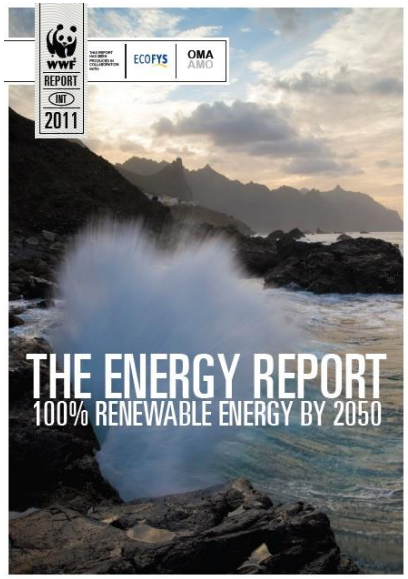
ECOFYS

sustainable energy for everyone



Pathway to a fully sustainable global energy system by 2050 "The Energy Report"

Prof. dr. Kornelis Blok
with Yvonne Deng, Stijn Cornelissen and Sebastian Klaus

Brandstof of bedelstaf?
KIVI, Eindhoven, 21 Feb. 2014

"Every hour, we receive as much energy from the sun as we use in a year"

"Most Americans and Europeans believe that renewable energy will have replaced most fossil energy by 2050. As the hard truths make clear, this simply isn't going to happen"
Jeroen van der Veer, CEO of Shell, June 2007

"Every year, we don't even manage to improve our energy efficiency to keep up with wealth increases, let alone to cut emissions"
John Barrett, author of the SEI reports to both Defra and WWF

Key question:

Is a fully sustainable global energy system possible by 2050 ?

Ecofys: experts in energy

Energy & Carbon Efficiency	Renewable Energy	Energy Systems & Markets	Energy & Climate Policy
Buildings	Wind Energy	Integrated Energy Systems	Policy Design & Evaluation
Sustainable Transport	Bioenergy	Power Systems & Markets	Market based Mechanisms
Industrial Processes			
Supply Chains	Solar Energy	Conventional Energy Systems	International Climate Policies



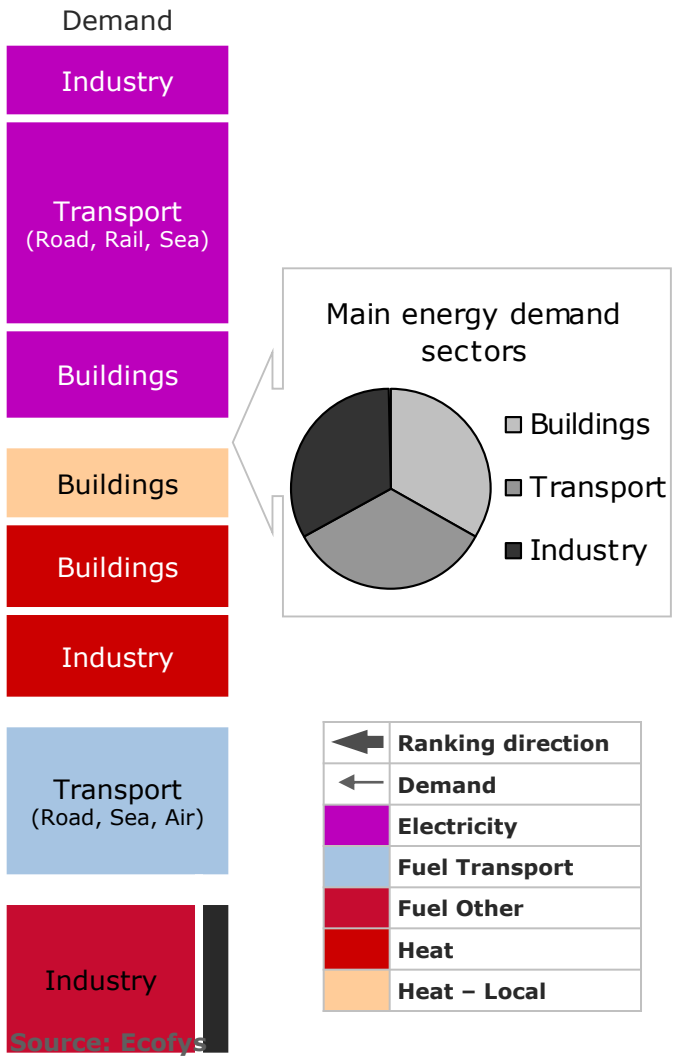

How we work

Traditionally: supply oriented approach

Energy generation → Energy conversion → Energy use

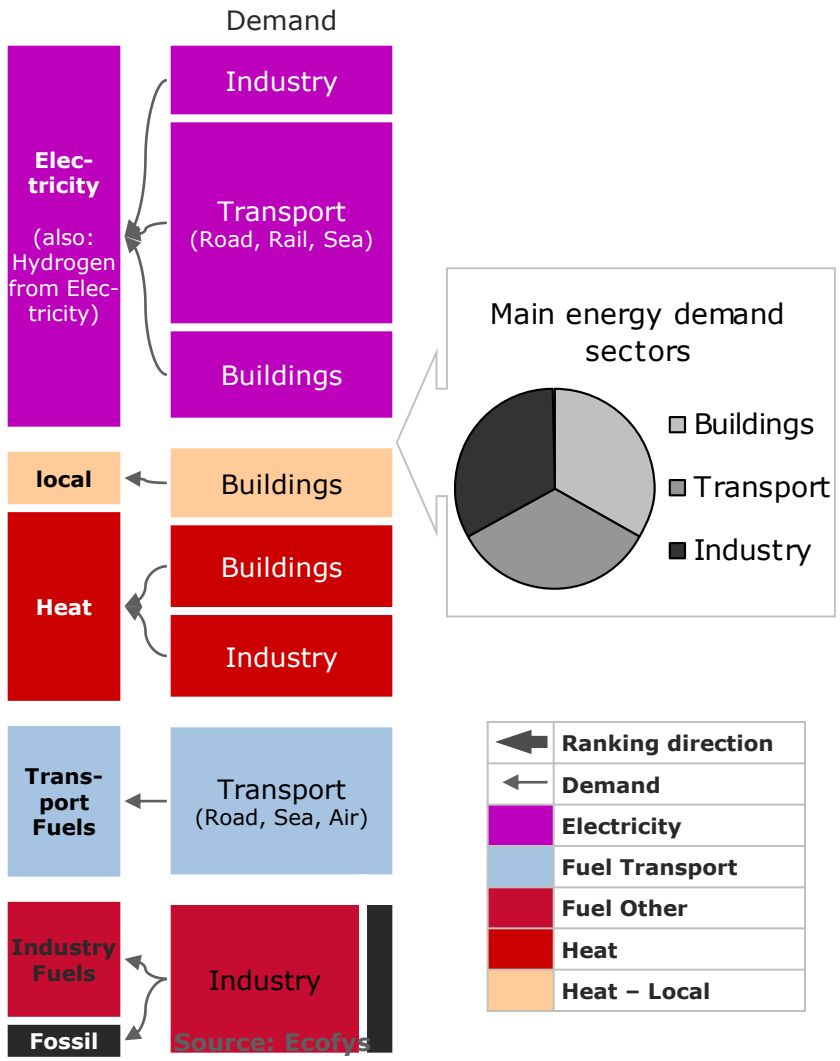
Ecofys thinking: start with (people) needs

1 a,b. Energy demand is forecast with strong efficiency assumptions



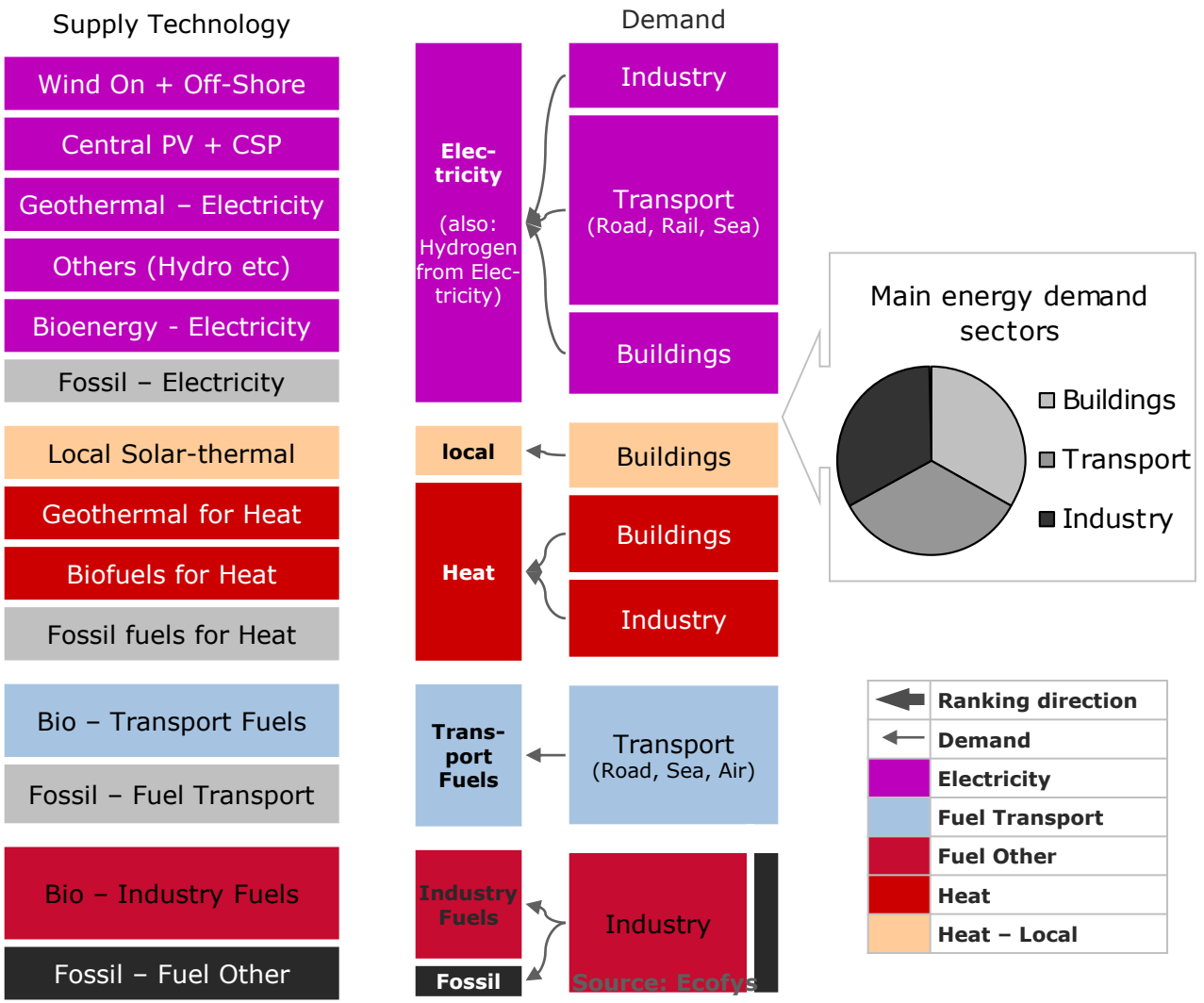
NB: The size of shapes here is NOT indicative of energy use per sector.

1 c. Energy demand is aggregated by carrier type



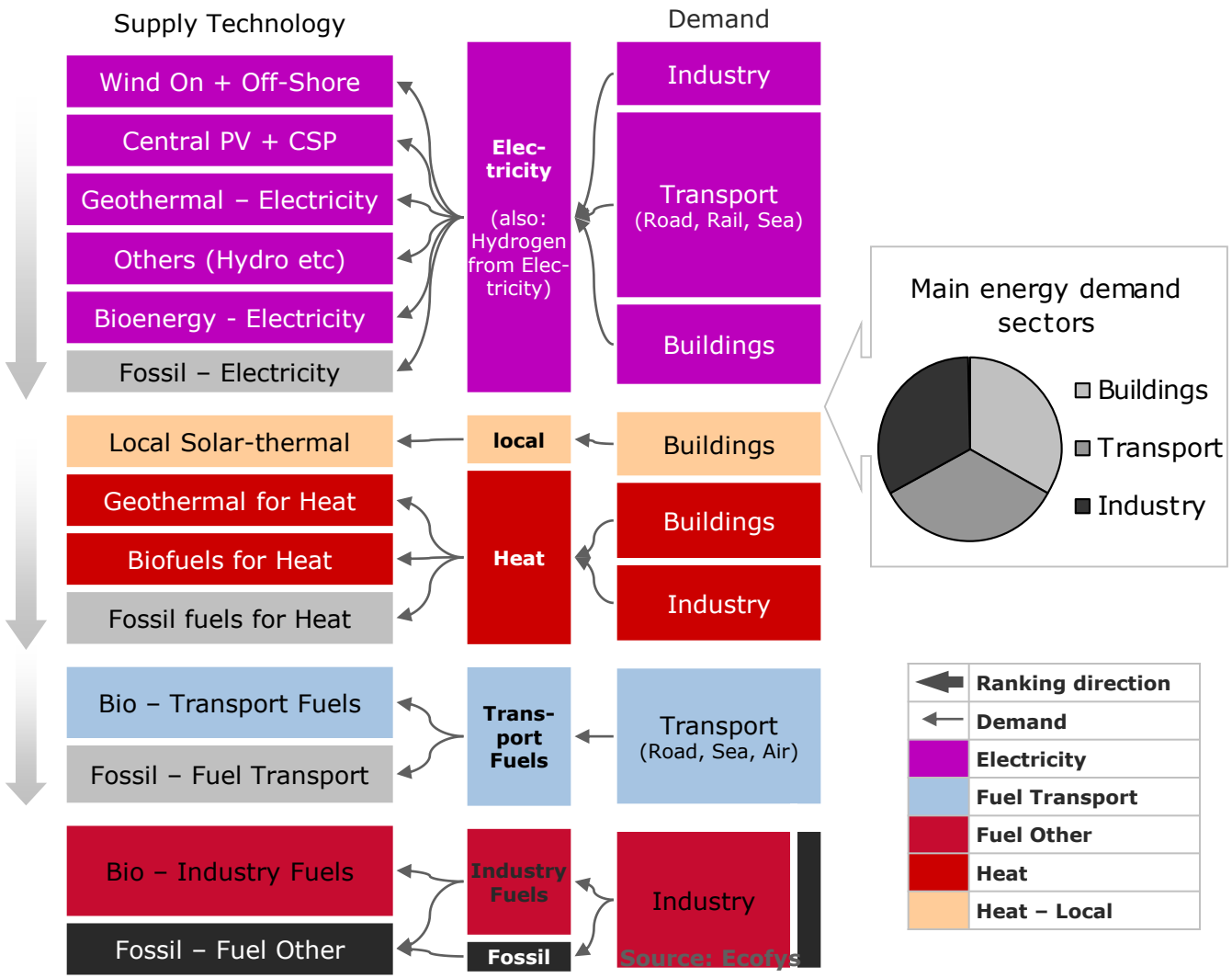
NB: The size of shapes here is NOT indicative of energy use per sector.

