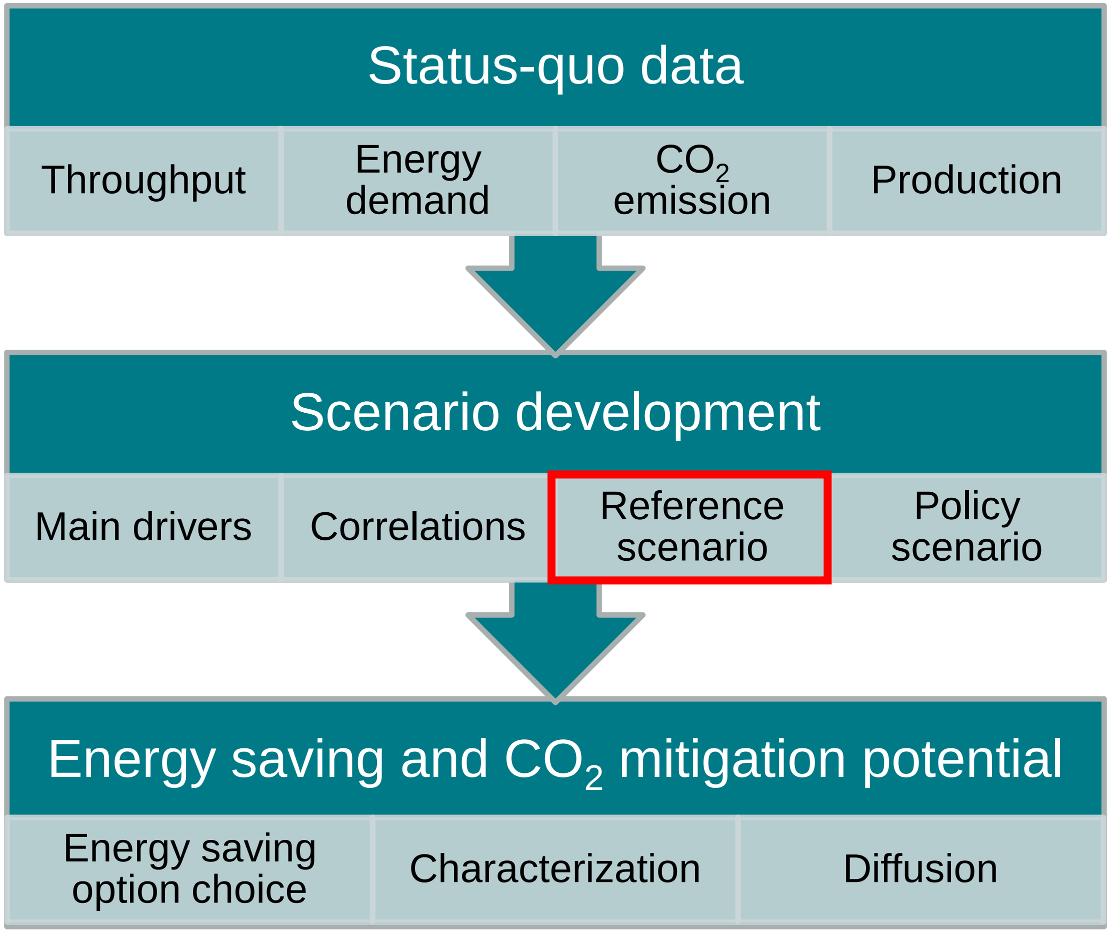

Figure 1. Research methodology based on bottom-up approach.

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Methodology- Reference Scenario

$$\mathrm{P}_{\mathrm{p,n,g,c,}y} = \mathrm{P}_{\mathrm{p,n,g,c,y-1}} * \left(1 + \Delta ED_{\mathrm{p,n,c,}y}\right)$$

With:

-$\Delta\mathrm{ED}$ (%) as the annual change of the product demand.

-index: p as the specific product (jet fuel, gasoline, diesel and heavy fuel oil)

$$\mathrm{E}_{\mathrm{r,c,}y} = \mathrm{E}_{\mathrm{r,c,}B} * \mathrm{P}_{\mathrm{t,n,g,c,}y}$$

$$\mathrm{e}_{\mathrm{r,c,}y} = \mathrm{e}_{\mathrm{r,c,}B} * \mathrm{P}_{\mathrm{t,n,g,c,}y}$$

With:

-E (toe) as the energy demand

-P (2015=100) as the relative production

-Indices: r as the refinery, c as the country and y as the year, B as the base year, t as the total, n as the complex, g as the geographical category.

