FRANKFURT UNIVERSITY OF APPLIED SCIENCES

Energy Economics

Fachbereich 2 Informatik und Ingenieurwissenschaften

Organizational matters

- office hours: Wednesday 1:30 - 2:30 pm, 8-110
- email: sebastian.schaefer@fb2.fra-uas.de

- lecture (with integrated exercises): 15 sessions until February 8
- final exam: 90 minutes

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Outline

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Recommended literature

- Pindyck, R. S., Rubinfeld, D., L.: Microeconomics, Pearson, 9th ed., 2018. Available at: https://hds.hebis.de/fuas/Record/HEB428675476
- Schweppe, C. F., Caramanis, M., Bohn, R. E., Tabors, R. D., Spot pricing of electricity, 1st ed., Kluwer Academic Publishers, Boston, 1988. Available at: https://hds.hebis.de/fuas/Record/HEB509855989
- Stoft, S.: Power system economics, IEEE Press, Picataway, 2002. Available at: https://hds.hebis.de/fuas/Record/HEB105049344
- Kirschen, D., Strbac, G.: Fundamentals of power system economics, 2nd ed., Wiley, Hoboken, 2019. Available at: https://hds.hebis.de/fuas/Record/HEB435306685
- Schwintowski, H.-P., Scholz, F., Schuler, A.: Handbuch Energiehandel, 5th ed., Erich Schmidt Verlag, Berlin, 2021. Available at: https://hds.hebis.de/fuas/Record/HEB485488310
- Schäfer, Altvater, L.: On the functioning of a capacity market with an increasing share of renewable energy. *Journal of Regulatory Economics* 2019, **56**, 59-84. Available at: https://link.springer.com/article/10.1007/s11149-019-09389-6

Power, energy, work

- energy [$\frac{kg \cdot m^2}{s^2}$, J, Ws, VAs, kWh, MWh]
- power [$\frac{kg \cdot m^2}{s^3}$, J/s, W, VA, kW, MW]
- work [$\frac{kg \cdot m^2}{s^2}$, J, Ws, VAs, kWh, MWh]
- **kinetic energy** of the wind is partially transformed into **mechanical work**
- a generator is used to transform **mechanical work** of the rotor into **electric energy**

Energy demand and supply

energy demand

- energy cannot vanish nor it can be consumed
- Nevertheless, in this lecture you will hear terms like “energy cunsumption” or “energy consumers”

energy supply

- energy cannot be produced or generated
- Nevertheless, in this lecture you will hear terms like “energy production” or “electricity generation”

$\Rightarrow$ “consumers” and “producers” are technical terms in economics.

Total energy supply

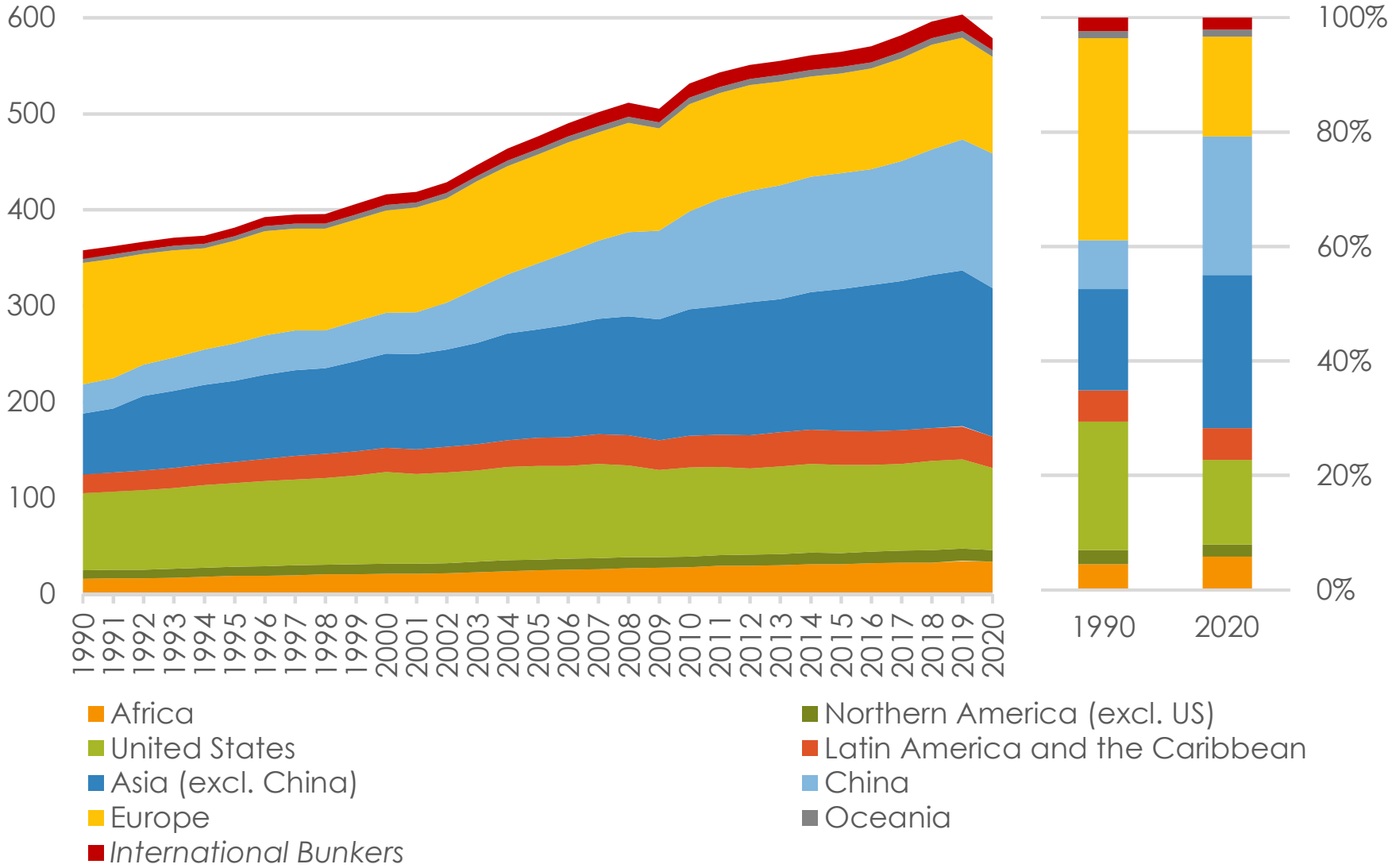


Figure: Total energy supply [EJ] worldwide by region, 1990-2020; source: United Nations (2023).

Energy intensity

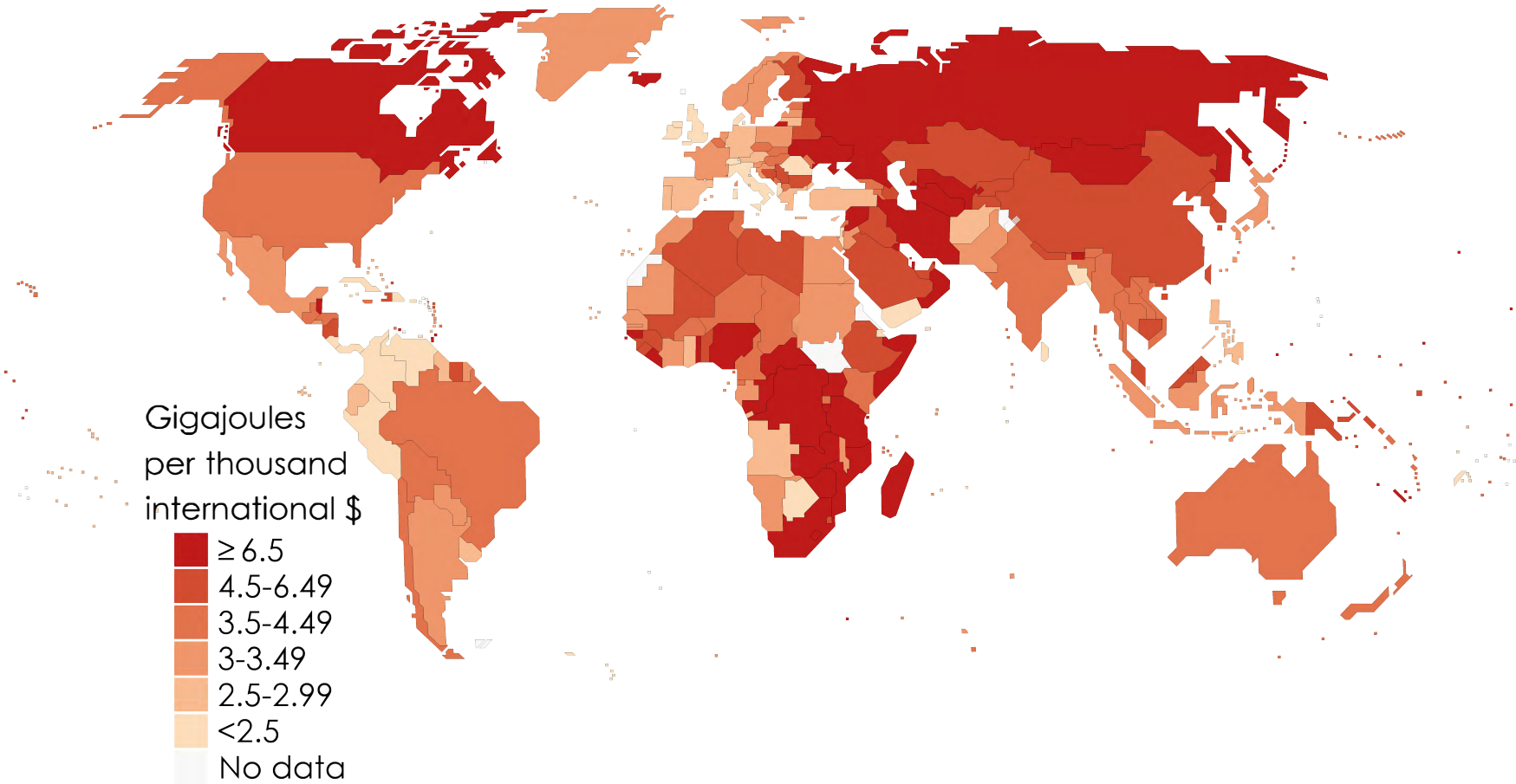


Figure: Energy intensity [MJ/int. $], 2019; source: United Nations (2023).