2 a. The potential of renewable energy options is assessed



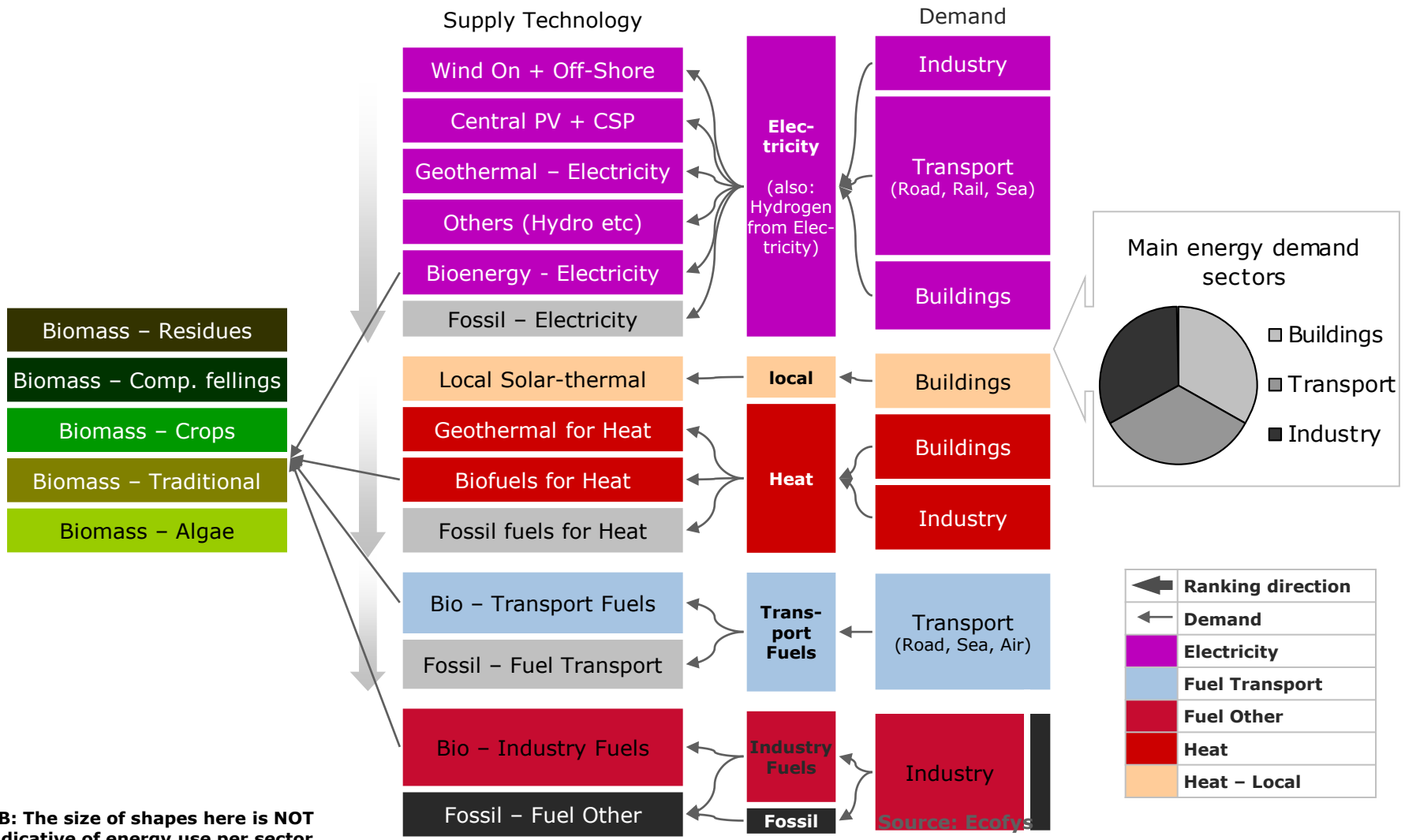
NB: The size of shapes here is NOT indicative of energy use per sector.

2 b i. Demand is matched with supply; non-bioenergy options are preferred



NB: The size of shapes here is NOT indicative of energy use per sector.

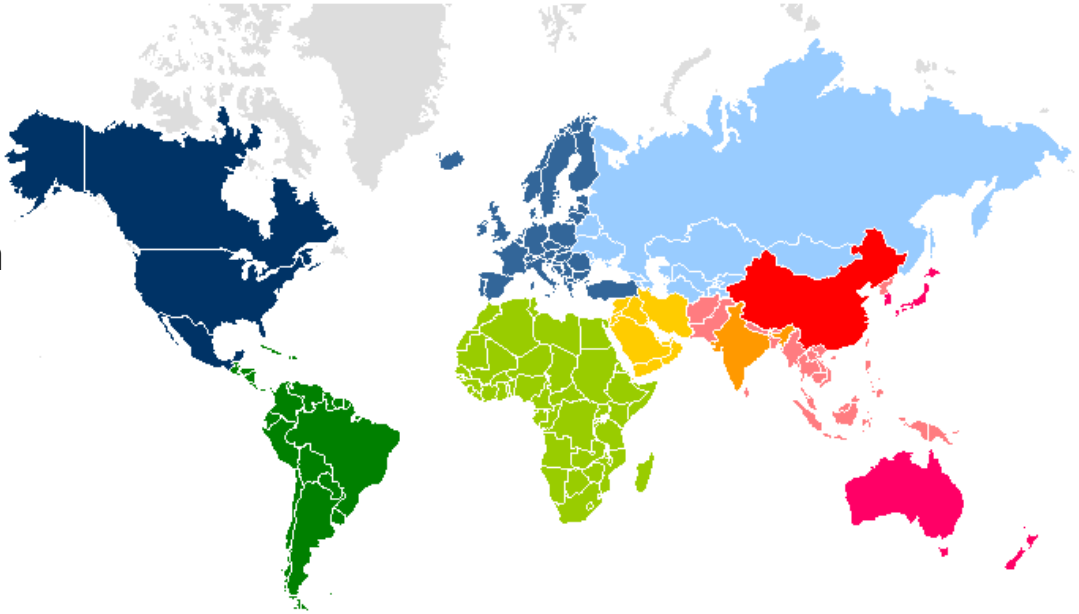
2 b ii,iii. Remaining demand is supplied from bioenergy up to the sustainable potential, then 'conventional' sources



NB: The size of shapes here is NOT indicative of energy use per sector.

Demand and supply are examined in 10 world regions

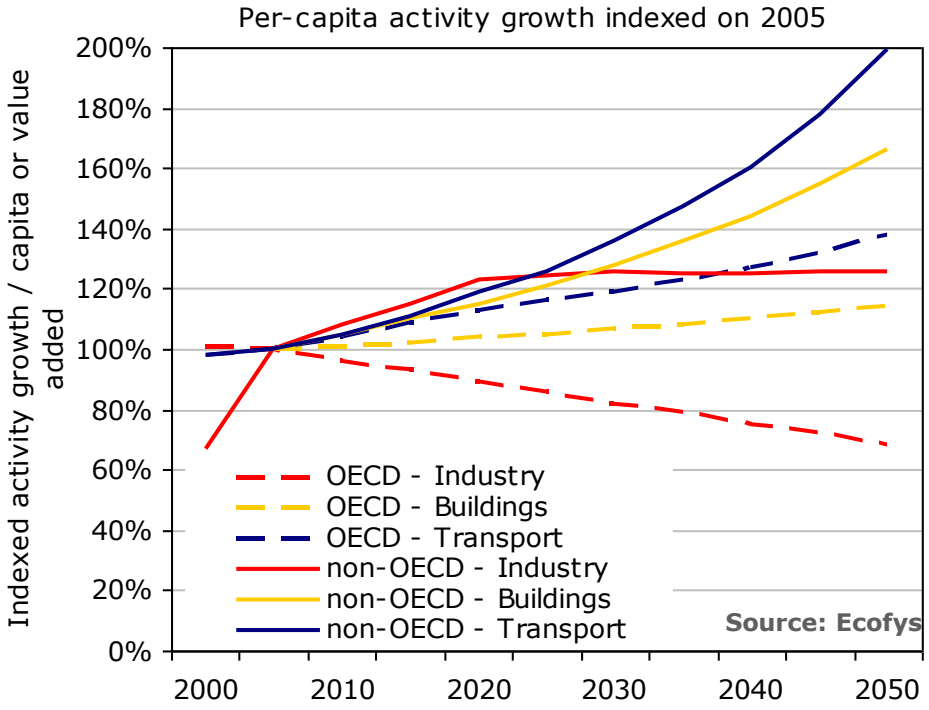
- Europe
- North America
- Latin America
- Russia and other Eurasia
- Middle East
- OECD Pacific
- China
- India
- Rest of Asia
- Africa

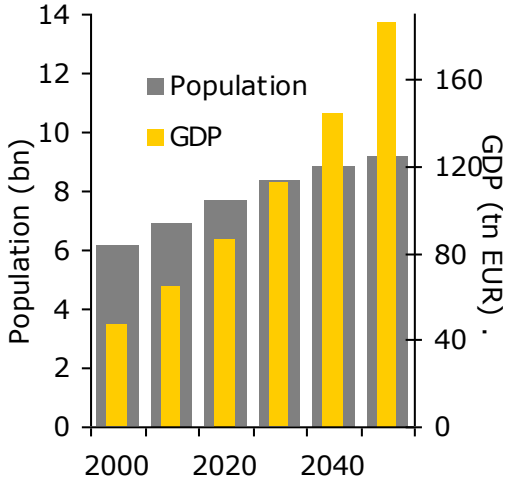


Currently, the Scenario is only valid at the global level, but future regional studies are possible

Activity increases, most strongly in non-OECD regions

> The only exception is the industry sector in OECD regions which sees a per capita and absolute activity decrease driven by ambitious material efficiency assumptions





Metrics shown in graphs

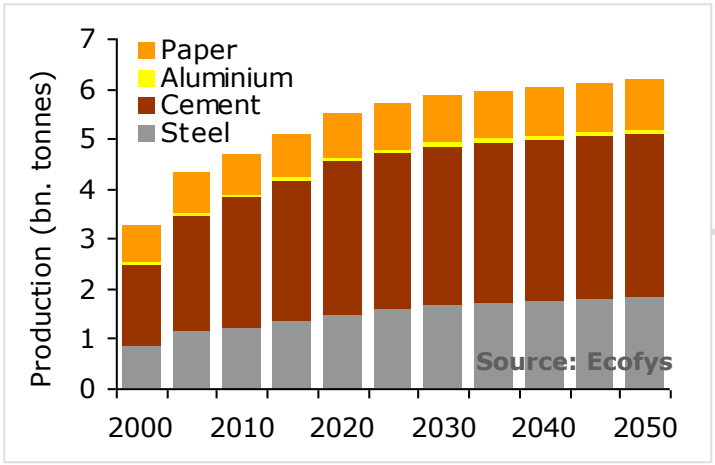
Industry: Tonnes produced per capita (steel, aluminium, cement, paper)

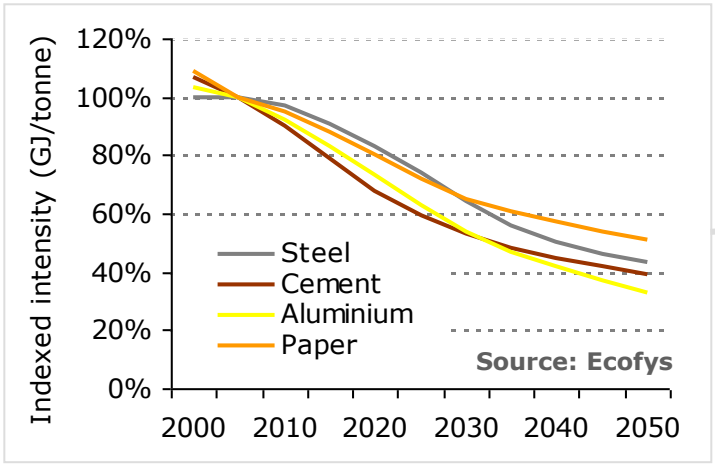
Buildings: Total floor space per capita

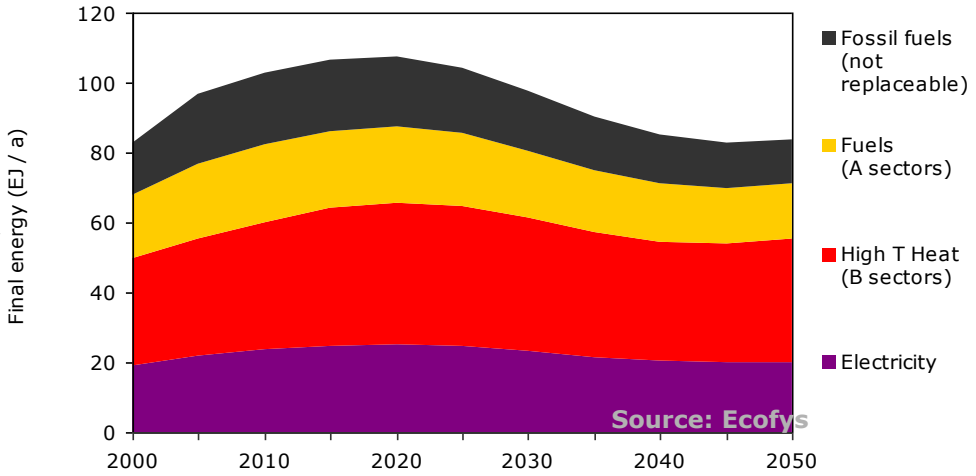
Transport: Passenger-km per capita

Sources used for these input assumptions:
Population: United Nations, World Urbanization Prospects: The 2006 Revision
GDP: IEA WEO GDP projections to 2030
Industry, Buildings: own assumptions
Travel: IEA/SMP (2004). Model Documentation and Reference Case Projection for WBCSD's Sustainable Mobility Project (SMP), plus own assumptions on modal shift