Methodology- Main Drivers for Reference Scenario

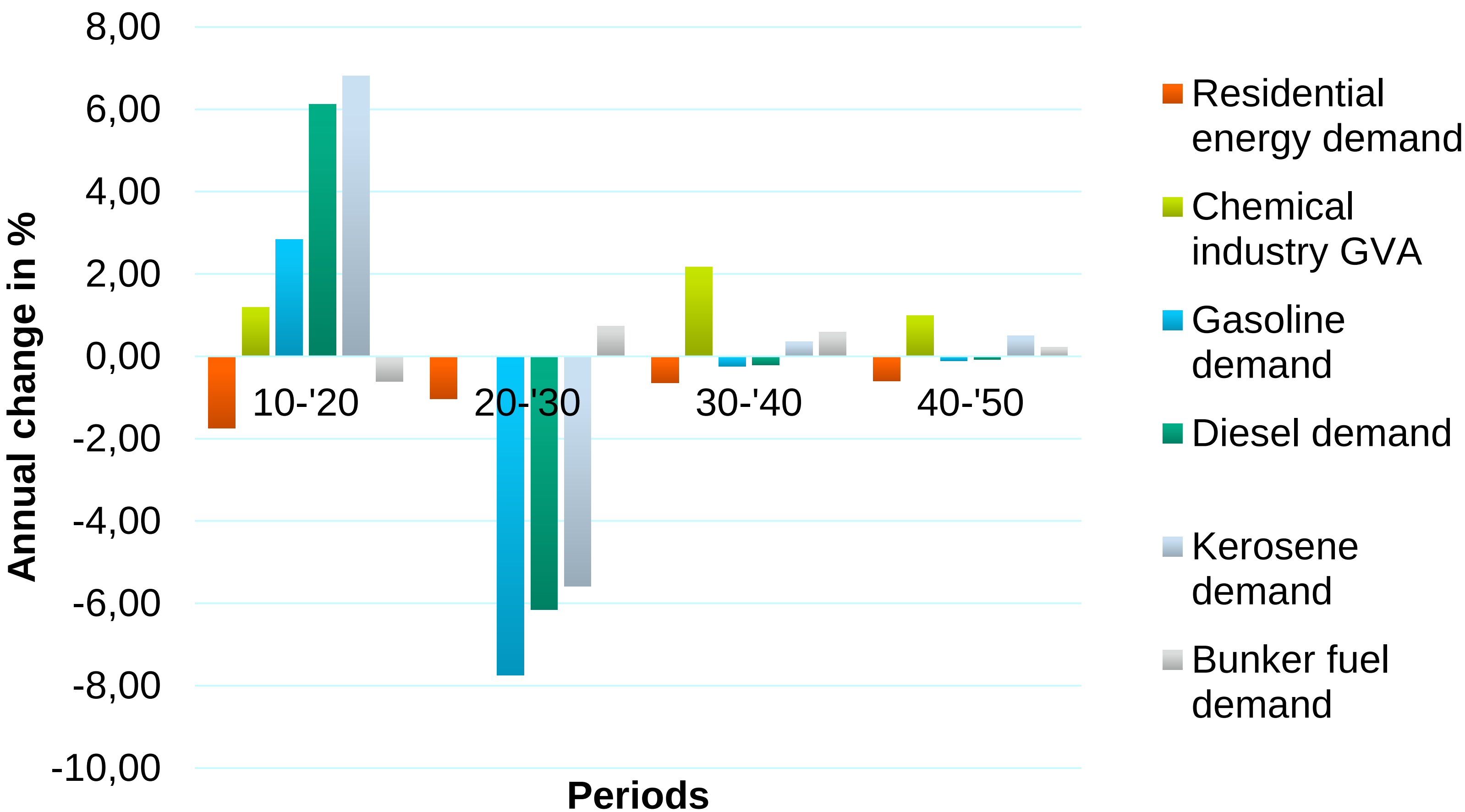

Figure 4. Change of activities as main drivers for EU-28 from EU reference scenario 2016

Vita, A. de, Tasios, N., Evangelopoulou, S., Forsell, N., Fragiadakis, K., Fragkos, P.,. . . Zampara, M. (2016). *EU reference scenario 2016: Energy, transport and GHG emissions : trends to 2050*. Luxembourg: Publications Office