Indicators for energy supply

Country	TES	Country	TES per capita	Country	Energy intensity[2]
China	140.2	Iceland	988.2	Iceland	18.9
United States	85.5	Qatar	635.2	Trinidad and Tobago	17.7
India	38.2	Bahrain	451.2	New Caledonia	14.1
Russian Federation	31.5	Trinidad and Tobago	405.0	Liberia	14.0
Japan	16.1	United Arab Emirates	391.6	Zimbabwe	13.7
Brazil	11.9	Brunei Darussalam	369.7	Dem. Rep. of the Congo	13.5
Canada	11.9	Kuwait	350.9	Uganda	12.3
Germany	11.6	Gibraltar	320.8	Turkmenistan	11.9
World	**578.6**	**World**	**73.8**	**World**	**4.6**

Figure: Total energy supply (TES) [EJ], TES per capita [GJ] and energy intensity [MJ/int. $] of major countries, 2019; source: United Nations (2023).

Primary production of coal, oil and gas

Coal		Oil		Natural gas	
China	80.5	United States	30.4	United States	33.0
Indonesia	14.3	Russian Federation	21.9	Russian Federation	24.8
Australia	12.3	Saudi Arabia	20.8	Iran (Islamic Republic of)	8.2
India	11.6	Canada	11.0	China	7.7
United States	10.8	Iraq	8.5	Canada	6.5
Russian Federation	9.7	China	8.2	Qatar	6.2
South Africa	5.8	United Arab Emirates	7.5	Australia	5.3
Kazakhstan	1.9	Brazil	6.7	Saudi Arabia	4.8
Others	12.4	Others	60.6	Others	45.3
World	**159.4**	**World**	**175.6**	**World**	**141.8**

Figure: Primary production of coal, oil and gas in the major countries, 2019; source: United Nations (2023).

Total energy supply

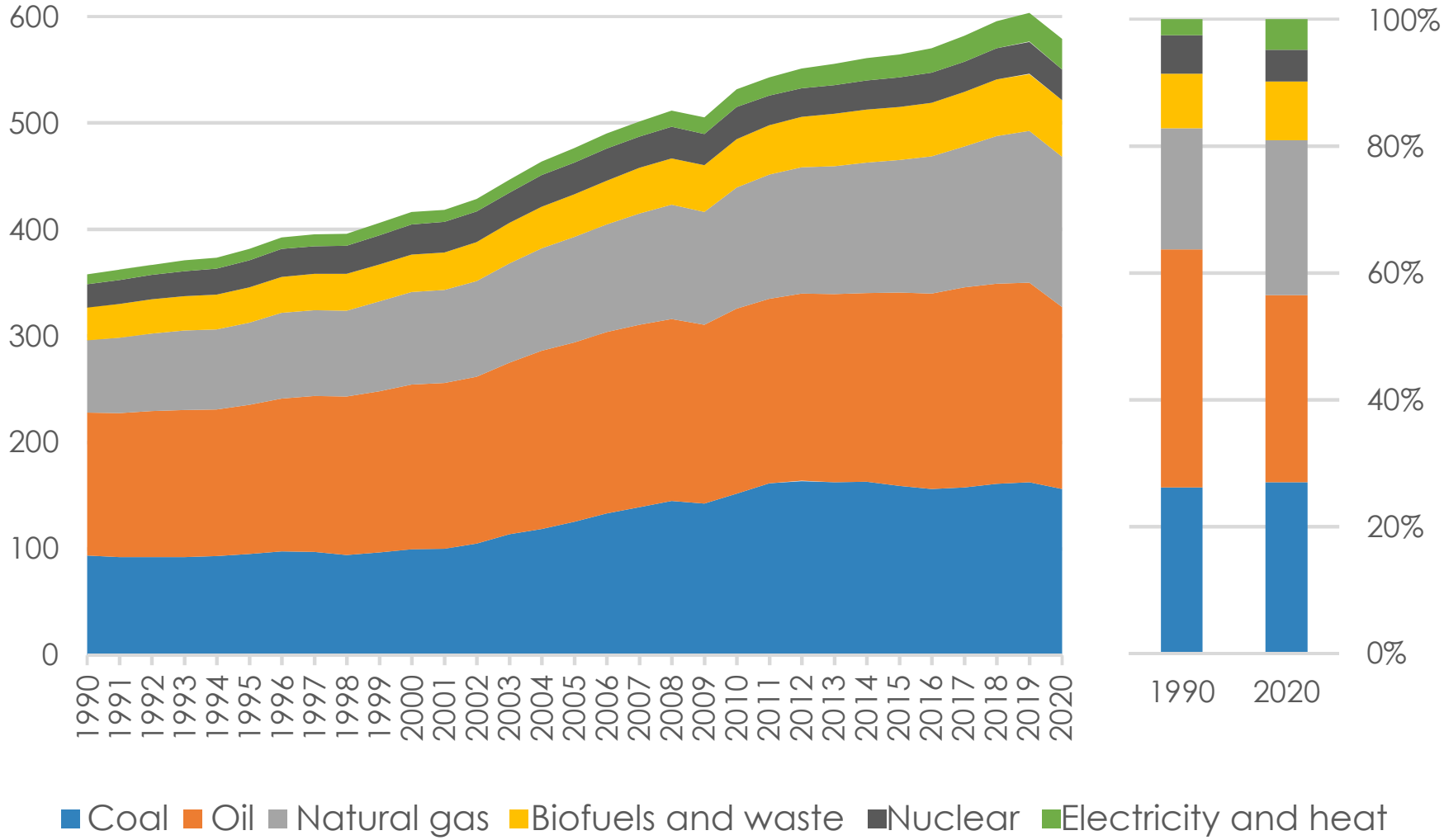


Figure: Total energy supply [EJ] worldwide by source, 1990-2020; source: United Nations (2023).

Total energy consumption

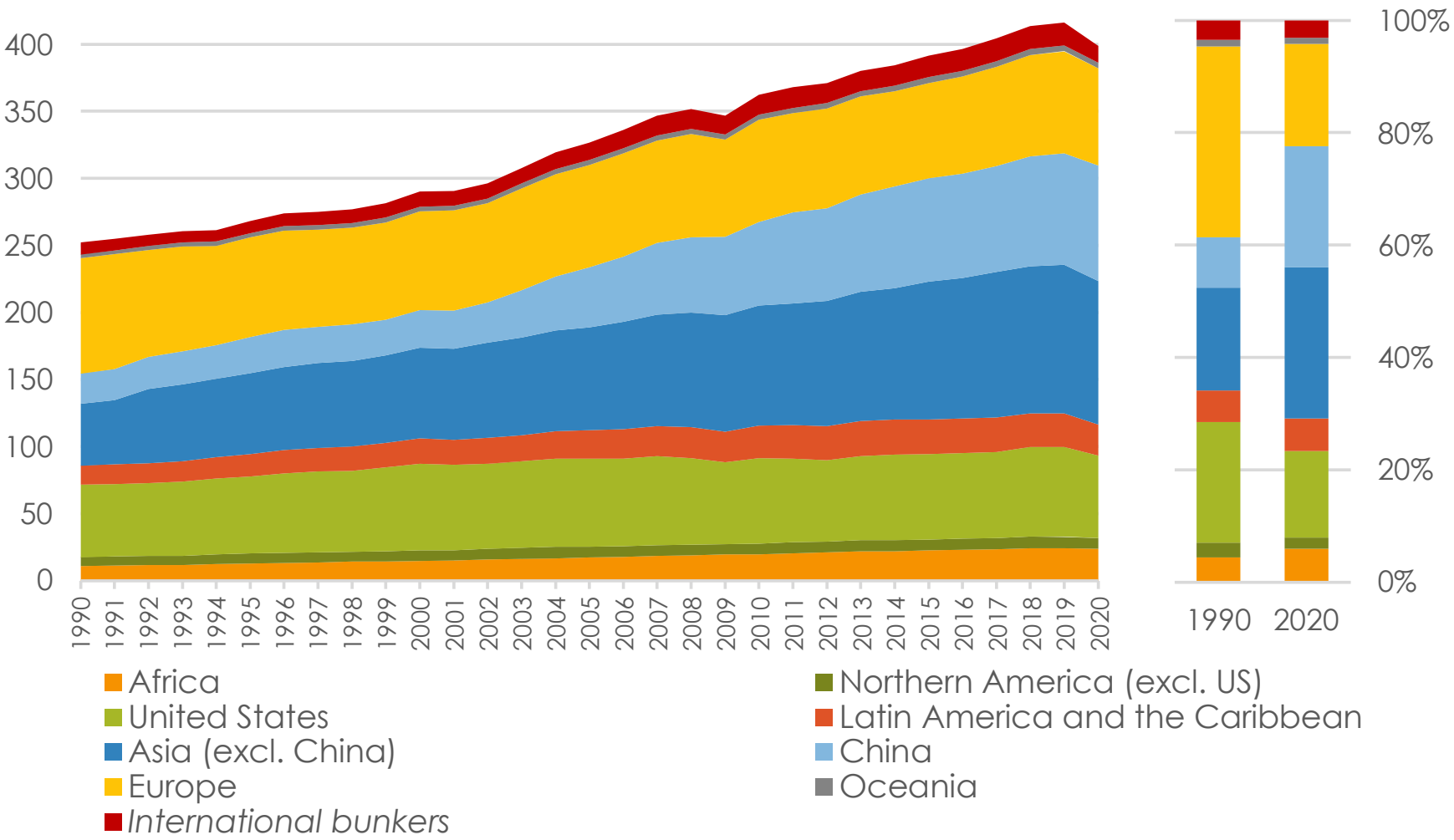
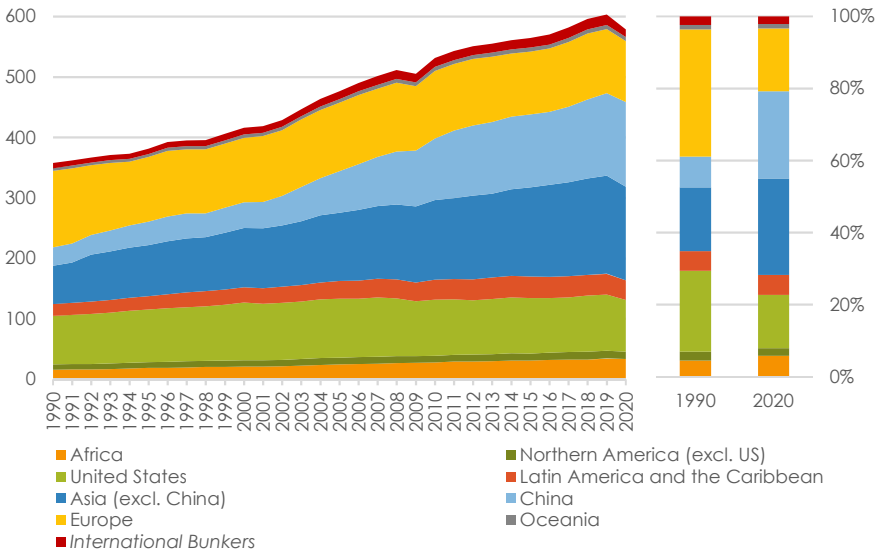