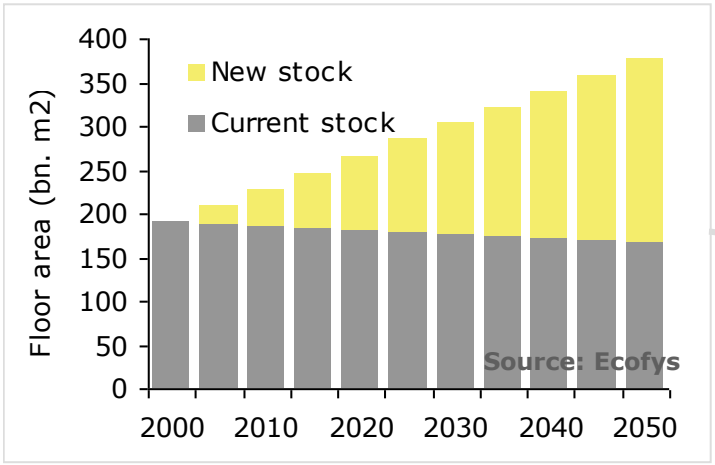
The stabilisation in energy demand in the industry sector results from ambitious efficiency improvements

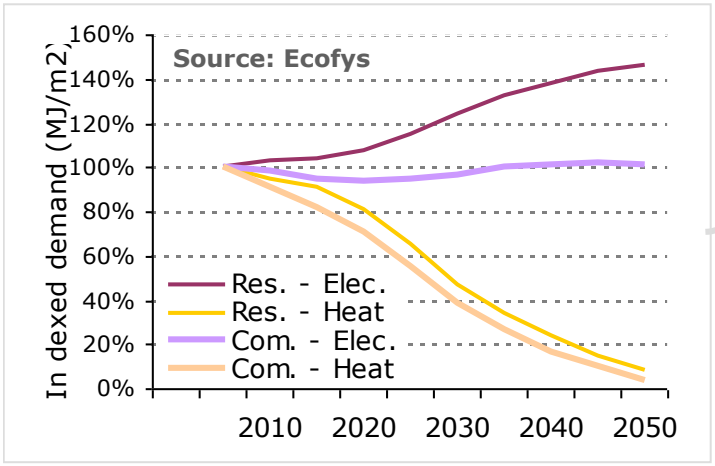


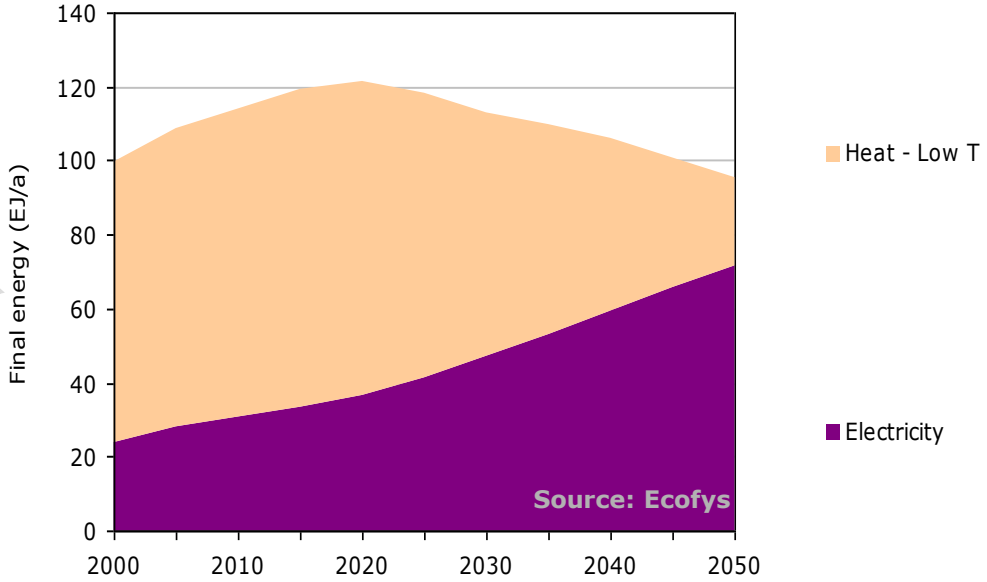




The stabilisation in demand in the built environment results from ambitious energy efficiency improvements

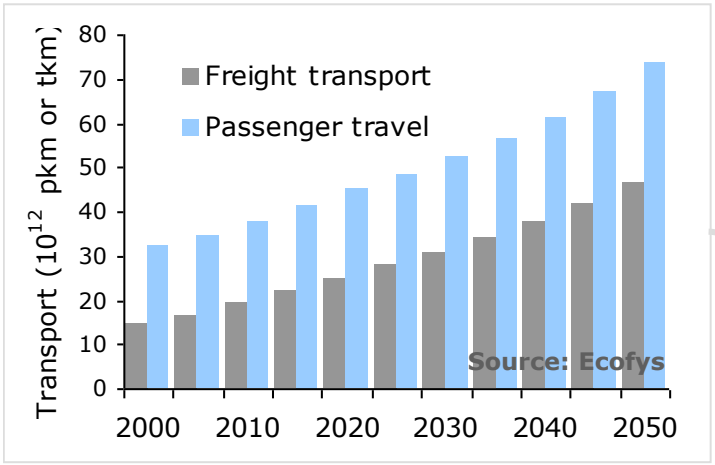


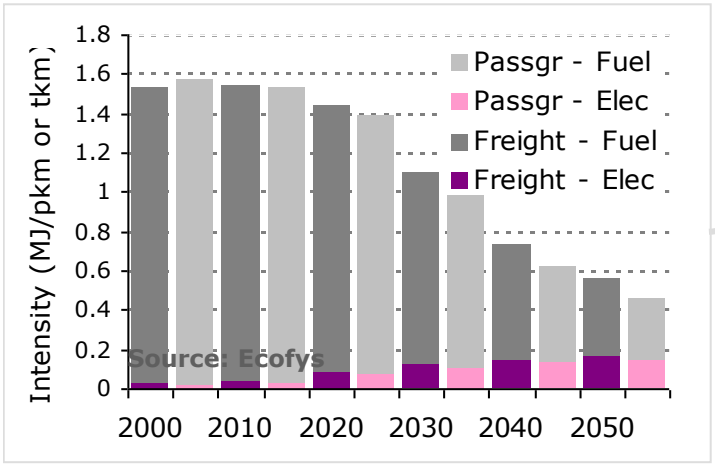


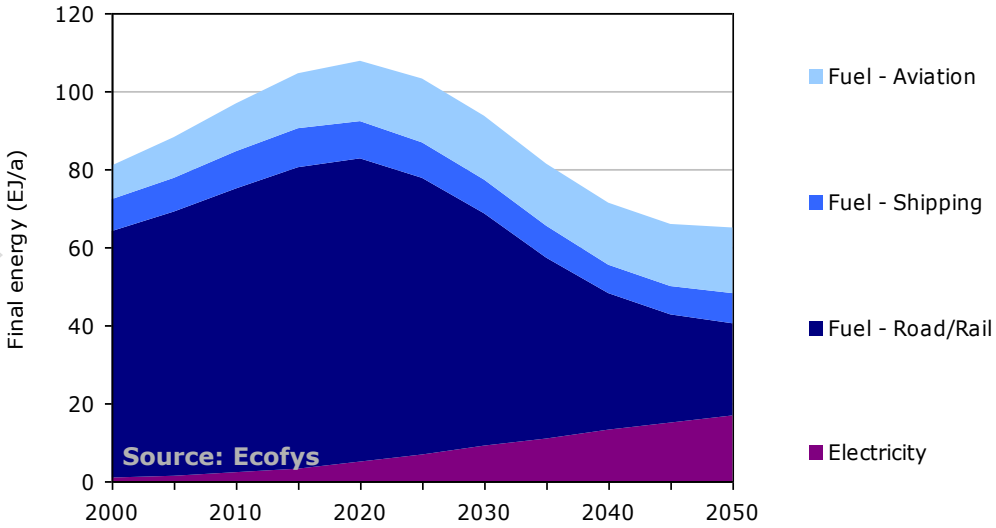


Floor area and specific energy use are shown for Residential sector only for illustrative purposes.

The stabilisation in demand in the transport sector results from ambitious energy efficiency improvements



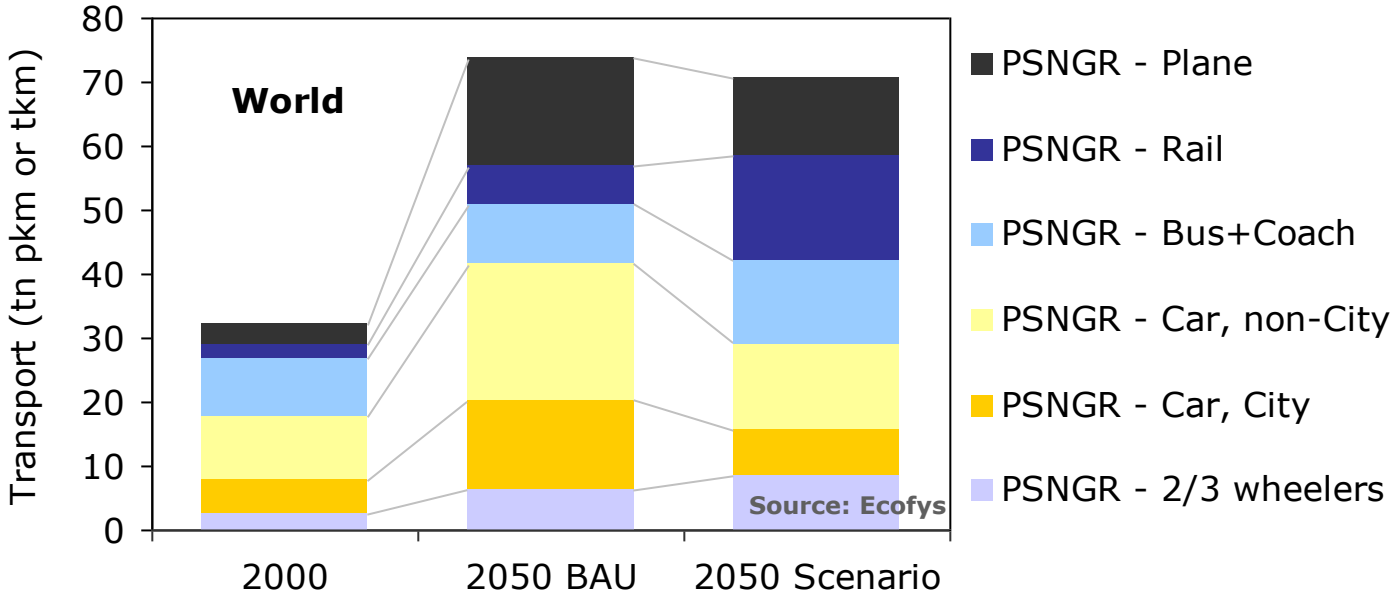




Activity graph excludes shipping. Shipping energy demand is based on GDP growth and relative efficiency savings in line with other modes.

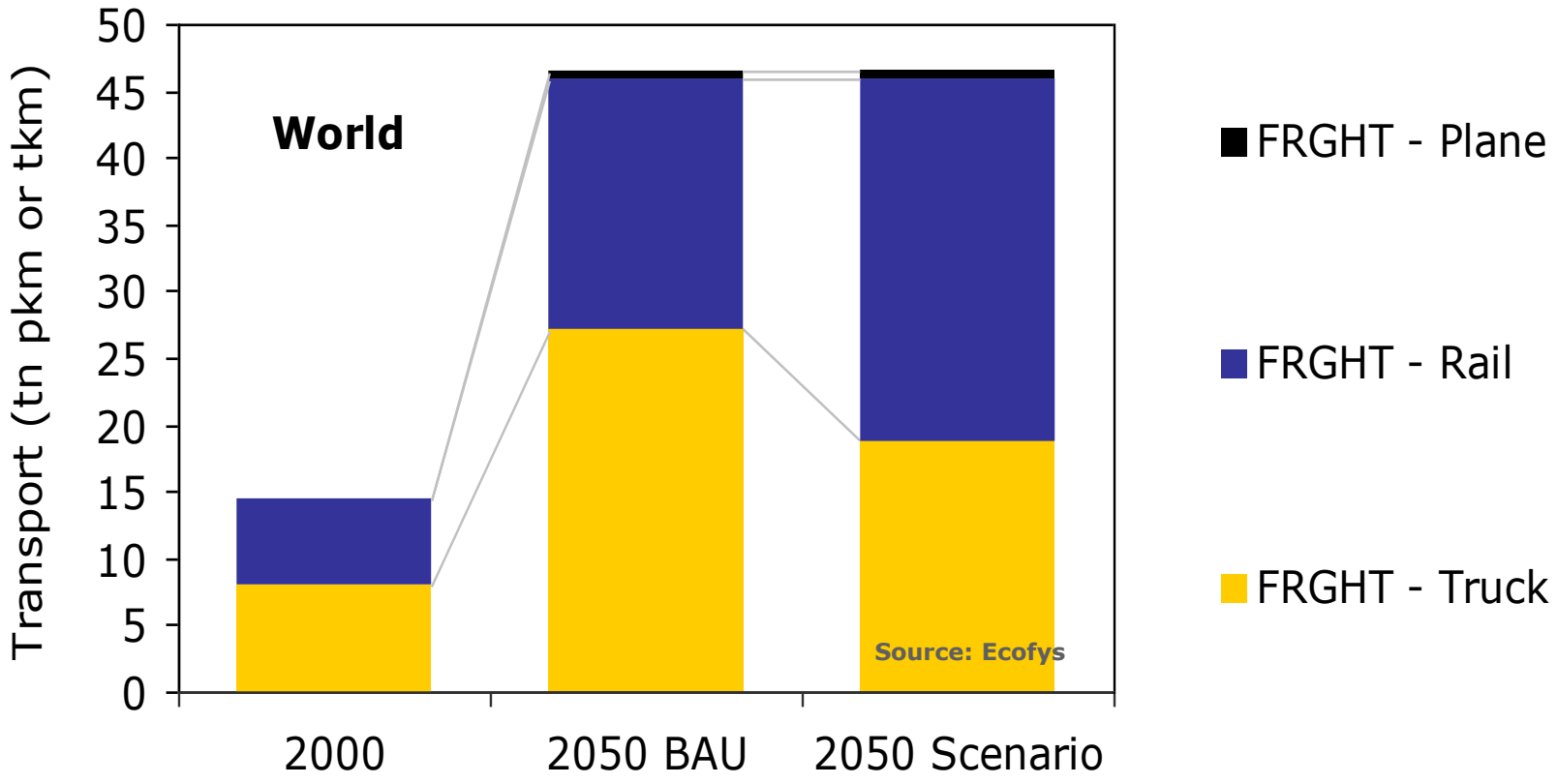
Moderate modal shift in the passenger transport sector leads to moderation of car and aviation transport