Methodology

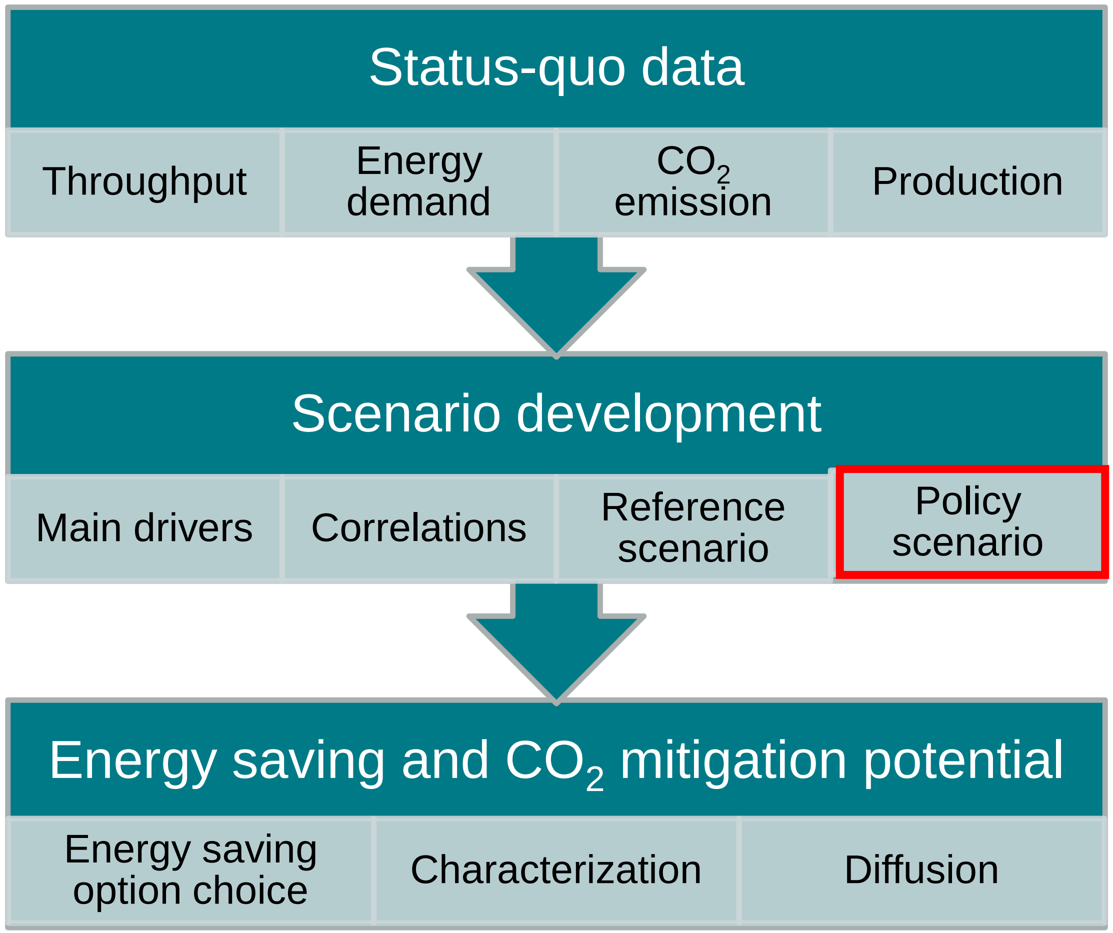

Figure 1. Research methodology based on bottom-up approach.

Methodology- Policy Scenario

Comparison of two scenarios:

1. Decarbonization scenario in EU Roadmap (European Commission, 2011)
2. Reference scenario in EU Reference scenario (Vita et al., 2016)

Inputs for the policy scenario:

- Fuel mix change in transportation sector and residential sector
- Efficiency increase in industry sector