Figure: Total energy consumption [EJ] worldwide by region, 1990-2020; source: United Nations (2023).

Total energy supply and consumption



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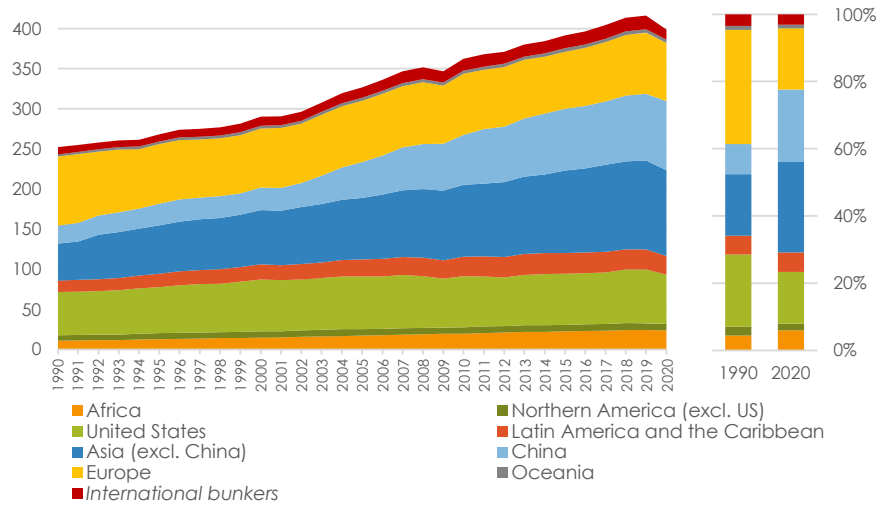


Figure: Total energy consumption [EJ] worldwide by region, 1990-2020; source: United Nations (2023).

World energy balance 2019

Energy balance, 2019 (Exajoules)										
World	Primary coal	Coal products	Primary oil	Oil products	Natural gas	Biofuels and waste	Nuclear	Electricity	Heat	Total	of which: renewables[10]
Primary production	167.8	0.0	189.3	0.0	145.7	53.2	30.1	22.8	4.0	613.0	78.1
Imports	34.7	0.7	100.1	59.8	43.2	1.5	0.0	2.6	0+	242.7	1.5
Exports	-37.0	-0.8	-100.8	-62.4	-44.1	-1.1	0.0	-2.6	0-	-248.8	-1.1
Stock changes	-3.1	-0.1	-0.2	-0.3	-1.5	-0.01	0.0	0.0	0.0	-5.2	0.0
Total energy supply	162.5	-0.1	188.4	-2.9	143.2	53.5	30.1	22.8	4.0	601.7	78.4
Statistical difference	3.4	-0.2	-1.0	-2.4	2.0	-0.2	0.0	-0.1	0.0	1.5	23.1
Transfers	0.0	0.0	9.1	-4.7	0.0	-0.2	0.0	0.0	0.0	4.2	-0.2
Transformation	-126.5	13.3	-197.3	185.1	-57.7	-11.0	-30.1	73.9	11.9	-138.4	-12.8
Electricity plants	-87.9	-2.2	-1.3	-5.8	-39.9	-4.2	-30.0	66.4	-4.4	-109.3	-6.3
CHP and heat plants	-14.0	-0.9	0.0	-1.0	-15.4	-3.3	-0.1	7.5	16.2	-11.1	-2.9
Coke ovens	-21.5	23.4	0.0	-0.1	0-	0-	0.0	0.0	0.0	1.9	0.0
Oil refineries	0.0	0.0	-185.6	184.9	-0.1	0.0	0.0	0.0	0.0	-0.8	0.0
Other transformation	-3.1	-7.0	-10.3	7.0	-2.2	-3.5	0.0	0.0	0.0	-19.2	-3.5
Energy industries own use	-4.5	-1.3	-0.4	-10.2	-12.9	-0.6	0.0	-8.3	-1.8	-40.0	-0.6
Losses	-0.02	-0.1	-0.3	-0.01	-1.2	-0.01	0.0	-7.2	-0.8	-9.8	-0.01
Final consumption	28.1	12.0	0.5	169.7	69.4	41.9	0.0	81.3	13.2	416.1	41.8
Final energy consumption	25.4	11.5	0.1	141.5	61.2	41.9	0.0	81.3	13.2	375.9	41.8
Industry	20.7	11.3	0.1	12.4	25.9	10.8	0.0	34.6	6.1	121.9	10.3
Iron and steel	4.0	8.8	0+	0.3	2.7	0.2	0.0	4.4	0.6	21.0	0.2
Chemical and petrochemical	0.7	0.9	0.03	2.7	6.5	0.1	0.0	4.3	2.7	17.8	0.1
Non-ferrous metals	0.2	0.03	0+	0.3	0.5	0.01	0.0	1.7	0.02	2.7	0+
Non-metallic minerals	1.7	0.1	0+	1.4	1.9	0.3	0.0	0.8	0.1	6.4	0.1
Other industries	14.2	1.4	0.03	7.8	14.3	10.1	0.0	23.4	2.7	74.0	9.9
Transport[9]	0.1	0+	0+	104.9	5.0	3.9	0.0	1.5	0.0	115.4	3.9
of which Road	0.0	0.0	0.0	77.1	2.1	3.9	0.0	0.2	0.0	83.2	3.9
of which Aviation	0.0	0.0	0.0	14.5	0.0	0.0	0.0	0.0	0.0	14.5	0.0
Households	2.3	0.1	0.0	11.5	20.2	23.5	0.0	21.9	4.9	84.4	23.8
Commerce, public services	0.4	0.02	0.0	2.4	8.1	1.12	0.0	15.7	1.60	29.3	1.2
Other energy use	1.9	0.05	0+	10.2	2.0	2.6	0.0	7.6	0.6	24.9	2.6
Non-energy use	2.7	0.5	0.4	28.2	8.3	0.0	0.0	0.0	0.0	40.1	0.0

Figure: World energy balance; source: United Nations (2023).