- Urban and rural car transport per capita will decrease slightly, curbing recent growth trends
  - This will be a much stronger decrease in OECD regions
- Rail and bus/coach transport will benefit from the shift away from cars and planes



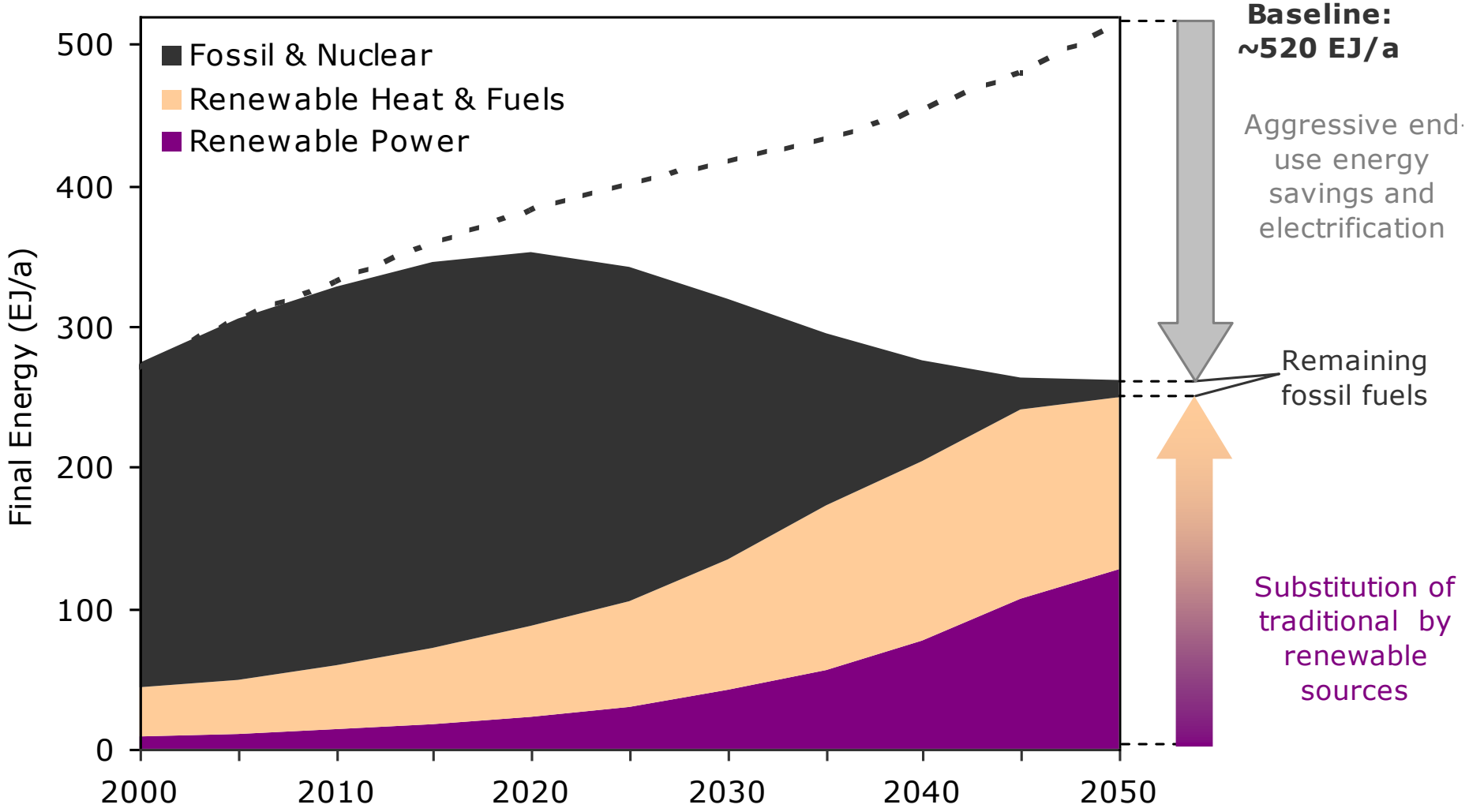
Similarly, growth in freight transport is directed much more strongly at rail than at road transport

> A re-prioritisation from truck to rail freight has been assumed

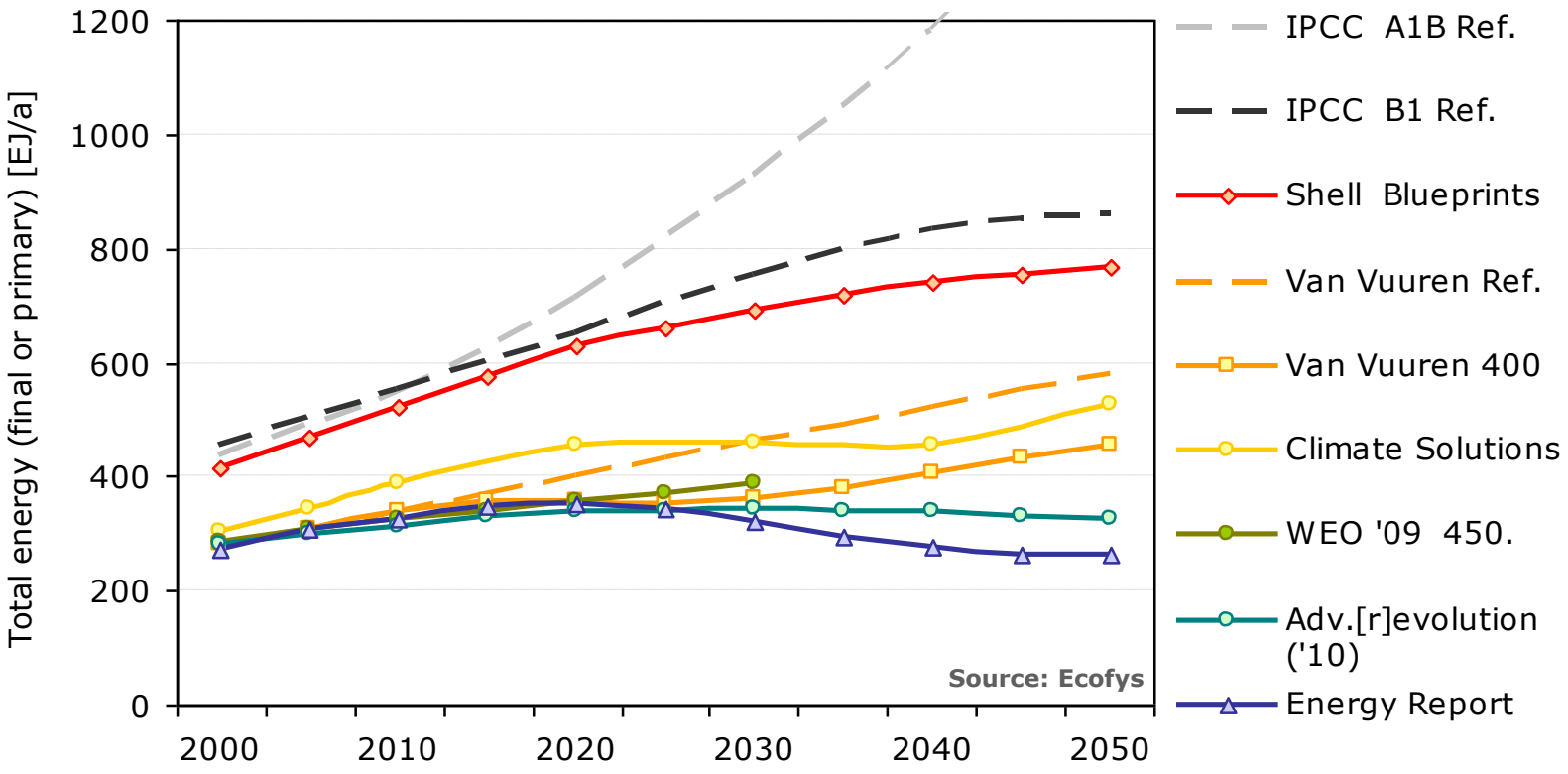


NB: Shipping freight is not represented as no activity forecasts for shipping were readily available. Shipping energy use was forecast based on a rate linked to, but lower than, the rate of GDP growth

Absolute energy use can be reduced without a reduction in energy services



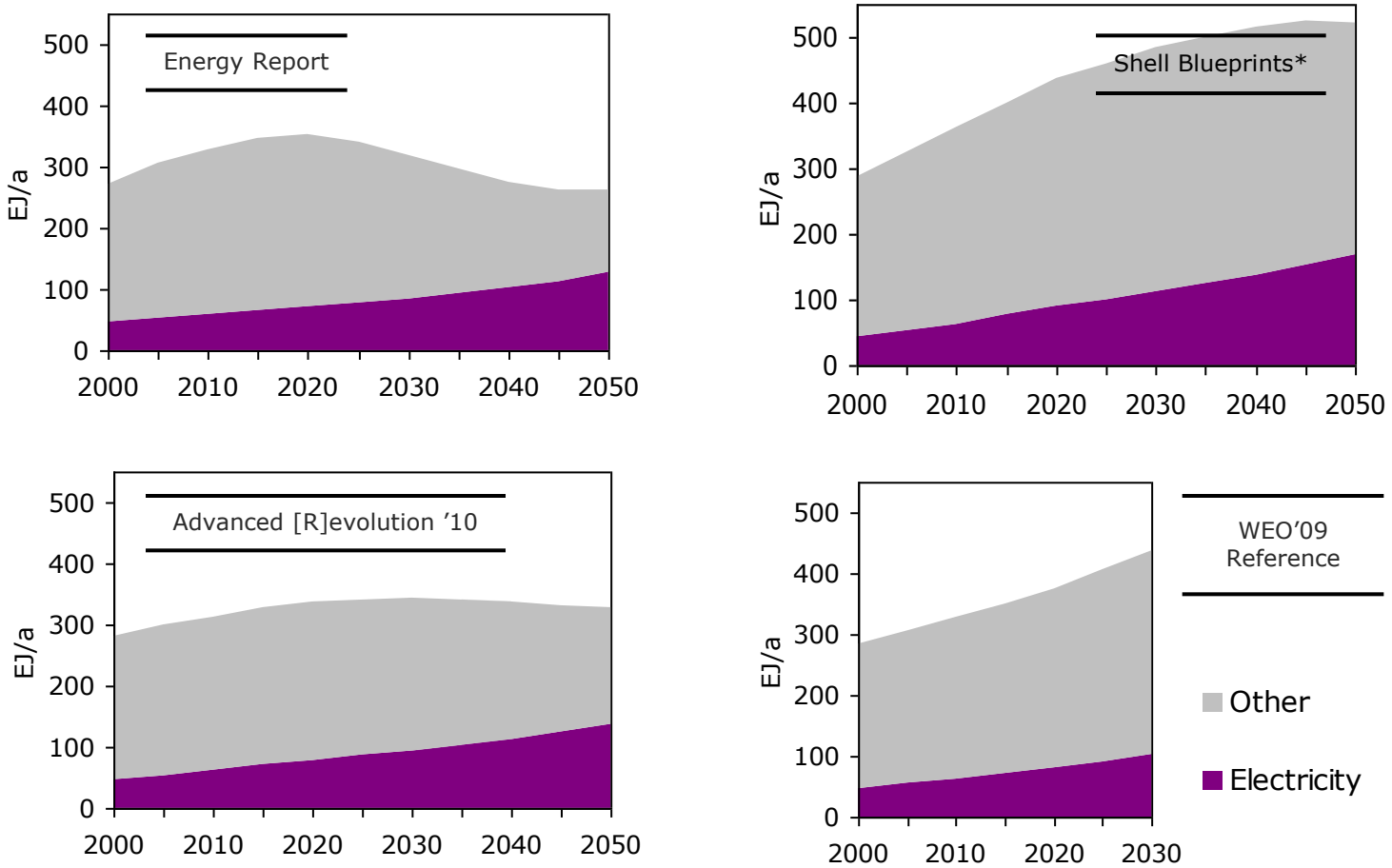
The Energy Report is amongst the most ambitious visions today



No other major scenario foresees a larger reduction in energy demand over the next 40 years