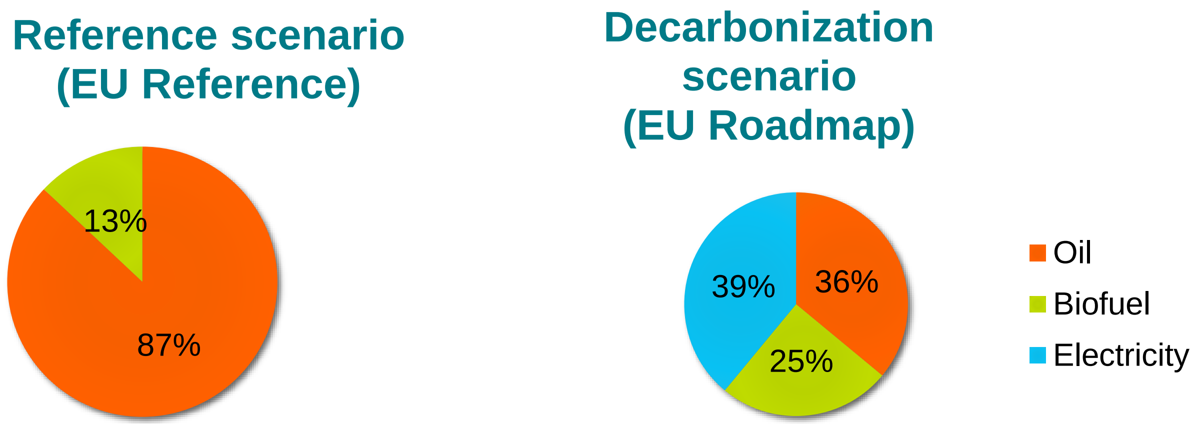

Figure 5. Fuel mix change comparison in road transportation in 2050.

Vita, A. de, Tasios, N., Evangelopoulou, S., Forsell, N., Fragiadakis, K., Fragkos, P.,. . . Zampara, M. (2016). *EU reference scenario 2016: Energy, transport and GHG emissions : trends to 2050*. Luxembourg: Publications Office

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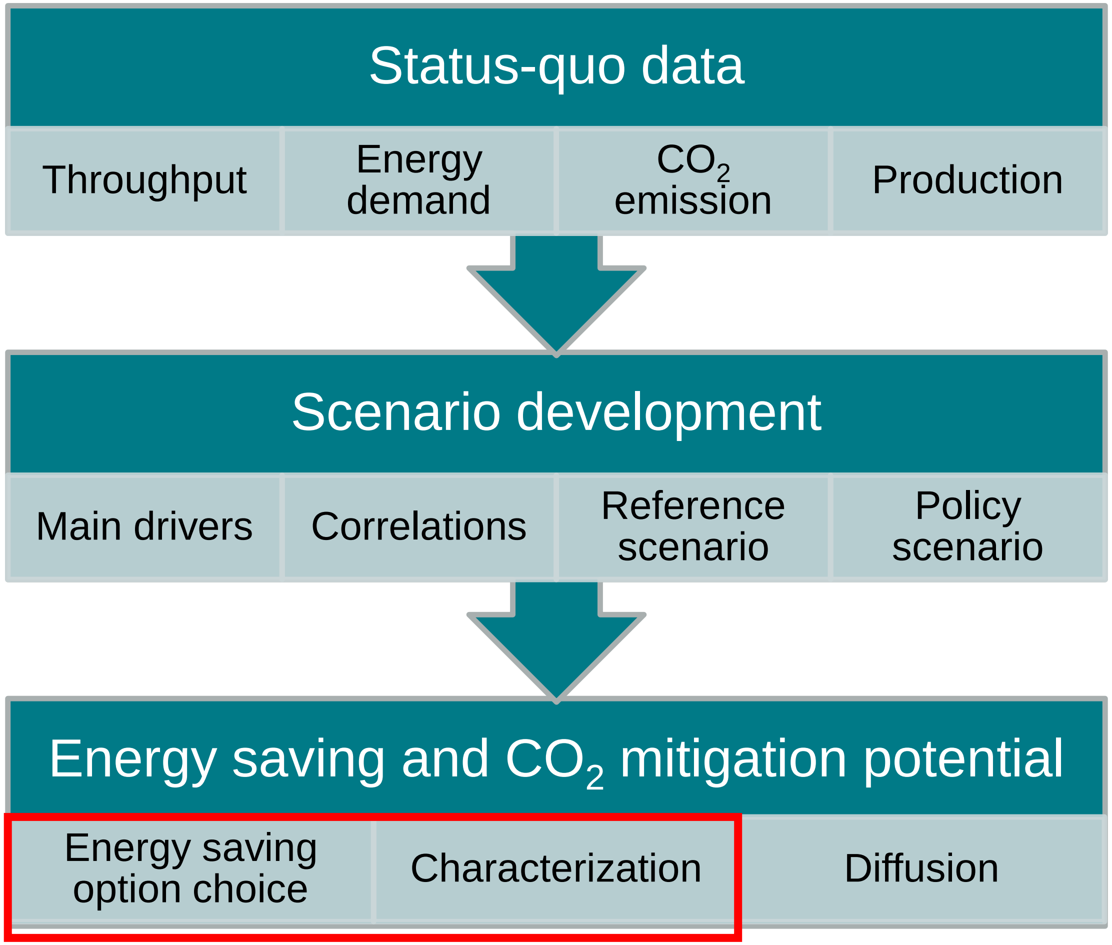

Figure 1. Research methodology based on bottom-up approach.