Total energy consumption

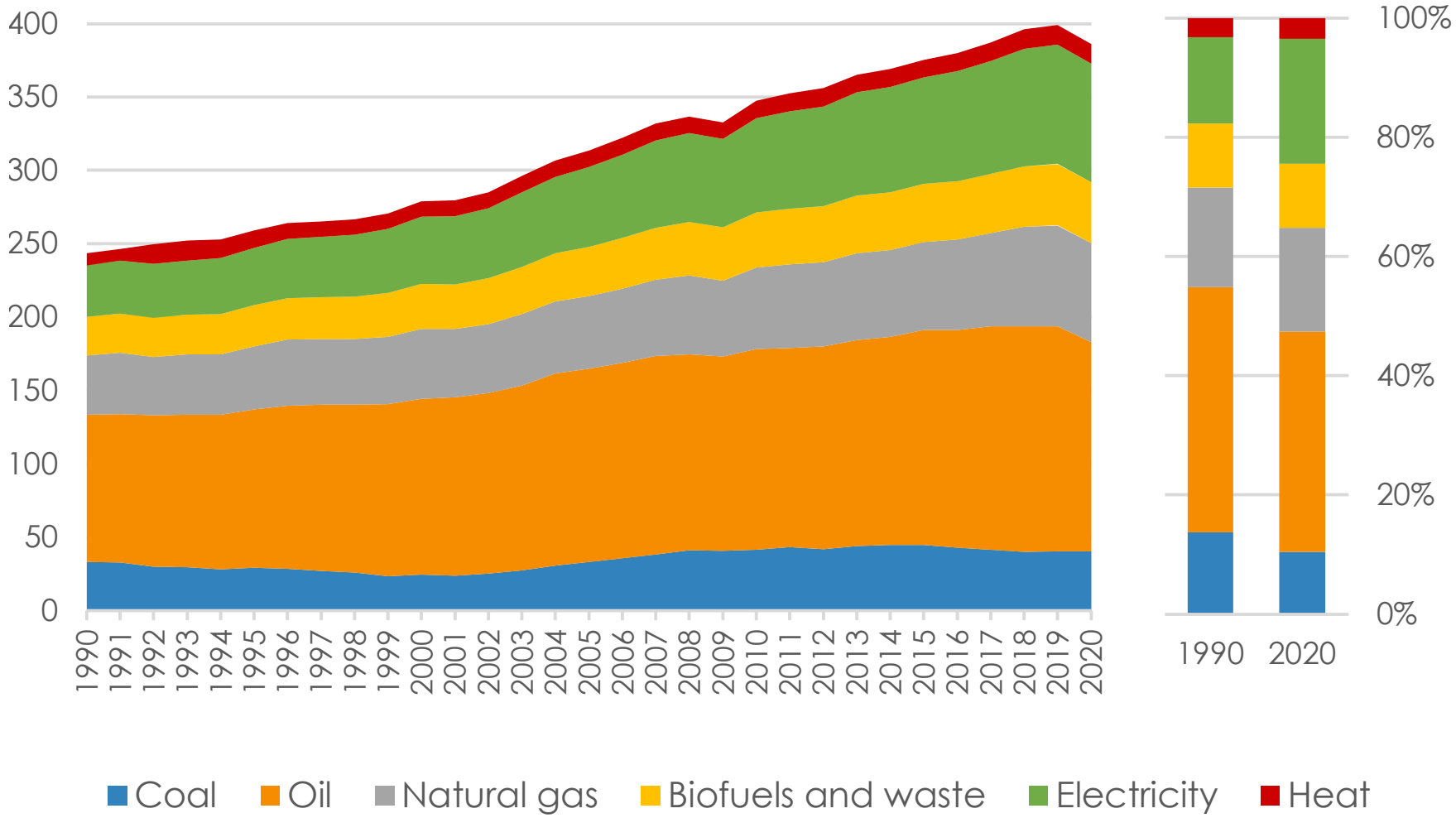
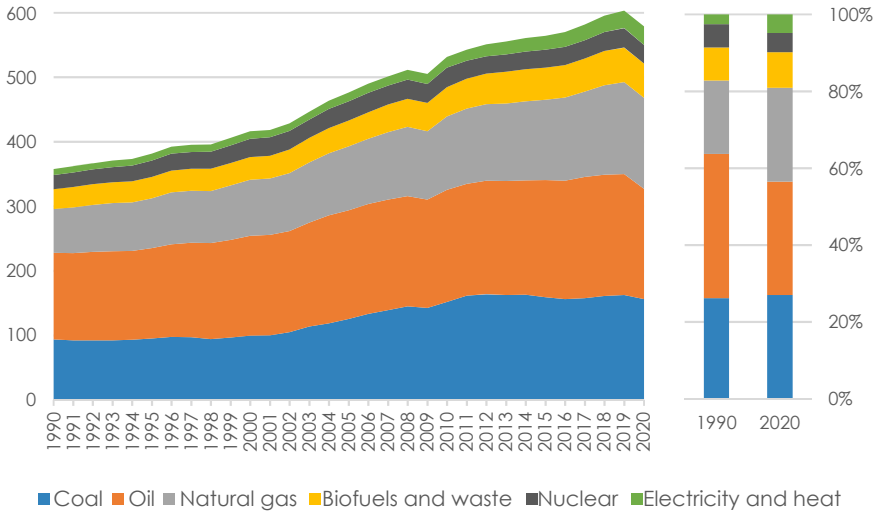


Figure: Total energy consumption [EJ] worldwide by source, 1990-2020; source: United Nations (2023).

Total energy supply and consumption



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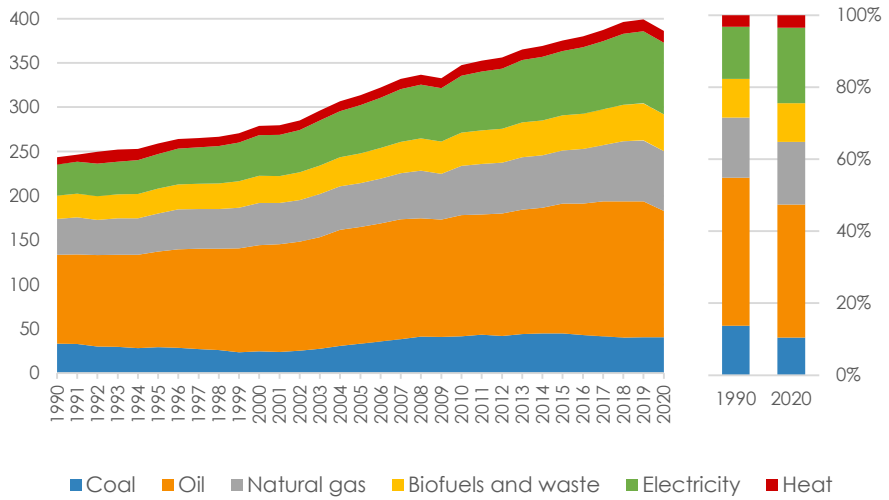


Figure: Total energy consumption [EJ] worldwide by source, 1990-2020; source: United Nations (2023).

World electricity generation

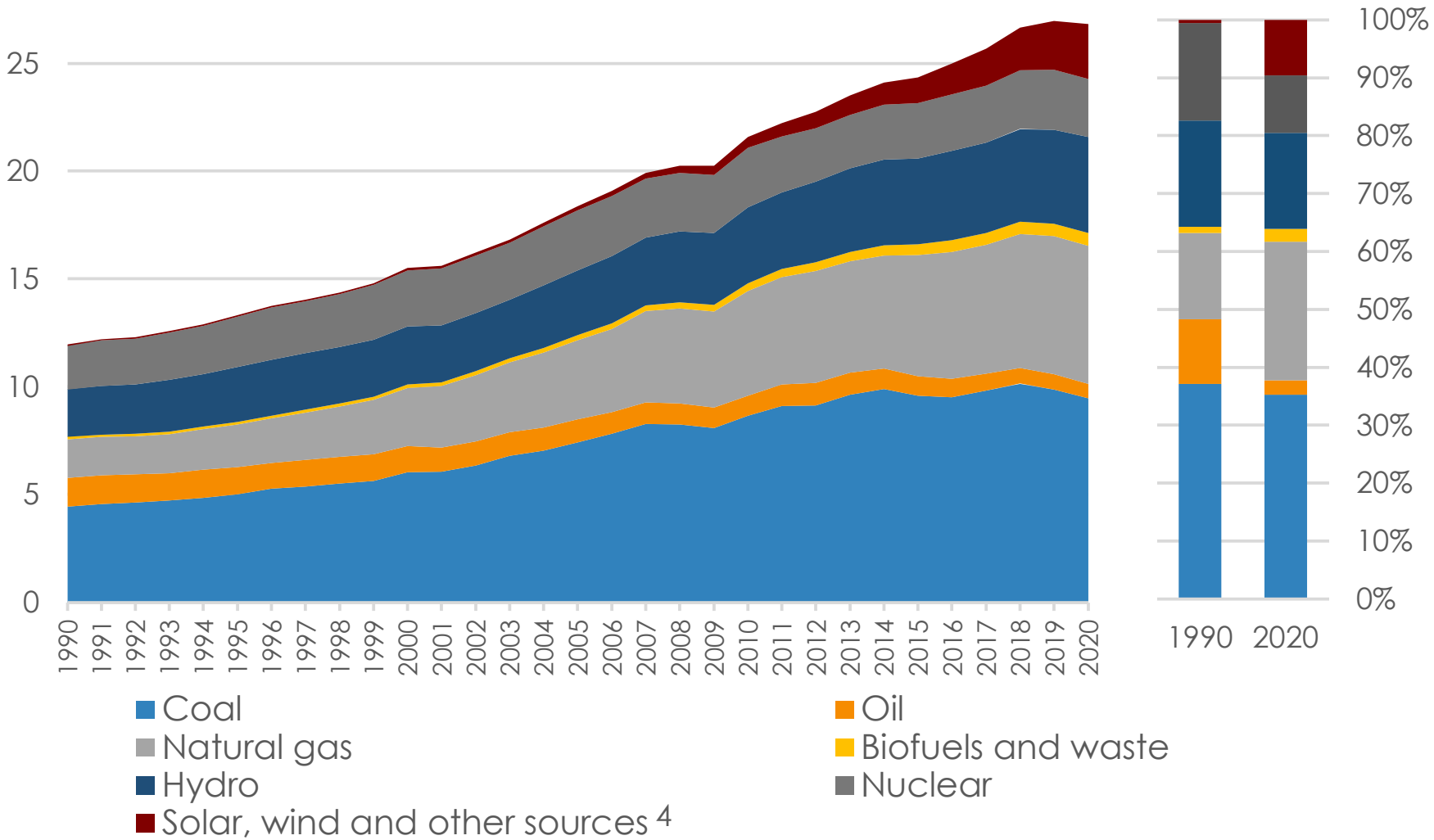


Figure: World electricity generation [PJ] by source, 1990-2020; source: United Nations (2023).