Upper lines are in primary, lower lines in final energy

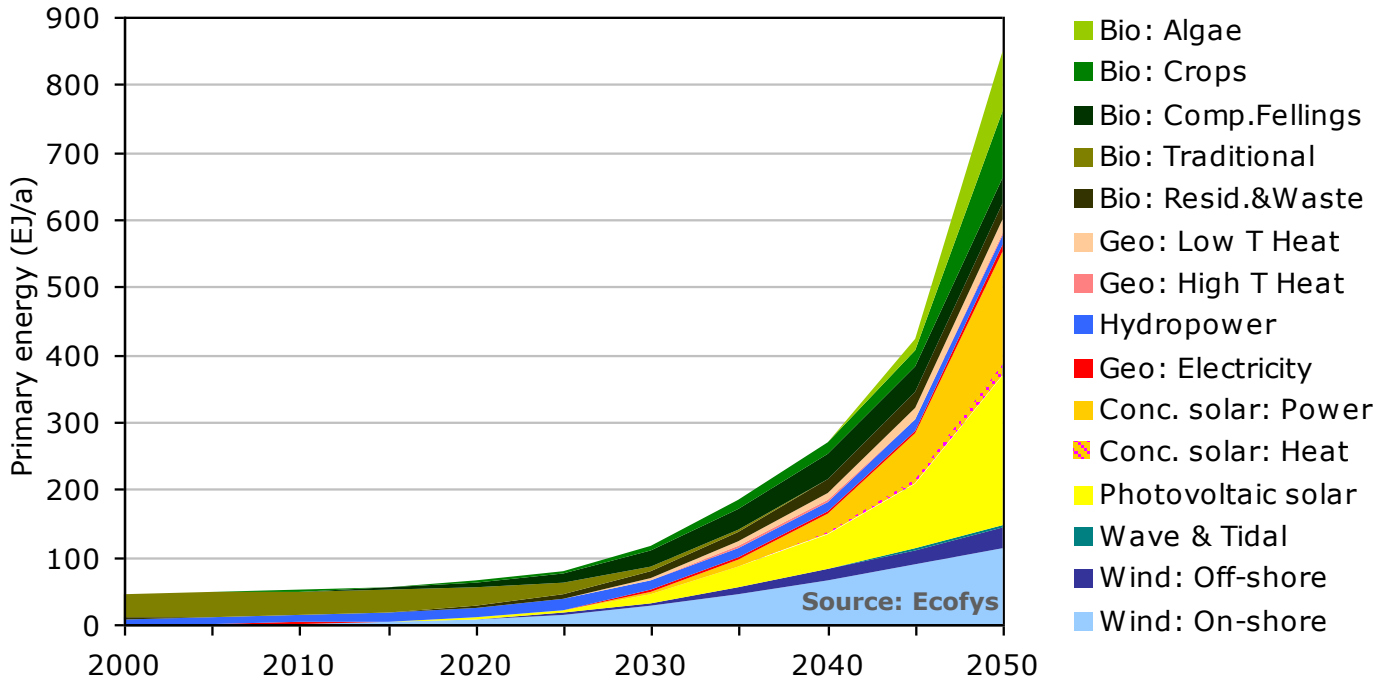
Strong electrification



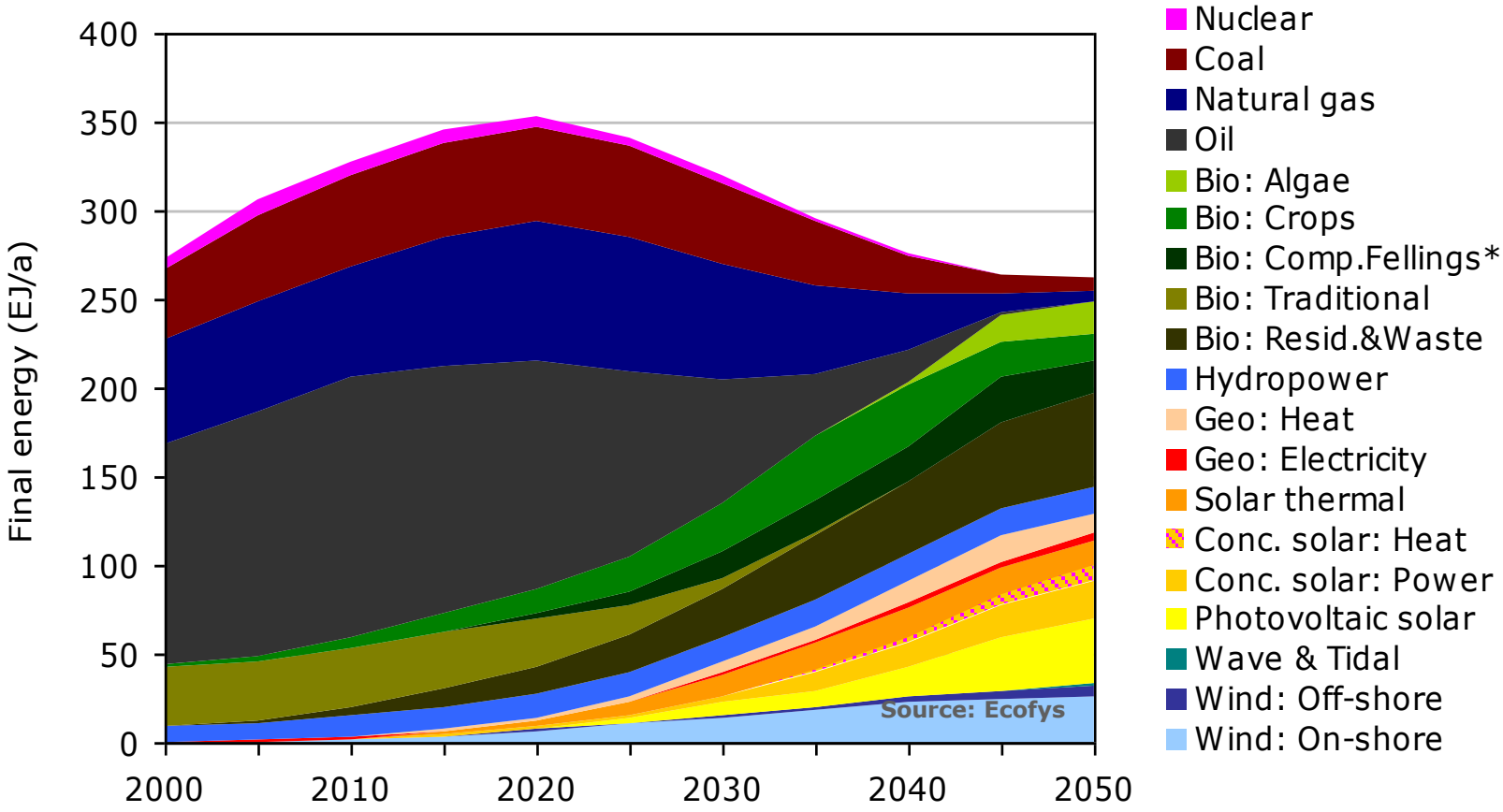
All values in final energy; *approximation

Renewable energy options will be prioritised in the development of our future energy system

- Renewable energy sources are largely untapped today
- Given the right incentives and legislative framework, this potential could be unleashed very quickly



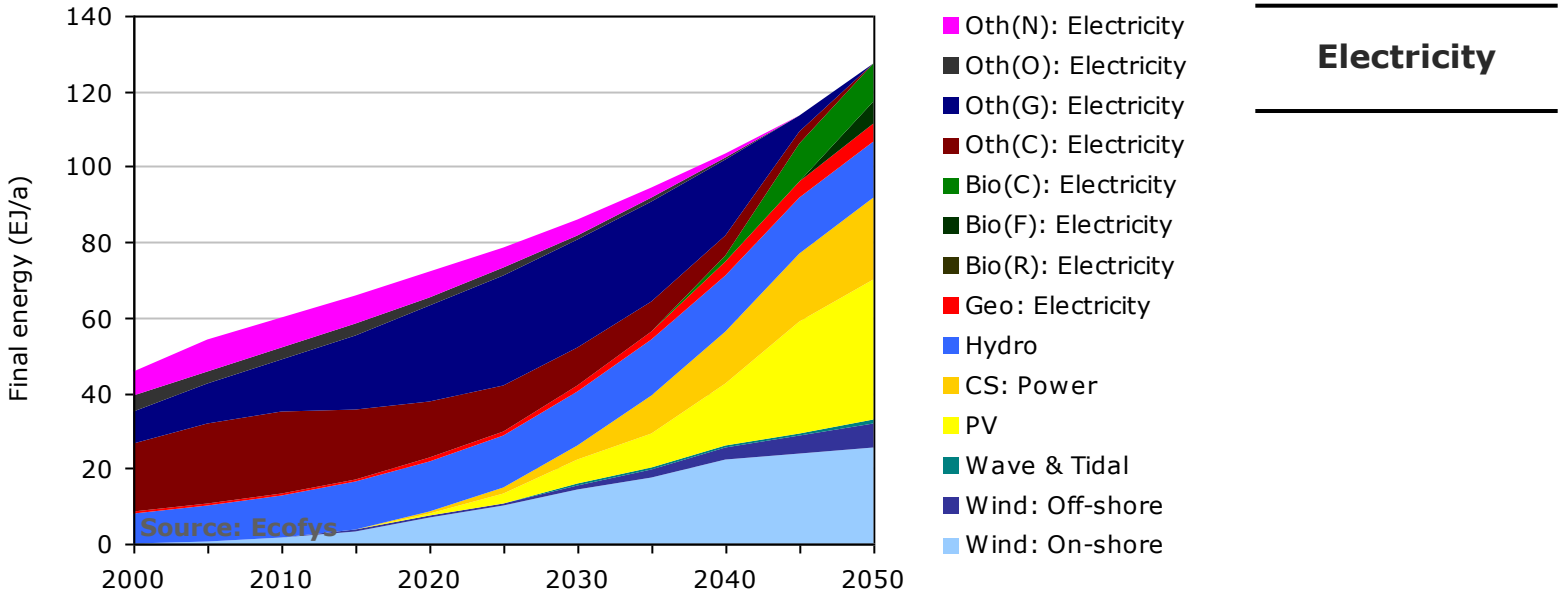
95% renewable energy worldwide by 2050 is possible…



* incl. sustainable share of traditional use

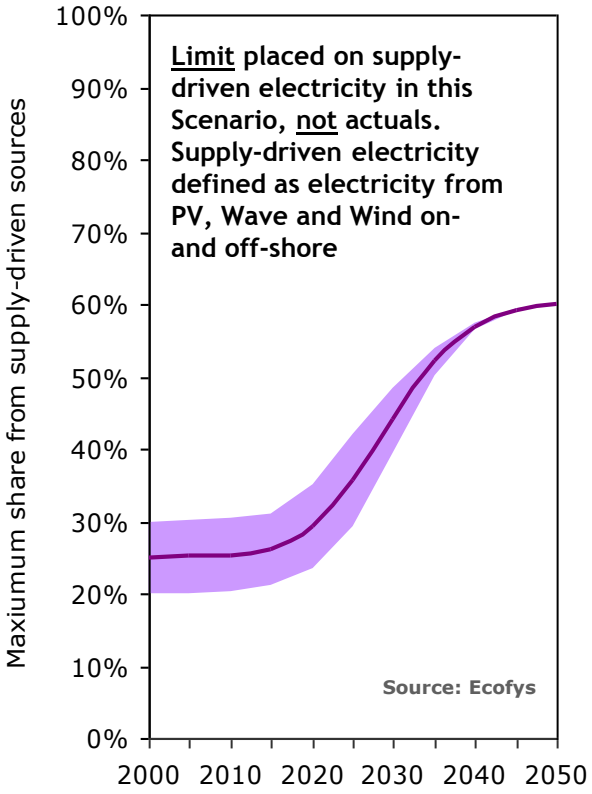
Renewable electricity growth potential will outpace electricity demand growth by 2050

- By 2050 exploitation of renewable electricity sources will be widespread
  - Renewable electricity will be so abundant that options will compete against each other even before 2050
- Supply-driven renewable sources are limited by grid capacity / stability in later years
- Hydro, Geothermal, CSP* and Bioelectricity will provide demand-driven electricitv



*CSP=Concentrated Solar Power

Regional electricity grids need to be upgraded and extended to be ready for RES power



> To equilibrate load patterns, electricity grids should be well-connected regionally

➔ **Remove bottlenecks to distribution by**

- increasing capacity and
- increasing range of transmission lines

➔ **Efforts to start <u>now</u> for results by 2030**

> Beyond 2020 may require better grid stability

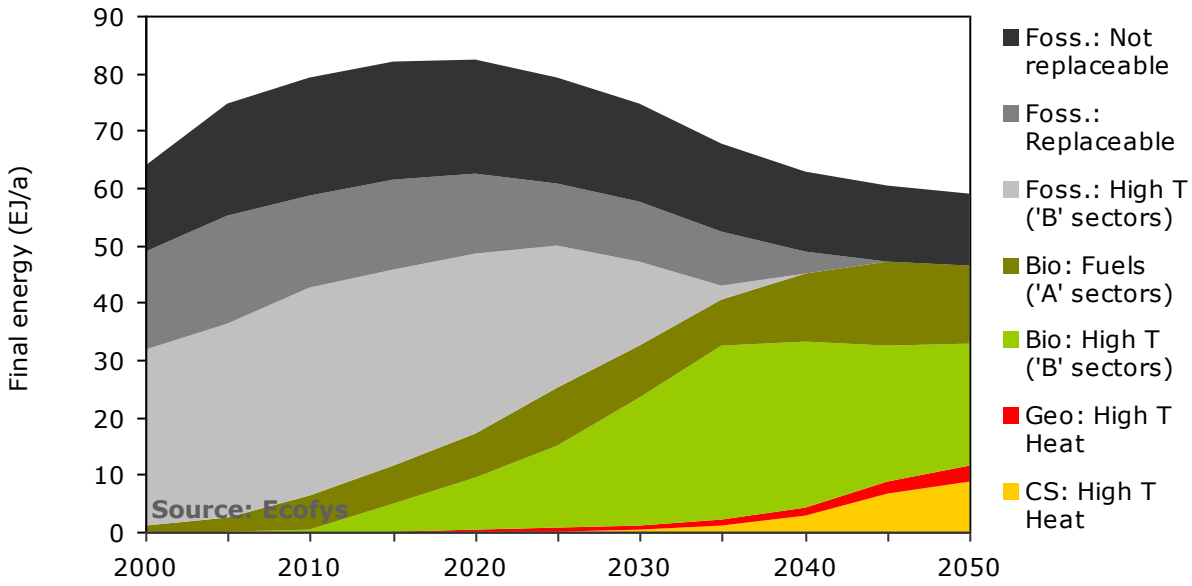
➔ **Re-focus R&D <u>now</u> to prepare our grids**