Methodology-Energy Saving Options

- From the literature Morrow III et al. (2013) Assessment of Energy Efficiency Improvement in the United States Petroleum Refining Industry
- Five energy saving options were chosen based upon penetration rate, total fuel savings.

Table 3. Characterization of energy saving options.

Number	Name	Fuel saving	Electricity saving	Payback period (year)
1	Installation of new internals	0-1.57 %	0.00-1.00 %	0.7
2	Flare gas recovery	1.09 %	0.67 %	2.0
3	Improvement of catalysts	0.20-1.17 %	0.01-0.13 %	1.0
4	Revamp heat integration	0.00-0.05 %	0.00-0.59 %	2.0
5	Installation of furnace air pre-heat	0.09-0.10 %	0.00 %	3.0

Note: Adopted from Morrow III et al. (2013).

Morrow III, W. R., Marano, J., Sathaye, J., Hasanbeigi, A., & Xu, T. (2013). *Assessment of Energy Efficiency Improvement in the United States Petroleum Refining Industry.*

Methodology

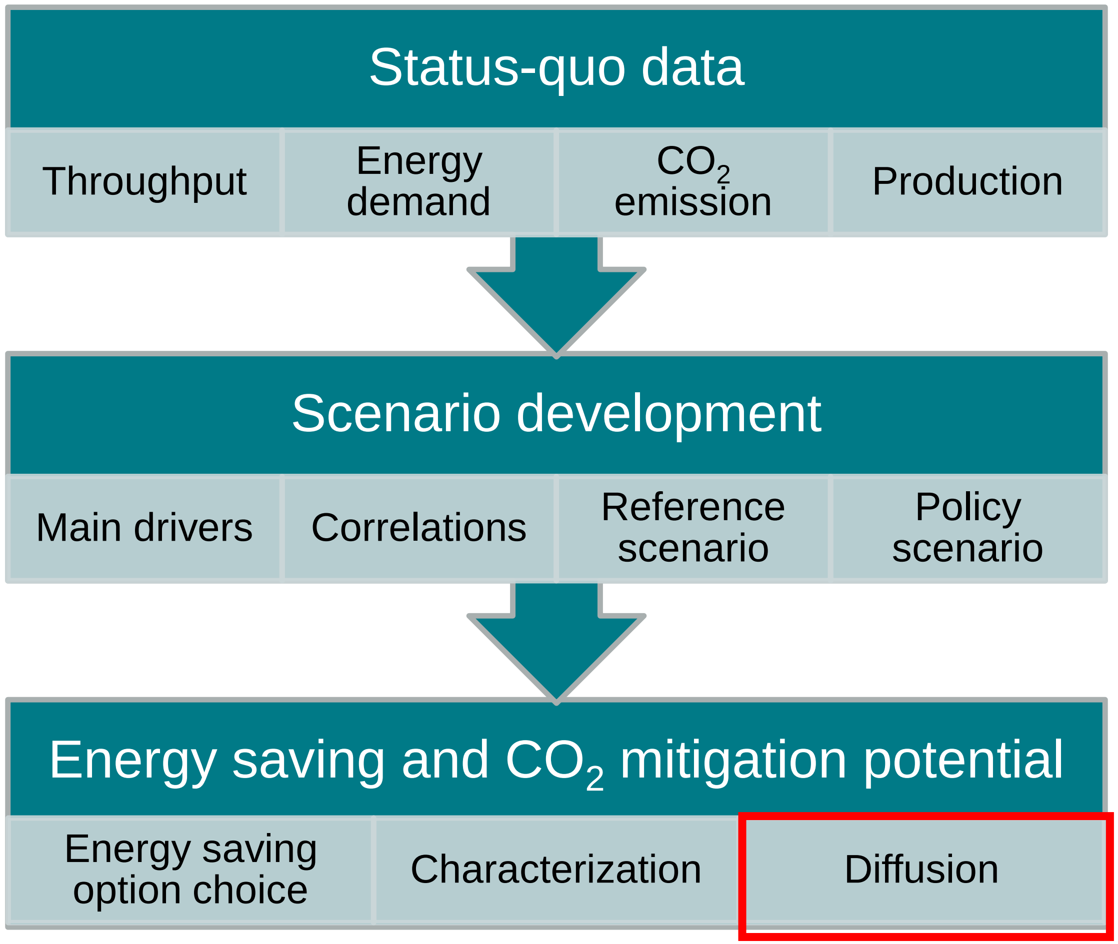

Figure 1. Research methodology based on bottom-up approach.