Worldwide RES-based electricity generation

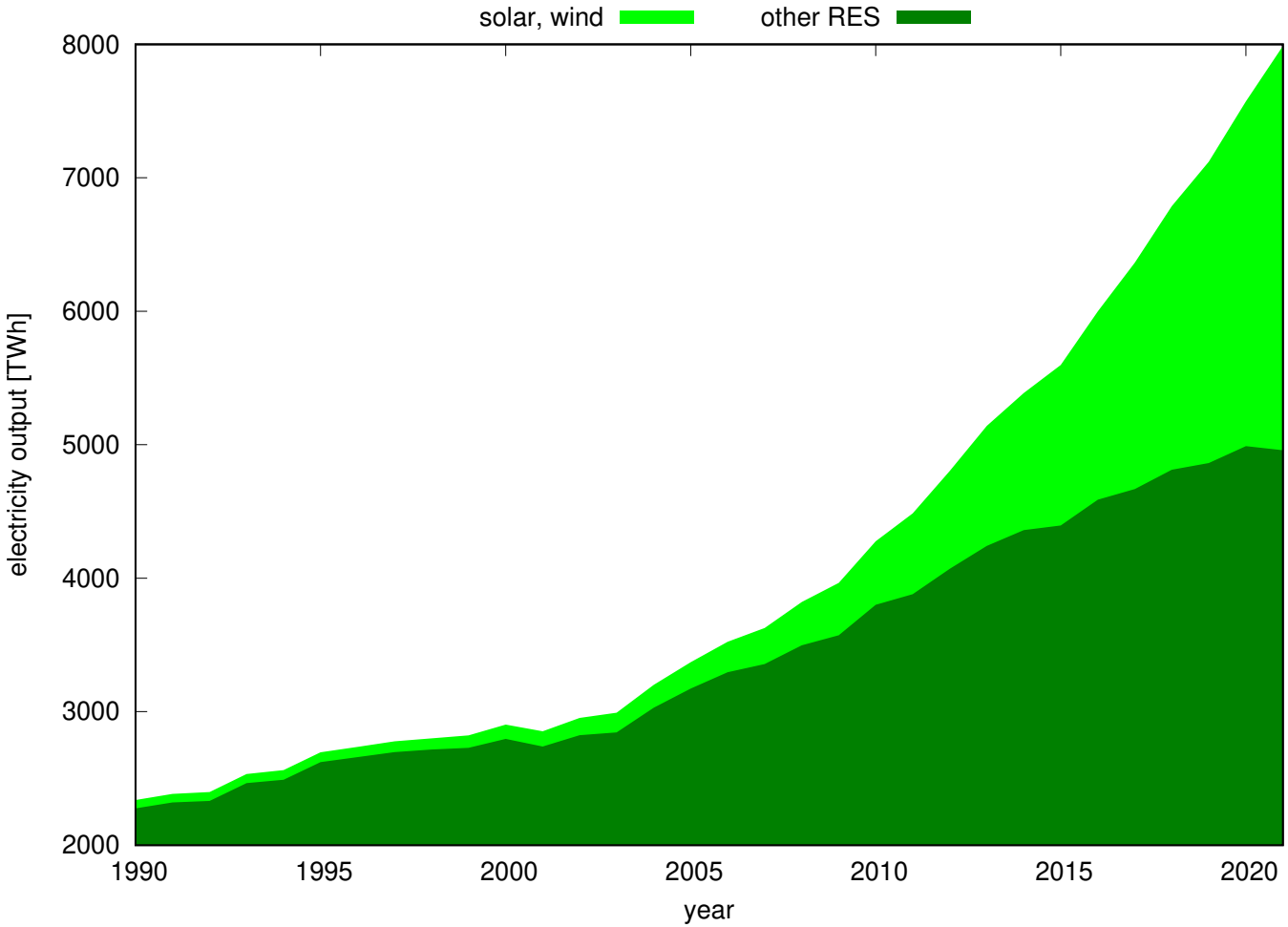


Figure: Stacked area chart illustrating the development of electricity generation based on wind and solar power plants and remaining renewable energy sources from 1990 until 2021; own illustration based on data provided by Enerdata (2023), Working Group on Energy Balances (2018).

Worldwide wind- and solar-based electricity generation

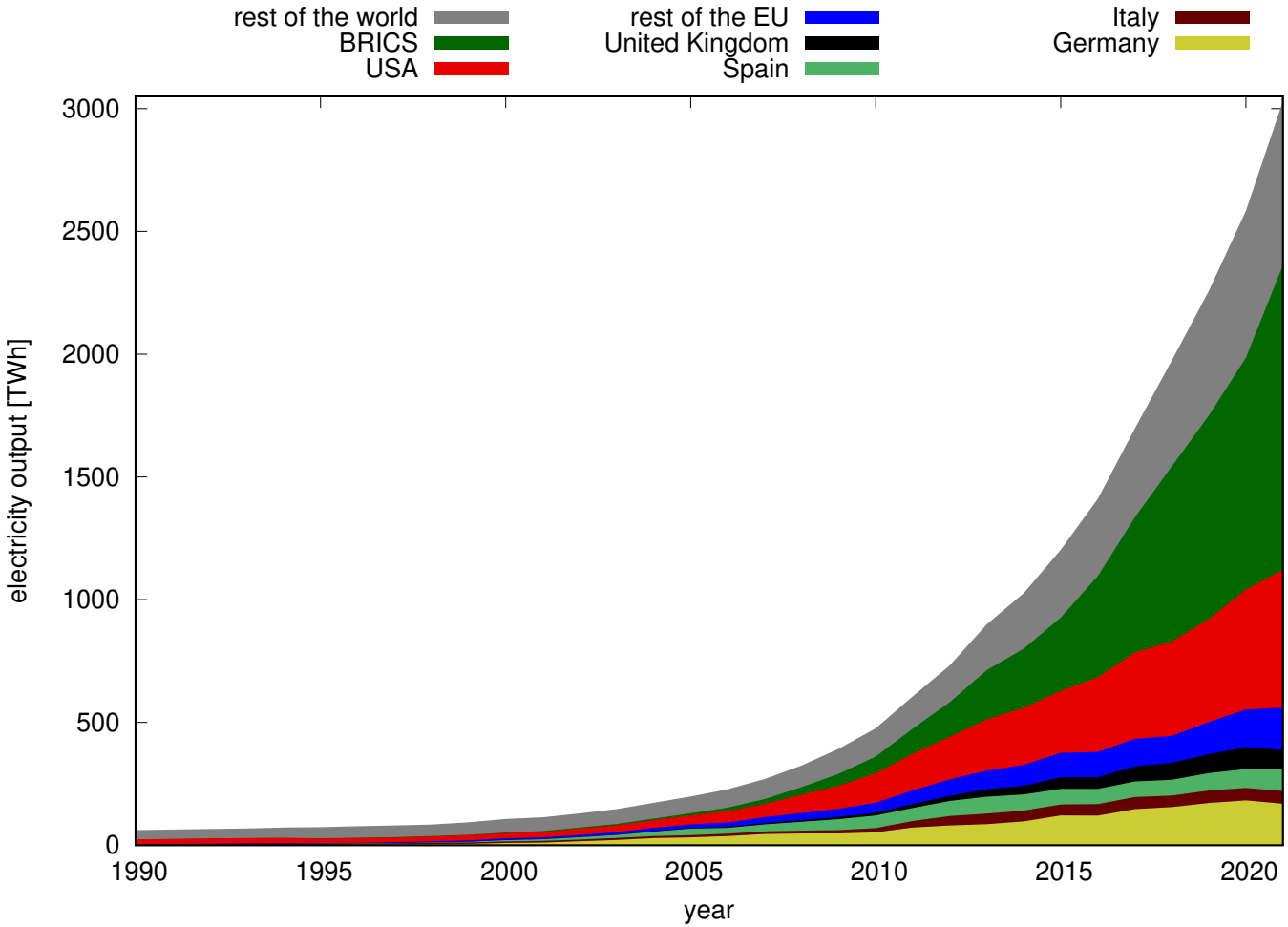


Figure: Stacked area chart illustrating the development of electricity generation based on wind and solar power plants in selected countries and worldwide from 1990 until 2021; own illustration based on data provided by Enerdata (2023), Working Group on Energy Balances (2018).

Consumers' decision

How do consumers decide on consumption?

- Consumers try to

  get the "best" what is "affordable"!

- What is the "best"?

  $\longrightarrow$ preferences

- What means "affordable"

  $\longrightarrow$ budget constraint

The budget constraint

- consumers pay for consumption with their income m:

  $p_1 x_1 + p_2 x_2 \leq m$
- exogenously given prices (p_1, p_2) and the income m determine which bundle of goods (x_1, x_2) the consumer can choose:

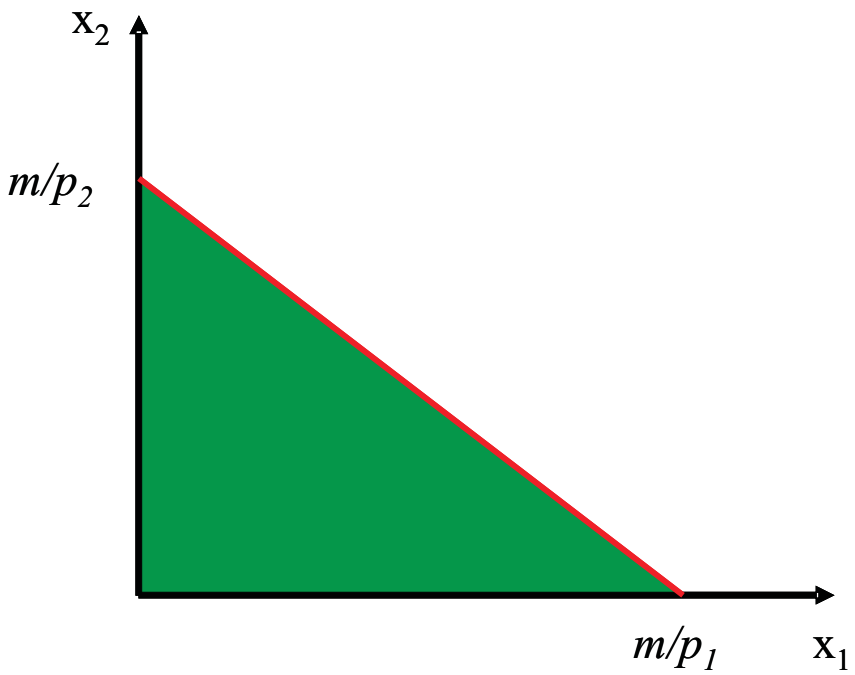
  it is his budget.
- The budget is limited by the budget constraint or budget line.