- For ultra-high RES shares beyond 2030 all of the following levers need to be employed:
  1. Grid improvements
  2. Demand side management
  3. Storage

➔ Note that to go beyond 60% supply-driven RES share, large over- and/or storage capacities would need to be built to provide peak loads

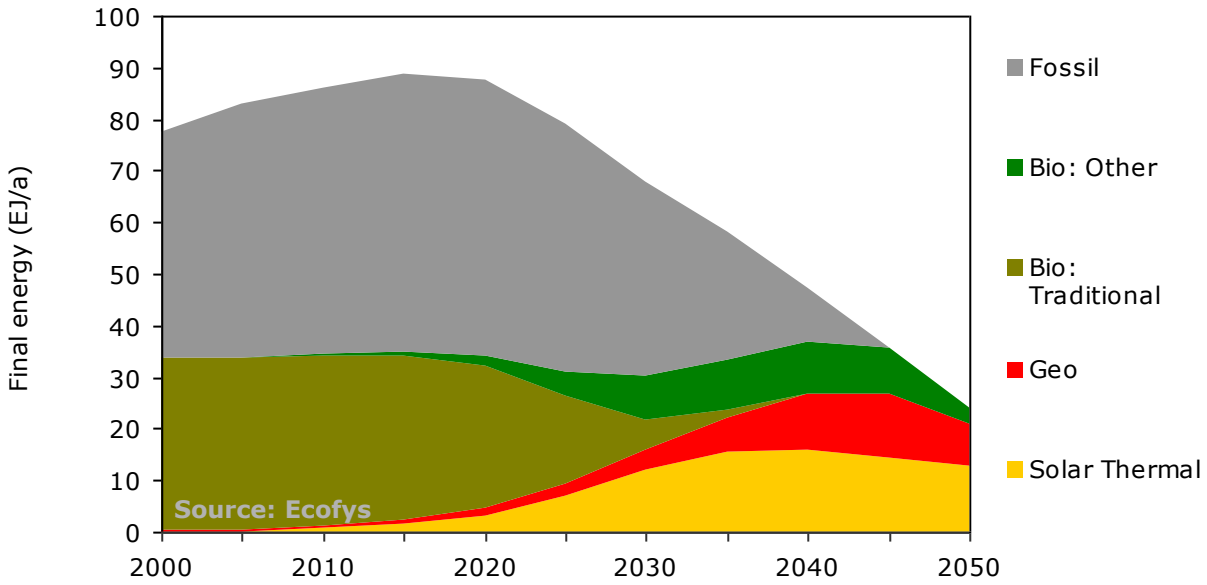
Biomass can provide a large share of industry energy needs

- Remaining heating for industry process heat, primarily for steam generation, will mostly be provided by renewable sources
  - Biomass will take the largest share of this, providing ~65%
- In addition, biomass will provide some fuel needs in industry
  - A residual need for fossil fuels remains, mainly for steel and cement production: These production processes rely on the specific properties of traditional fuels. Replacing these fuels will require the development and adoption of as yet unavailable new technologies



Renewables are expected to provide all building heat needs

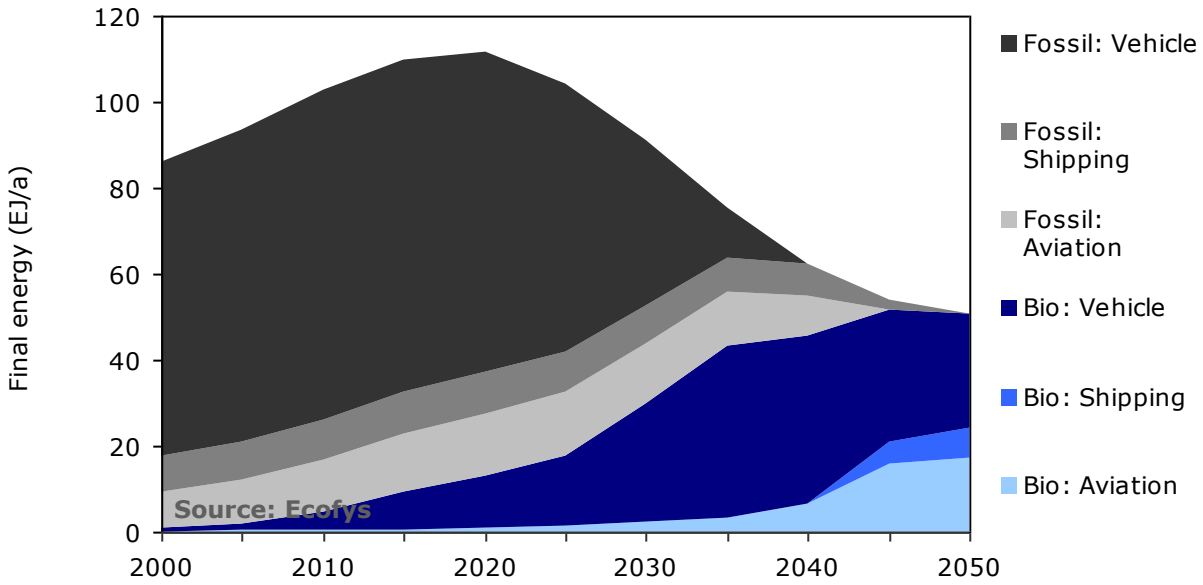
- Remaining space heating needs for buildings will be provided by
  - Decentralised solar heating and
  - Centralised or district-level renewable sources
    - Mostly geothermal heat and some bioenergy



*Solar water heating in buildings is a decentralised energy source but shown here for completeness

The largest requirement for biomass comes from liquid fuel transport

- This is primarily due to passenger air travel demand and freight transport which cannot (yet) be shifted to rail / electric transport
- NB: travel volume[1] used as activitiy indicator includes large increase in travel volume per capita in ALL regions

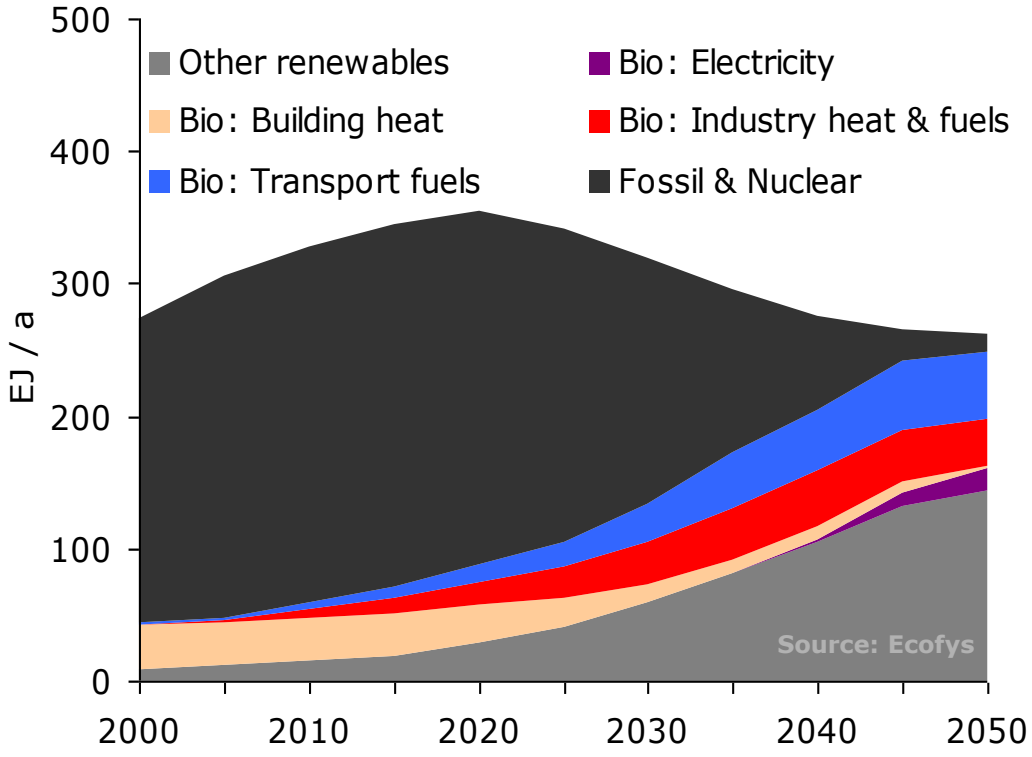


[1] IEA/SMP (2004). Model Documentation and Reference Case Projection for WBCSD's Sustainable Mobility Project (SMP)

Bioenergy is an important element of the energy supply

Bioenergy can fill energy demands where other renewables provide no or no complete alternative, e.g.:

- Transport fuels; especially:
  - Long distance road transport
  - Aviation
  - Shipping
- Industrial fuels; especially:
  - Applications that require very high temperature
  - Applications that require a specific energy carrier (e.g. gaseous fuel, solid fuel)



The Scenario uses these criteria to ensure bioenergy comes from sustainable residues, waste, complementary fellings and crops

Topic	Subtopic	Criteria applied to ensure sustainability topic is addressed
Land use and food security	Current land use	▪ Exclusion of current forested, protected and agricultural cropland
	Agricultural water use	▪ Exclusion of areas not suitable for rain-fed agriculture
	Biodiversity protection	▪ Partially contained in land use criterion ▪ Additional exclusion of land with high biodiversity value
	Human development	▪ Partially contained in land use criterion ▪ Additional exclusion of land for human development
	Food security	▪ Partially contained in land use criterion ▪ Additional exclusion of land for meeting food demand
Agricultural and processing inputs	Processing water use	▪ Closed loop for processing water in biofuel production
	Agricultural nutrient use	▪ N fertiliser production from sustainable energy and feedstock ▪ P and K fertiliser use: closed loop approach
Complementary fellings	Sustainable use of additional forest growth	▪ Exclusion of protected, inaccessible and undisturbed forest areas ▪ Exclusion of non-commercial species ▪ Exclusion of wood needed for industrial purposes
	Use of sustainable share of traditional biomass	▪ Exclusion of 70% of the current traditionally used biomass
Residues and waste	Availability of residues	▪ Exclusion of residues that are not available
	Sustainable waste use	▪ Additional recycling ▪ Exclusion of waste from non-renewable sources

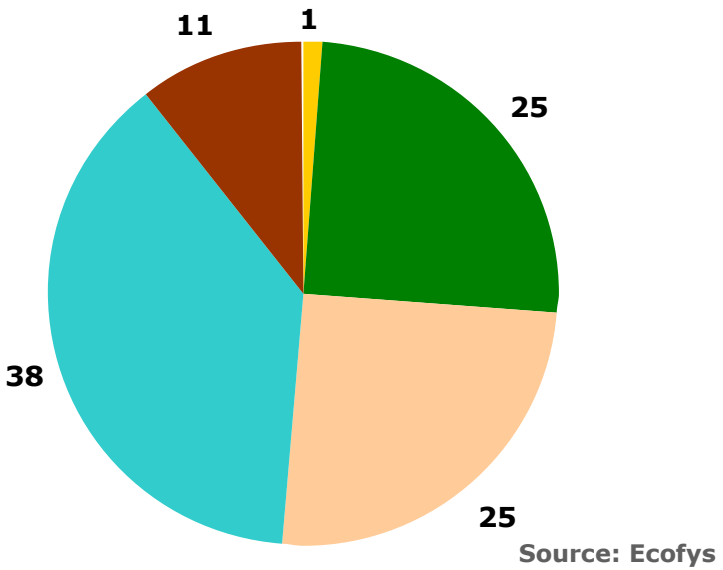
All sustainability criteria are detailed further on the following slides

Results on residues and waste

In total, ~100 EJ of potential for residues and waste was found for 2050, divided into 5 categories

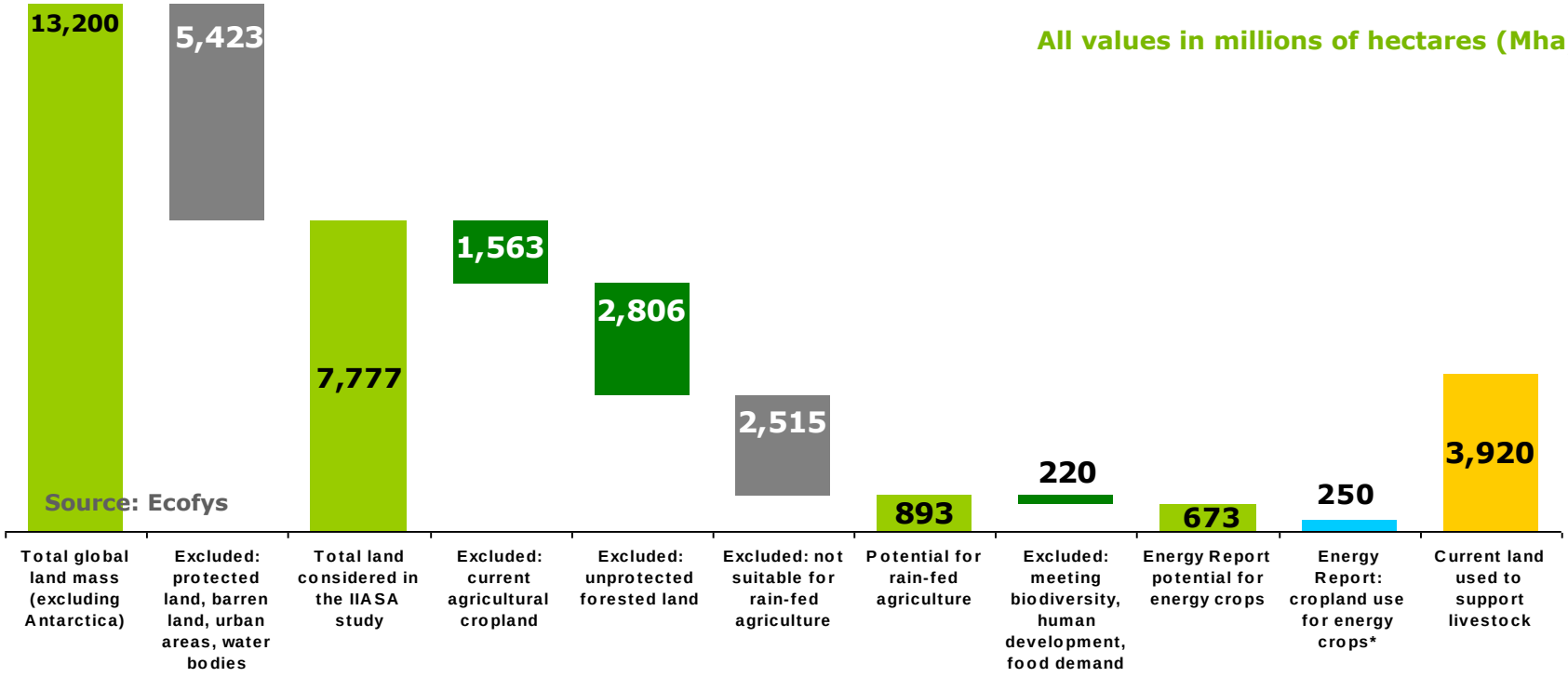
- Oils and fats (1 EJ):
  - Animal fat
  - Used cooking oil
- Forestry residues and wood waste (25 EJ):
  - Logging residues - ~5 EJ
  - Wood processing residues - ~10EJ
  - Wood waste - ~10EJ
- Agricultural residues (25 EJ):
  - Cereals
  - Rapeseed
  - Coffee
  - Soy
- Wet waste and residues (38 EJ):
  - Sugar beet processing residues
  - Potato processing residues
  - Manure
  - Oil palm empty fruit bunches
  - Palm oil mill effluent
  - Sugar cane
  - Cassava
  - Wet municipal solid waste
- Dry waste (11 EJ):
  - Dry municipal solid waste