Result-Status Quo

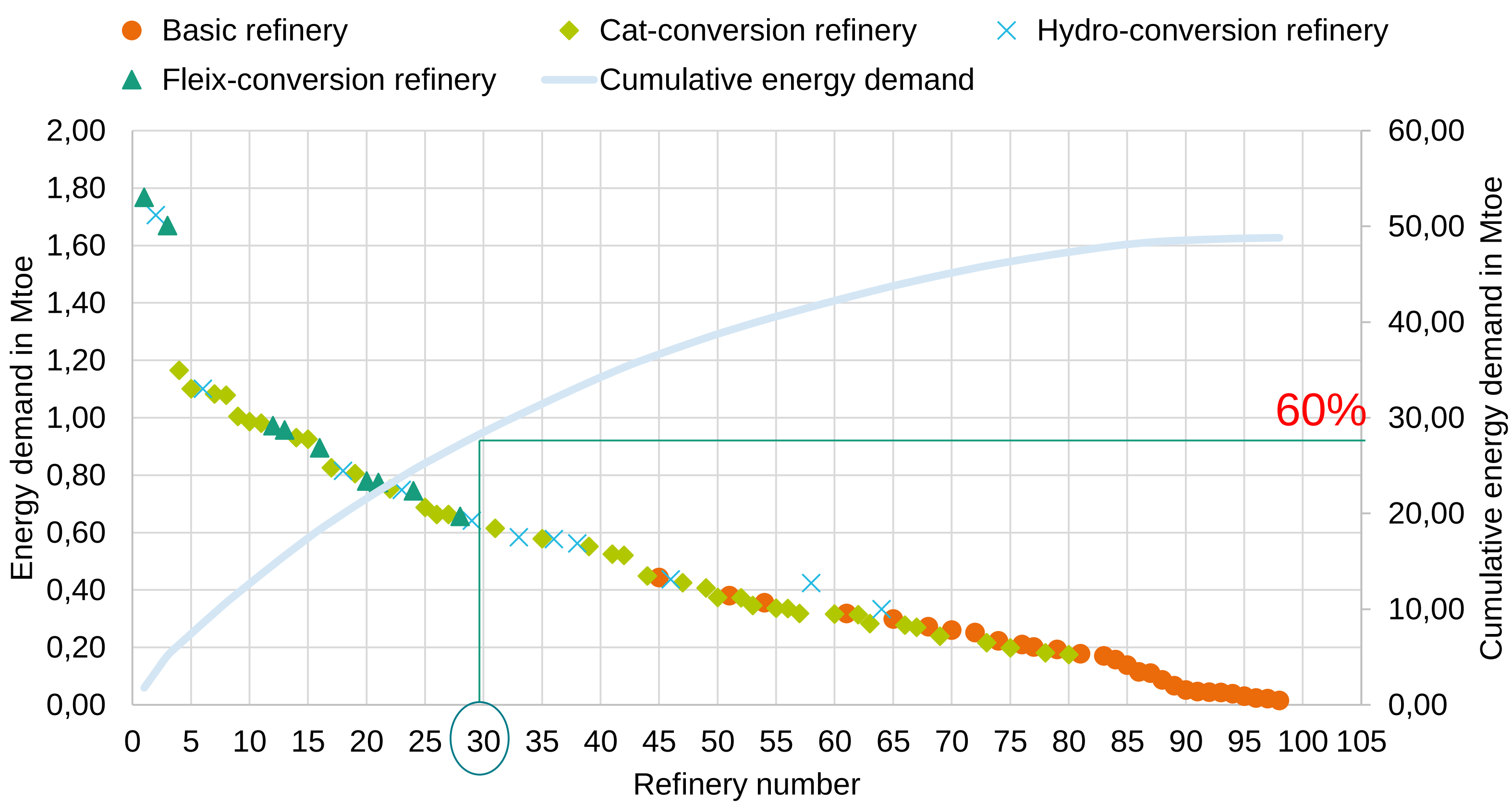

Figure 6. Status-quo of energy demand of refineries in EU-28 by the categories in 2015.