  $p_1 x_1 + p_2 x_2 = m$

Graphical presentation

The budget line $m = p_1 x_1 + p_2 x_2$ after rearrangement with respect to x_2 yields

$$x_2 = -\frac{p_1}{p_2} \cdot x_1 + \frac{m}{p_2},$$



Exchange ratio

- Let us have a closer look at the budget line

$$x_2 = -\frac{p_1}{p_2} \cdot x_1 + \frac{m}{p_2};,$$

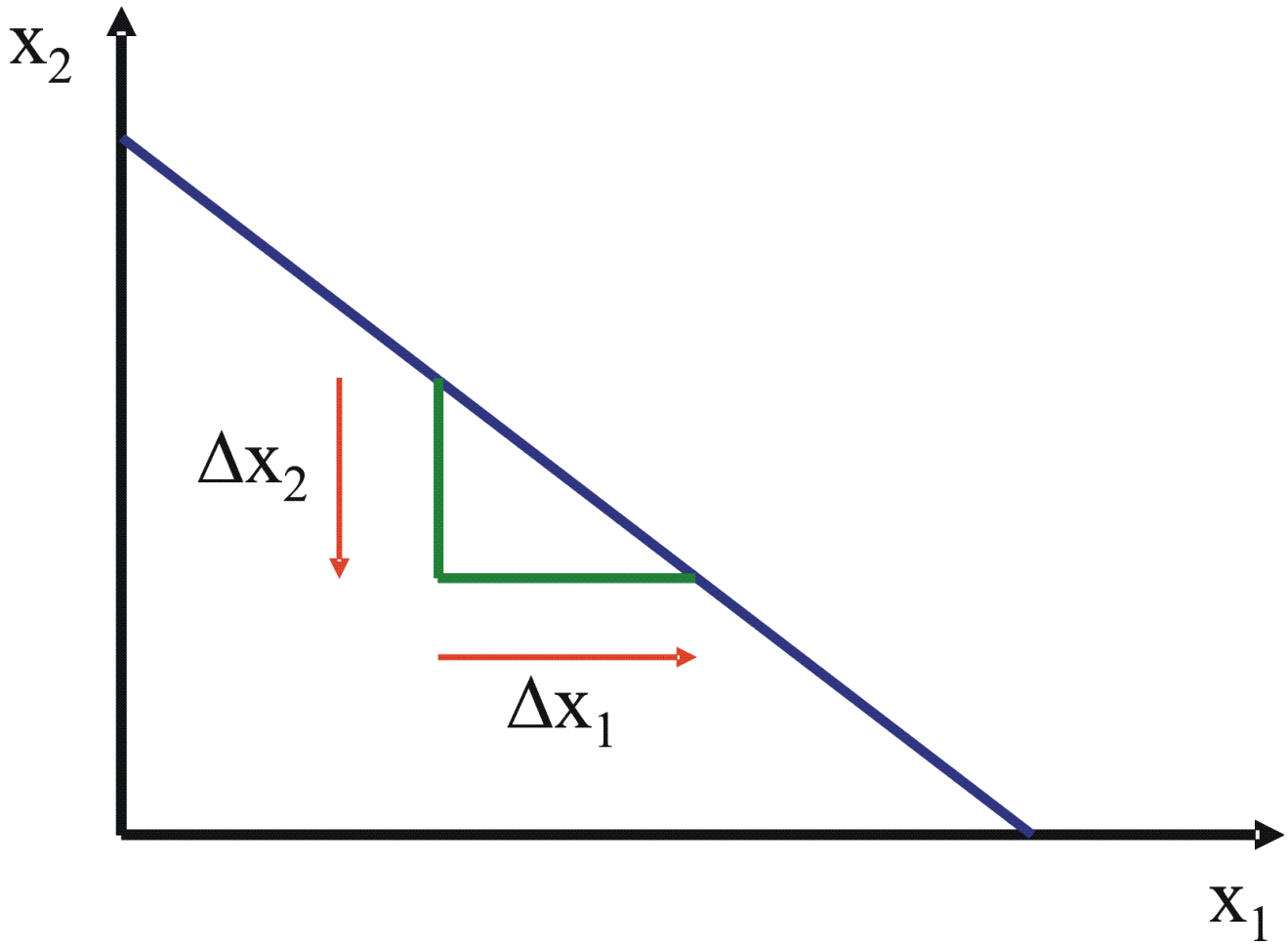
- slope of the budget line $\frac{p_1}{p_2}$

$\rightarrow$ necessary reduction of x_2 in order to receive an additional unit x_1 without changing spending

$\Rightarrow$ slope of the budget line: opportunity costs of x_1:

What does the consumption of an additional x_1 cost in units of x_2?

Graphical presentation of the exchange ratio



Example

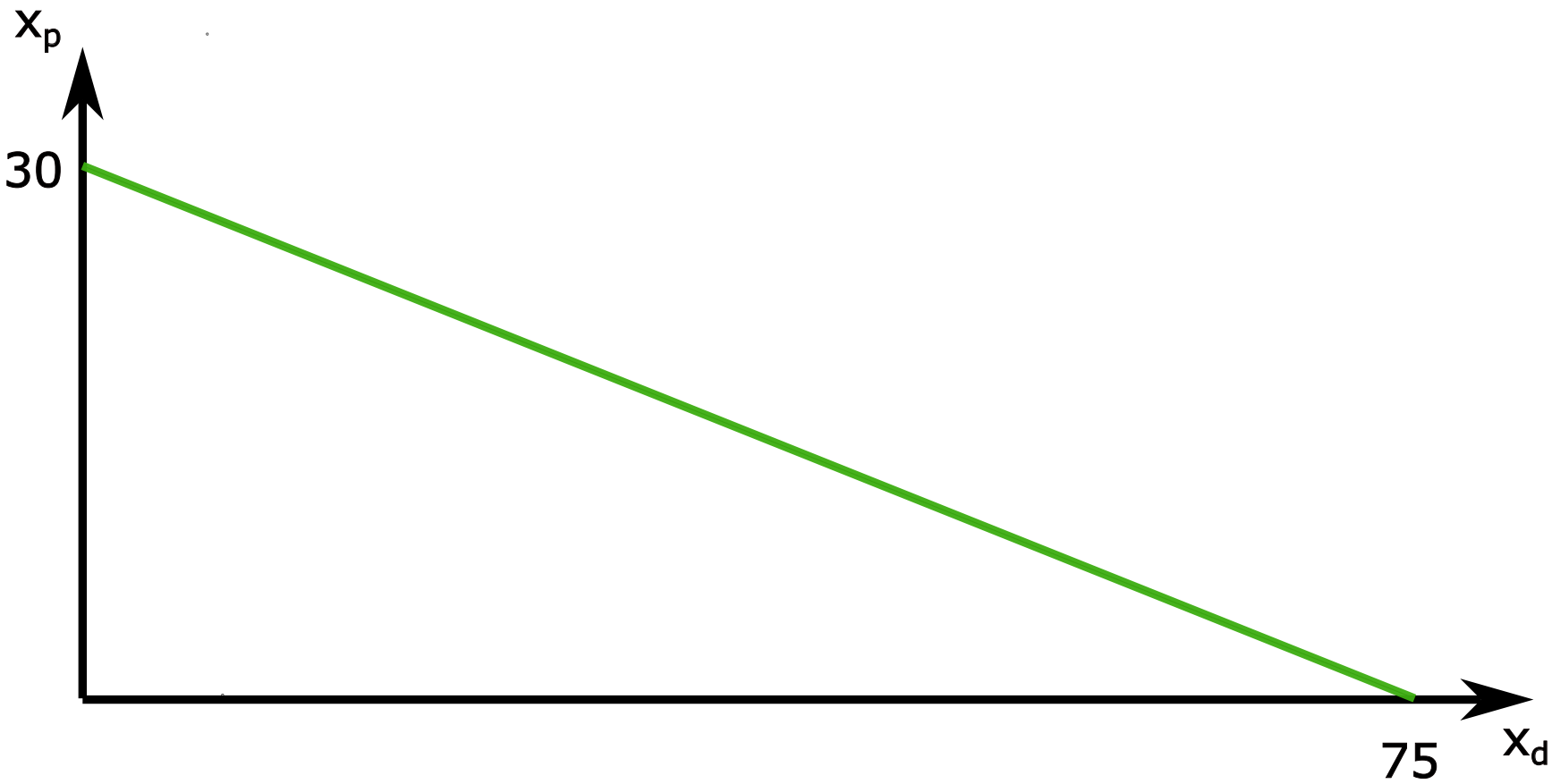
Zohra, a student in Frankfurt, receives 750,- € every month. 150,- € she uses to buy pizza and drinks in her favorite restaurant. The price for one pizza is p_p=5,- € while a drink costs p_d=2,- €.

- Calculate several bundles of pizza and drinks she can afford.
- Calculate the equation for the budget line and draw it.