Residue and waste potential found in the Scenario for 2050, divided into 5 categories



All values in EJ, for 2050

Results on land potential for rain-fed agriculture of energy crops in the Energy Report

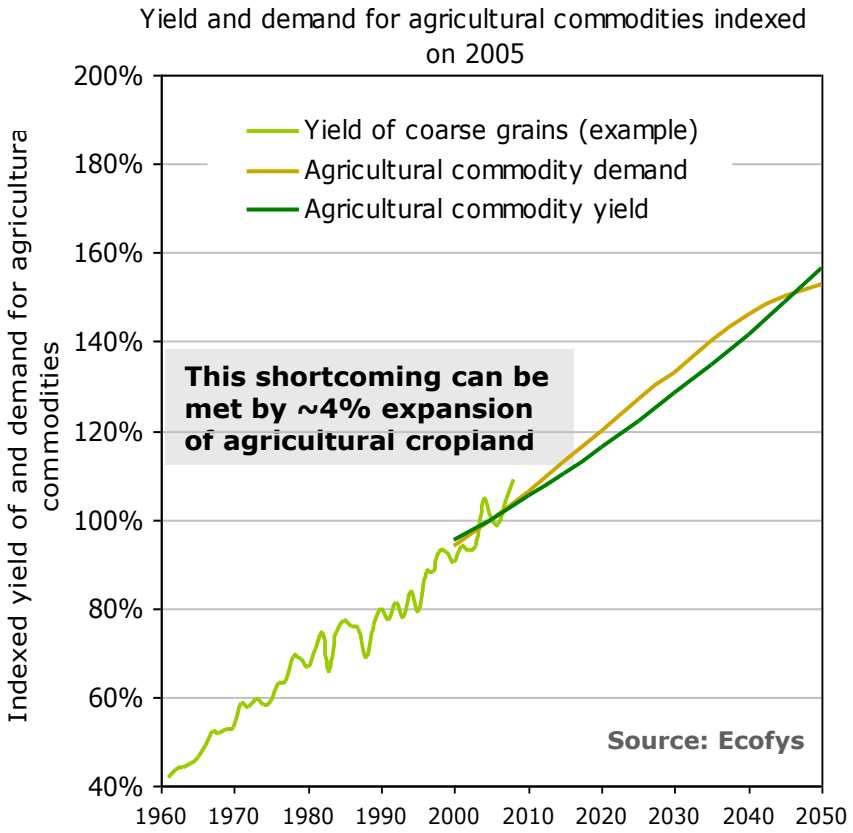


The following slides will explain how we arrived at these results

*** Cropland use for energy crops in Energy Scenario is maximum amount used during the 2005 – 2050 timeframe. This maximum occurs in 2050.**

Food security:

- Current agricultural cropland is excluded from use for energy crops in the Scenario
- Yield growth is estimated to be 1% per year based on literature
- Demand growth is based on:
  - Scenario population growth numbers
  - Scenario assumptions on constraint on per capita consumption of animal products in diets for 2050: on average ~110% of the current value
- Conclusion: ~4% of current agricultural cropland (63 Mha) was excluded from the Scenario for meeting future food demand
  - Demand growth can be met by yield increase in 2050
  - In intermediate period yield increase is not completely sufficient to meet growth in demand
  - Maximum expansion needed at any point in time is ~4% of current agricultural cropland

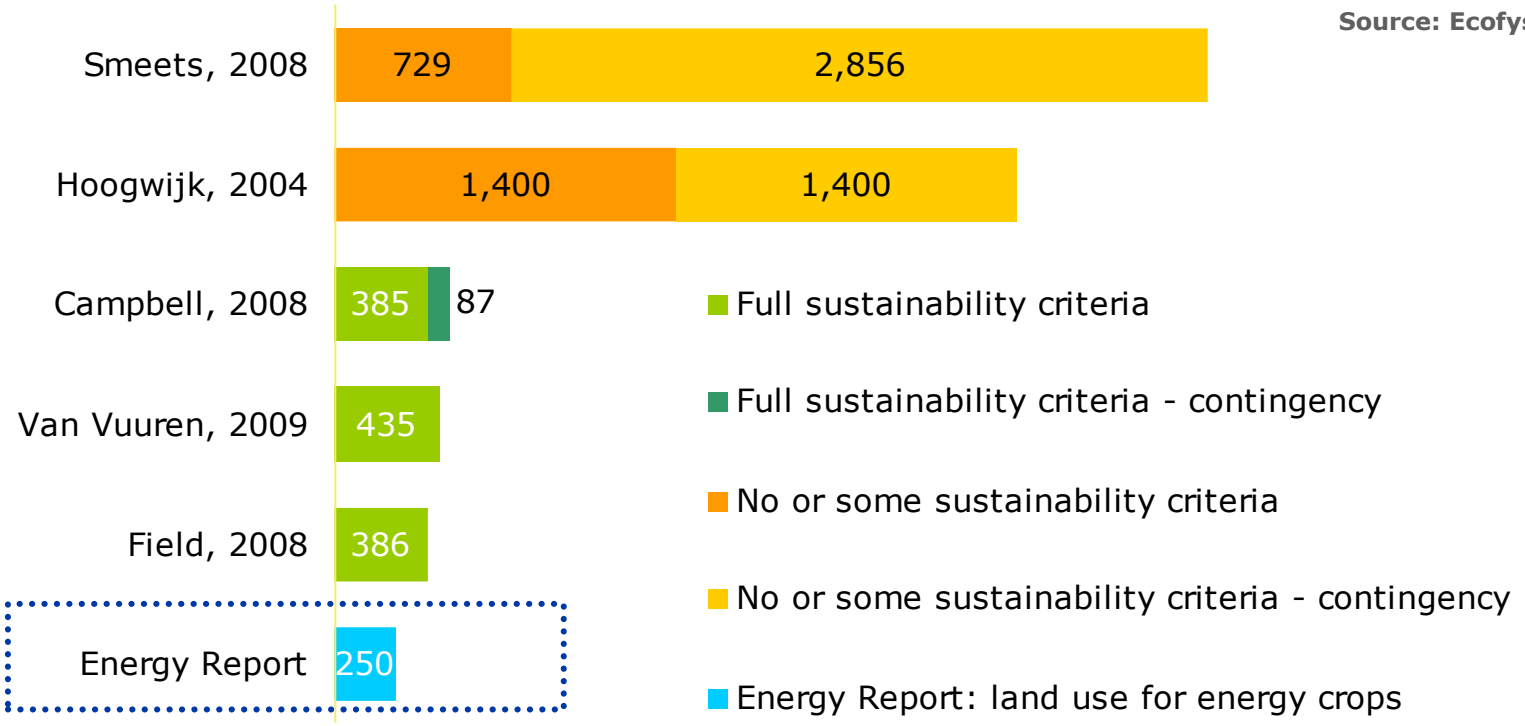


Constraint on consumption of animal products allows global food demand to be met with a minimum of land expansion

Most important sources used for this analysis:
FAO, Agricultural Outlook 2009 – 2018
FAO, World agriculture towards 2030/2050
FAO, FAOSTAT, Statistics on primary crops and livestock equivalent
Universität Klagenfurt and PIK, 2009, Eating the Planet: Feeding and fuelling the world sustainably, fairly and humanely – a scoping study

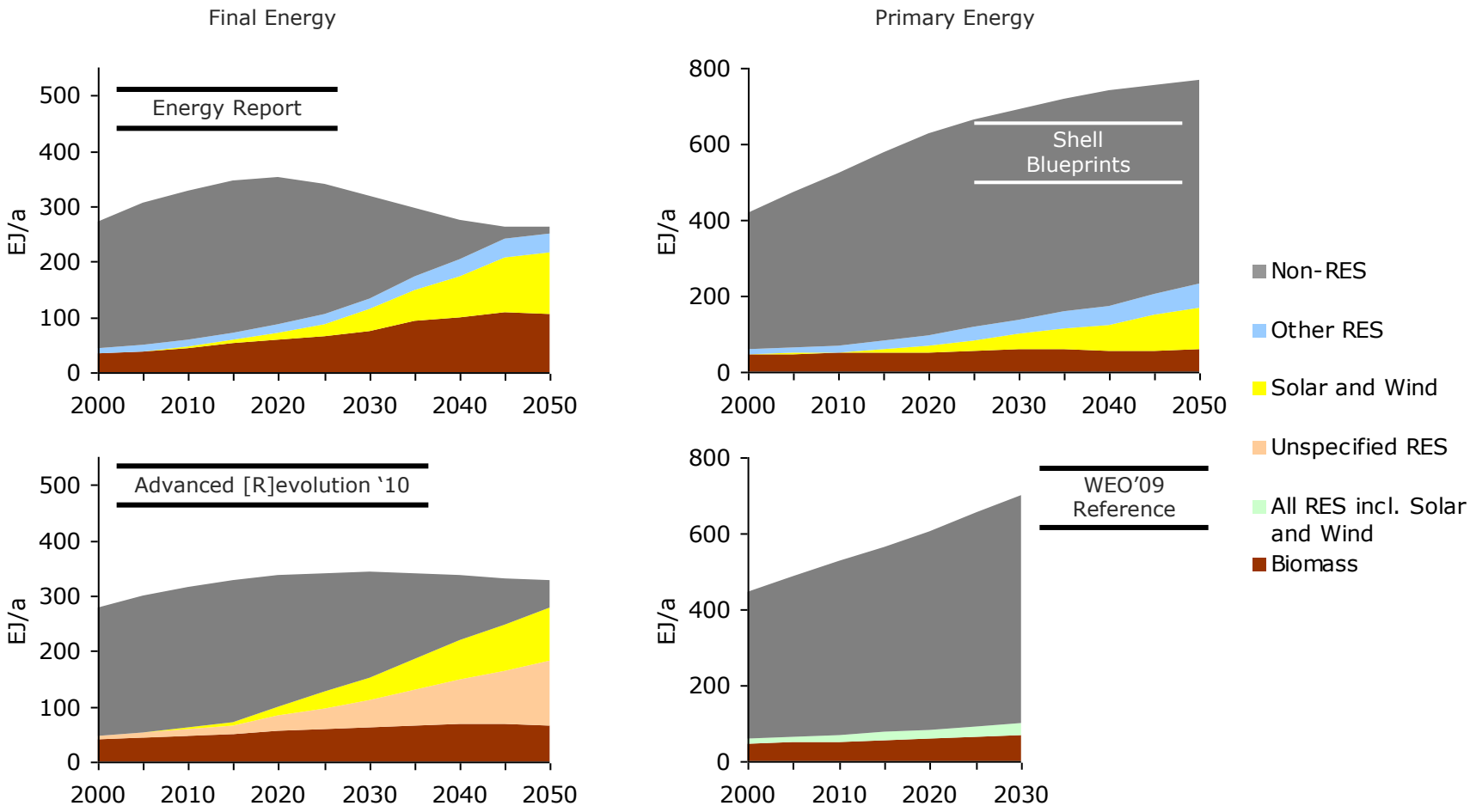
Energy Report land use for energy crops compared to area potential studies with sustainability criteria applied

All values in millions of hectares (Mha) for 2050



Notes:
1. Cropland use for energy crops in Energy Report is maximum amount used during the 2005 – 2050 timeframe. This maximum occurs in 2050.
2. Most of the studies shown above are basing their land potential on abandoned cropland

Widespread use of sustainable bioenergy allows the Scenario to reach a very high renewable energy share

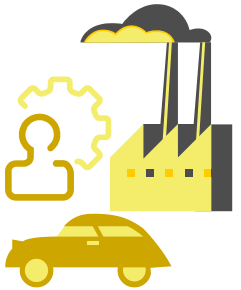


The methodology for assessing costs associated with the Energy Scenario is similar for all sectors