Result- Production Projection

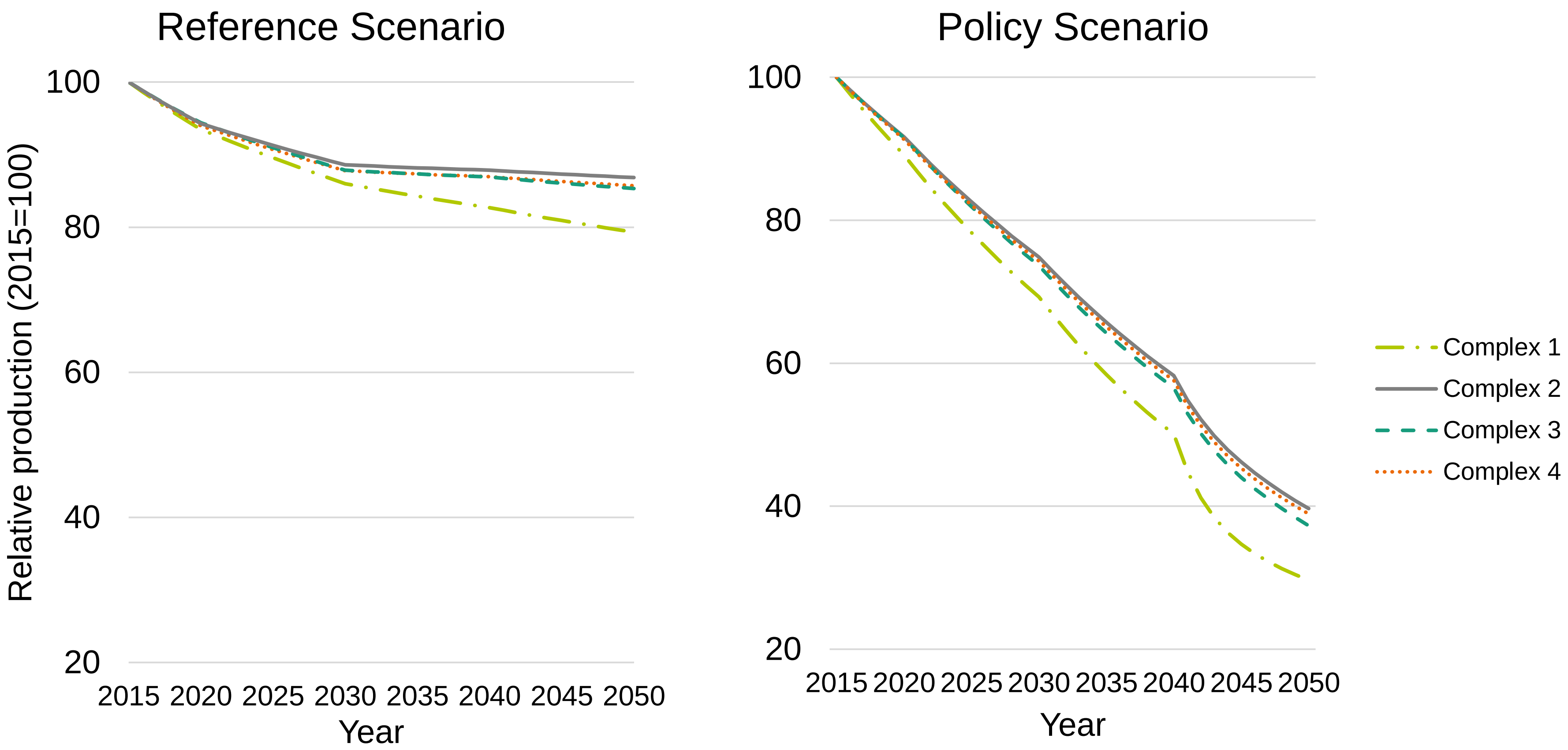

Figure 7. Production projection by complex in the reference scenario and policy scenario.

Kim, S. (2017). *Potential Costs of CO2 Mitigations for Refineries in Europe for 2050* (Master Thesis). Albert-Ludwigs-Universität Freiburg, Freiburg.