Example – solution

The budget line $m = p_d x_d + p_p x_p$ after rearrangement with respect to x_p yields

$$x_p = 30 - \frac{2}{5} \cdot x_d \quad ,$$



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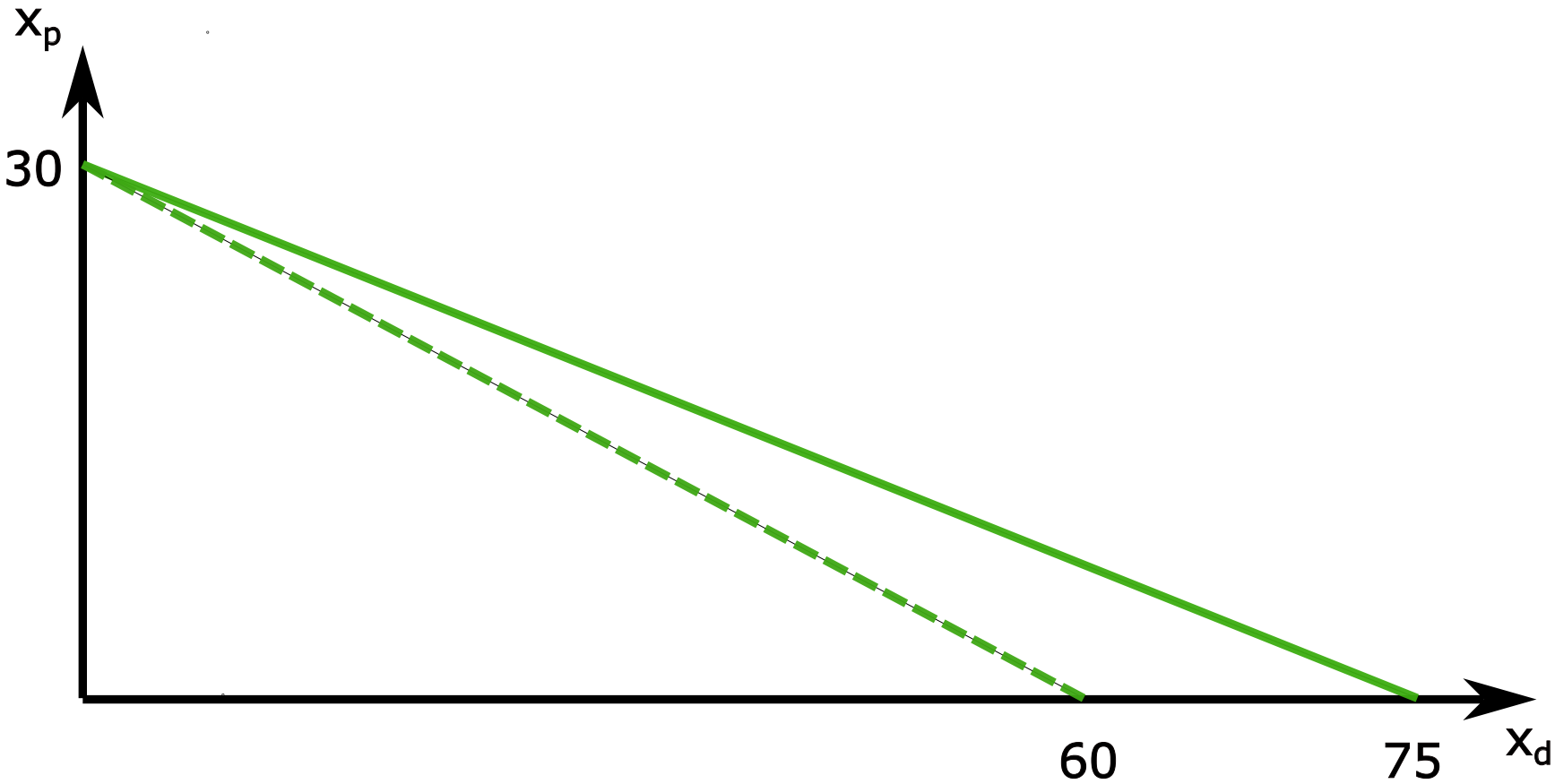
- The restaurant decides to increase prices for drinks to 2.50 €. What are the consequences?

Example – solution

The budget line $m = p_d x_d + p_p x_p$ after rearrangement with respect to x_p yields

$$x_p = 30 - \frac{1}{2} \cdot x_d \quad ,$$



Example

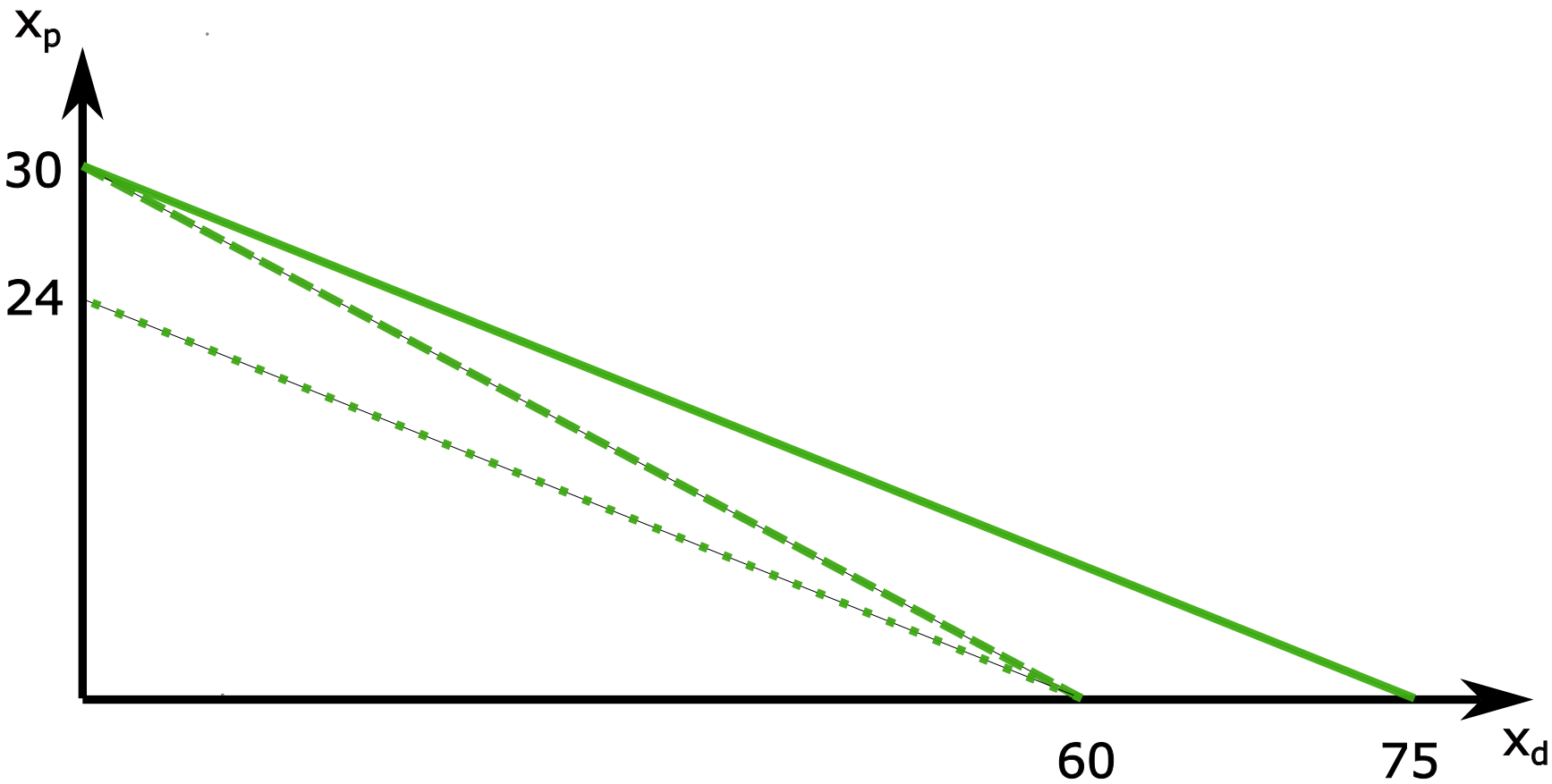
Zohra, a student in Frankfurt, receives 750,- € every month. 150,- € she uses to buy pizza and drinks in her favorite restaurant. The price for one pizza is p_p=5,- € while a drink costs p_d=2,- €.

- Calculate different bundles of pizza and drinks she can afford.
- Calculate the equation for the budget line and draw it.
- The restaurant decides to increase prices for drinks to 2.50 €. What are the consequences?
- Zohra's parents are not happy about her fast food consumption. After some discussion they decide to cut their monthly support to 600,- €. What may be the consequences?
- Since Zohra is quite stubborn, she decides to cut all expenses in the same ratio. Furthermore, she agrees with the restaurant owner that he will decrease the prices for drinks to 2,- € . What are the consequences for her spending?

Example – solution

The budget line $m = p_d x_d + p_p x_p$ after rearrangement with respect to x_p yields

$$x_p = 24 - \frac{2}{5} \cdot x_d \quad ,$$



Consumers' decision

How do consumers decide on consumption?

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  get the "best" what is "affordable"!

- What is the "best"?

  $\longrightarrow$ preferences

- What means "affordable"

  $\longrightarrow$ budget constraint

Preferences

What do preferences describe?