Total activity over time from the Energy Scenario

Capacity changes / year
- *e.g. installed GW*

Activity / year
- *e.g. produced GWh*



CapEx / unit
- *e.g. € / GW*

Other assumptions
- *e.g. learning curves*

OpEx / unit
- *e.g. € / GWh*

CapEx / year

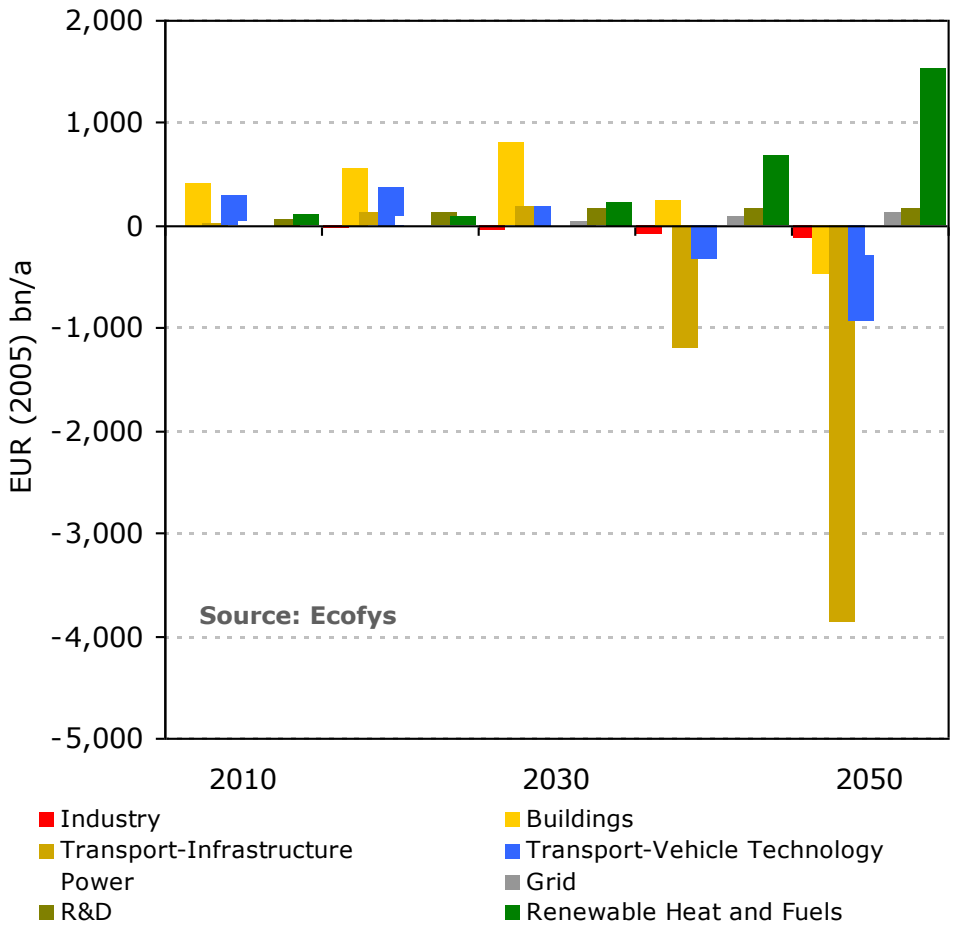
OpEx / year

Investment in buildings dominates until 2030, savings from transport afterwards

- Net annual costs peak at 1,800 bn EUR in 2025
- Net annual savings peak at 6,000 bn EUR in 2050

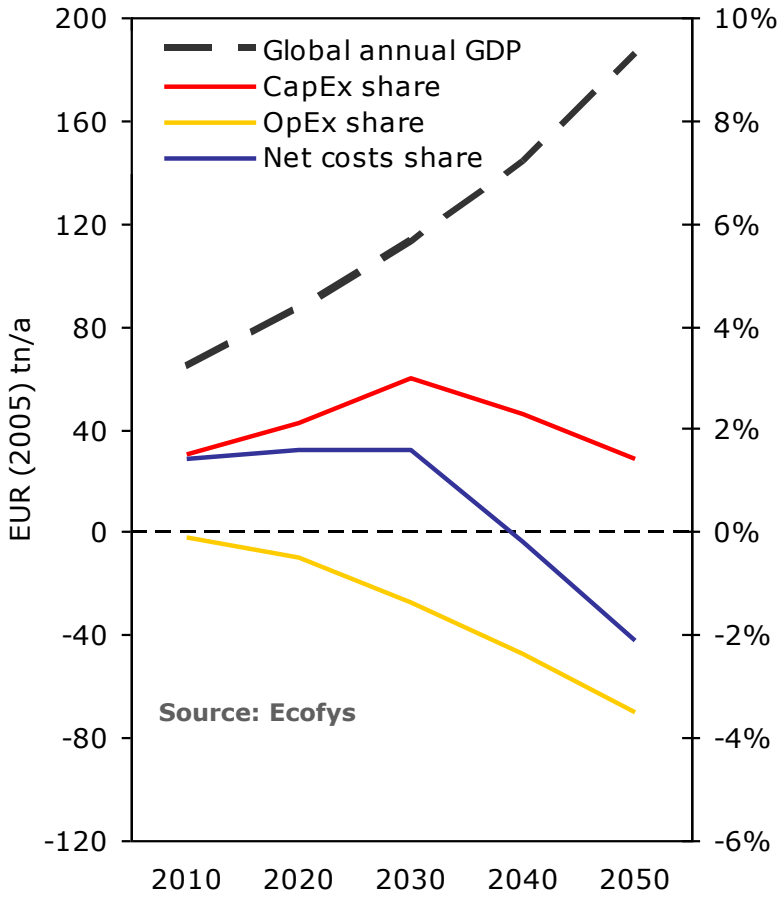
- Dominant parameters:
  - Transport investment assumptions
  - Fuel price assumptions (+1% to +4% annually)
  - Efficiency improvements on the demand side

- Uncertainties/Sensitivity:
  - Learning rates
  - Regional detail

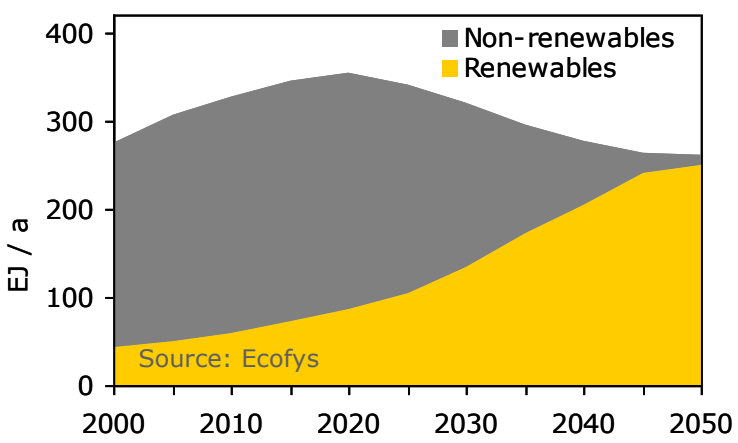


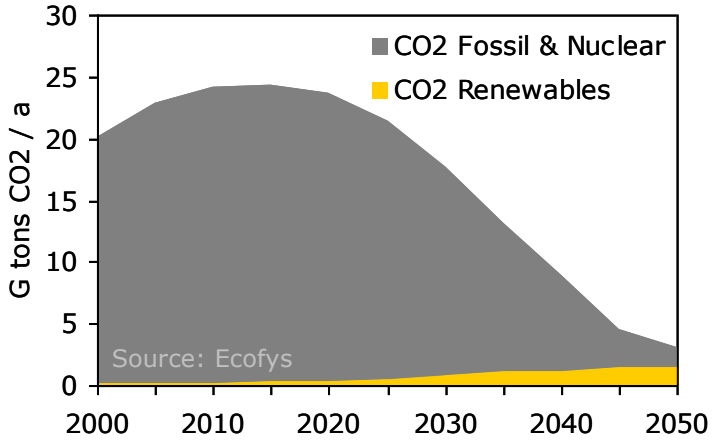
Global net costs will peak below 2% of GDP, and will turn to net savings after 2035

- Net annual costs peak just below ~2% in 2025, and turn into more than ~2% annual savings worldwide in 2050
- CapEx peaks at ~3% in 2030, then decreases to below ~1.5% in 2050
- Savings from saved energy rise constantly to ~3.5% in 2050, with increased growth after 2020



The Scenario also heavily reduces CO_2 emissions





- In our vision, worldwide CO_2 emissions from the energy system would decrease by ~80%[1] by 2050 vs 1990 levels
- Phasing in CCS from 2020 onwards would result in further emission reductions in the later years
- NB: emission from renewable sources include lifecycle emissions from biomass as well as the (low) emissions from hydropower

[1] These are 'raw' emissions. When correcting for the fact that a larger share of the remaining emissions are emitted by aviation, this reduces to ~75%.

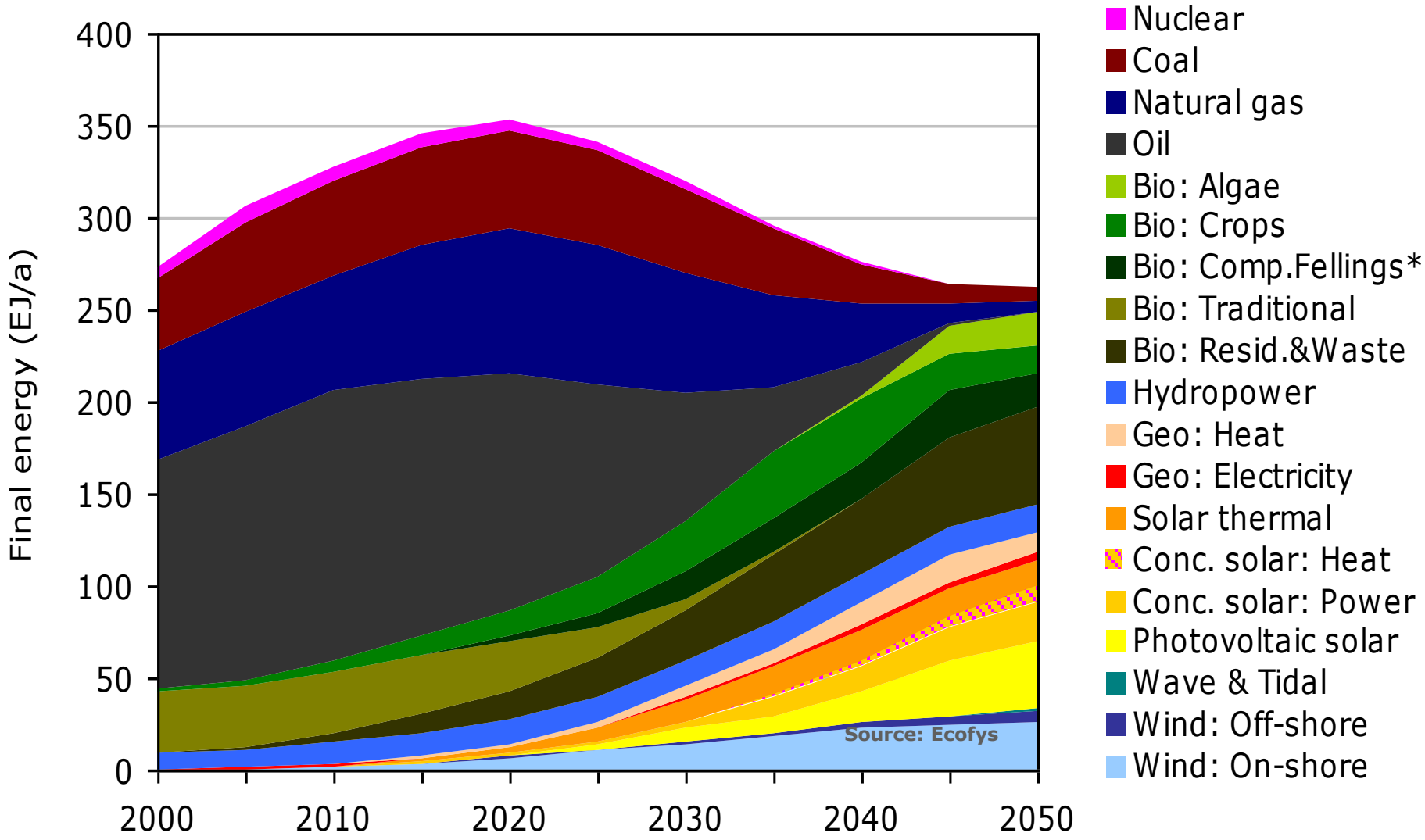
Strong leadership is required to make this transformation happen

	Demand			Supply
	Buildings	**Transport**	**Industry**	

Setting consistent and ambitious **frame-works**	▪ Incentives to achieve **performance levels** of BAT*
	  ▪ in 5-10 yrs for all new stock
	  ▪ in 20-30 yrs for existing stock (retrofit)
	▪ "Top-runner" approach to appliances
		▪ **Performance standards** on fuel efficiency for all transport modes
		▪ Incentives to shift to rail, especially for freight
			▪ Incentives to achieve **performance levels** of BAT*
			  ▪ now for new plants
			  ▪ in 10-20 yrs for existing plants
			▪ Optimal recycling rates
			▪ Incentives to stimulate Industry R&D
				▪ **Comprehensive**, reliable and flexible **support schemes** to incentivise deployment of renewable energy technologies
				▪ Connection obligations for grid operators
				▪ Optimisation of planning processes
				▪ Incentives to stimulate grid **infrastructure** investments

Public **invest-ments**	▪ Investment support for building retrofits	▪ Investments into public transport, e.g. (electric) rail **infrastructure**	▪ R&D into new production processes ▪ Recycling infrastructure	▪ R&D into dynamic grid stability and smart grids
Private leadership	▪ Incorporating **highest performance levels** into all building projects	▪ Pushing the development and deployment of **highest performance** transport modes	▪ Incorporating **highest performance** levels into all new plants ▪ Improving performance of existing plants with **long-term vision**	▪ Pushing the **development and deployment** of renewable power sources

*** BAT = best available technology, for buildings this would mean near-zero energy-use**


Final energy (EJ/a)
400
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Source: Ecofys
Nuclear
Coal
Natural gas
Oil
Bio: Algae
Bio: Crops
Bio: Comp.Fellings*
Bio: Traditional
Bio: Resid.&Waste
Hydropower
Geo: Heat
Geo: Electricity
Solar thermal
Conc. solar: Heat
Conc. solar: Power
Photovoltaic solar
Wave & Tidal
Wind: Off-shore
Wind: On-shore

Thank you!

Prof. dr. Kornelis Blok
Director of Science

Ecofys
Kanaalweg 15-G
3526 KL Utrecht
The Netherlands

Phone: +31-30-6623399
E-mail: k.blok@ecofys.com
Twitter: @kornelisblok

www.ecofys.com

sustainable energy

for everyone