Result- Scenarios With Saving Potential

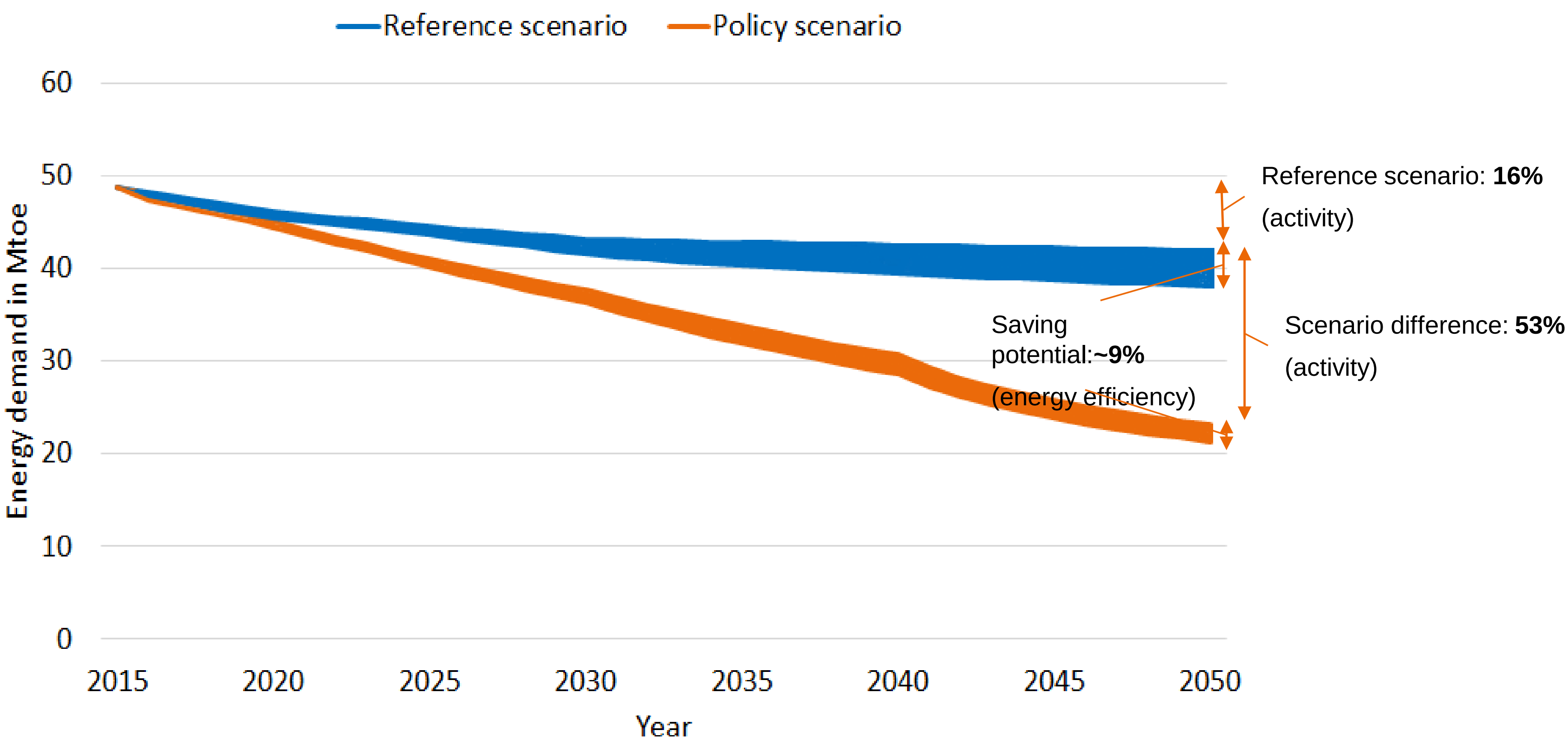

Figure 8. Energy demand projection in the reference and policy scenario with saving potential

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Conclusion

- The study contributes to energy system research by;

  - First, bottom-up approach to model the refinery sector on site-level.
  - Second, projection methodology using production development.
  - Finally, calculation of energy saving and CO_2 mitigation potential of applying ESOs that are not likely employed yet, under different diffusion cases.

- Further research:
  - Elaboration of the correlations between demands and production (considering international trades).
  - Economic structure of refineries by type.

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Q&A

Bottom-up approach

Refinery status-quo

Energy demand

Categorization

CO2 emission

Production

Scenario Analysis

Main drivers correlations

Production projection

Reference scenario

Policy scenario

Energy saving &

Mitigation potential

ESOs

Payback period

Technical diffusion

Economic diffusion

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