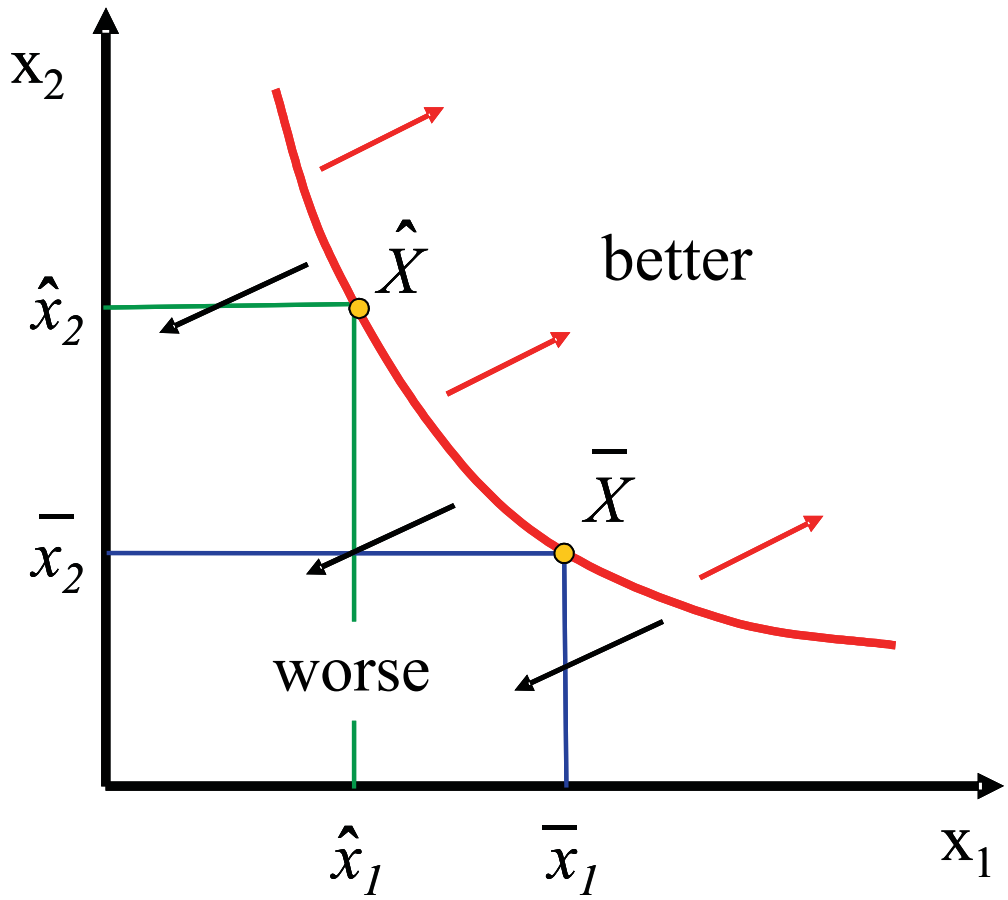
- Consumers can choose between *bundles of goods*.
- The quantites of goods within a bundle of goods *completely* describe all relevant alternatives.
- preferences correspond to the consumer's relative appreciation for possible alternatives.

preferences allow to answer e.g. the question

2 wine and half a pizza or

1 wine and a complete pizza?

Indifference curve



Consumers are indifferent between all bundles of goods located on the indifference curve, e.g. $\bar{X} \sim \hat{X}$.

Preferences for different bundles of goods

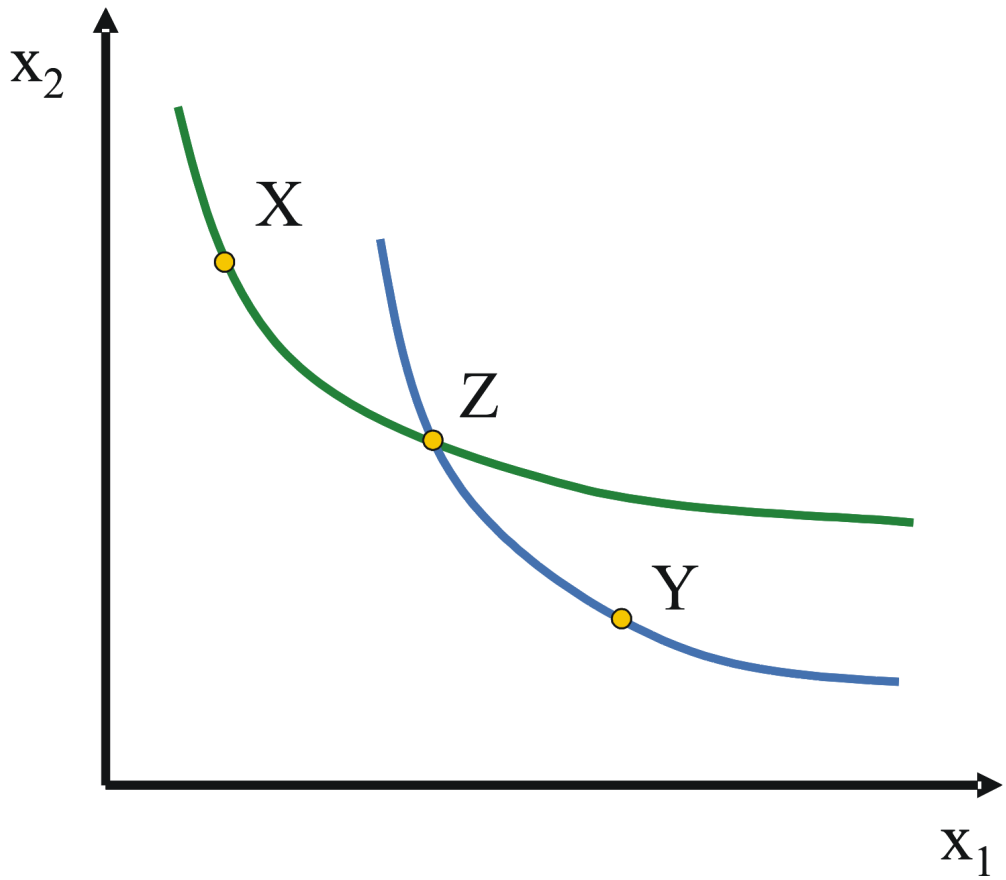
- indifference curves illustrate which bundles are equally preferred
- a statement about which bundle is "better" or "worse" needs additional asumptions:

In general we expect that "more" is "better" yielding all bundles

- above the indifference curve are "better"

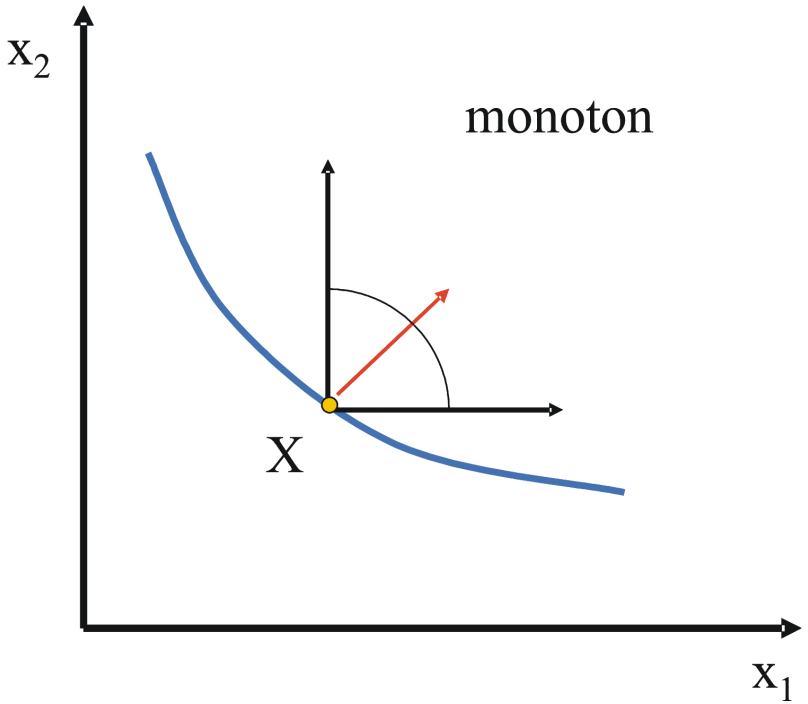
  while all bundles
- below the indifference curve are "worse".

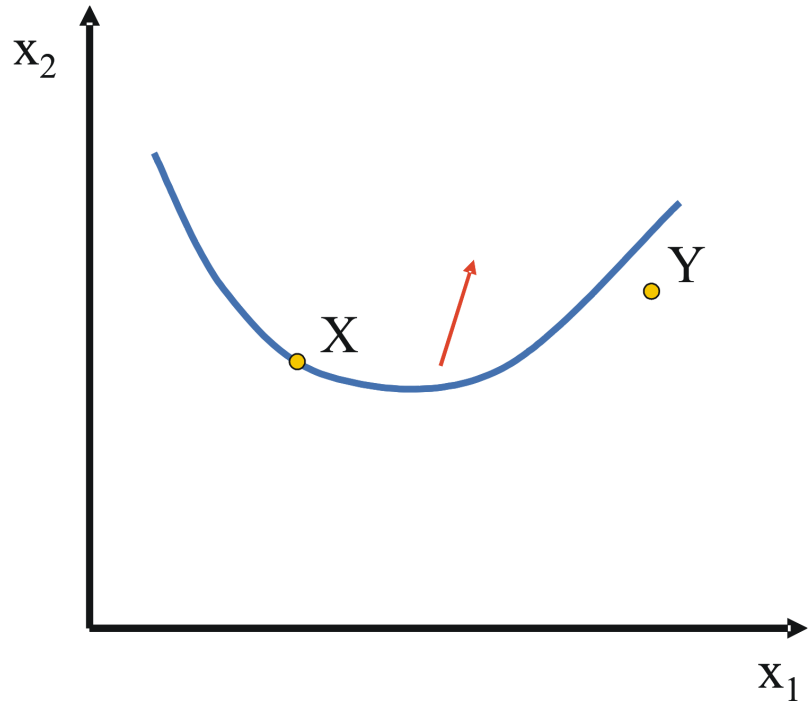
Several indifference curves



Two indifference curves can never intersect.

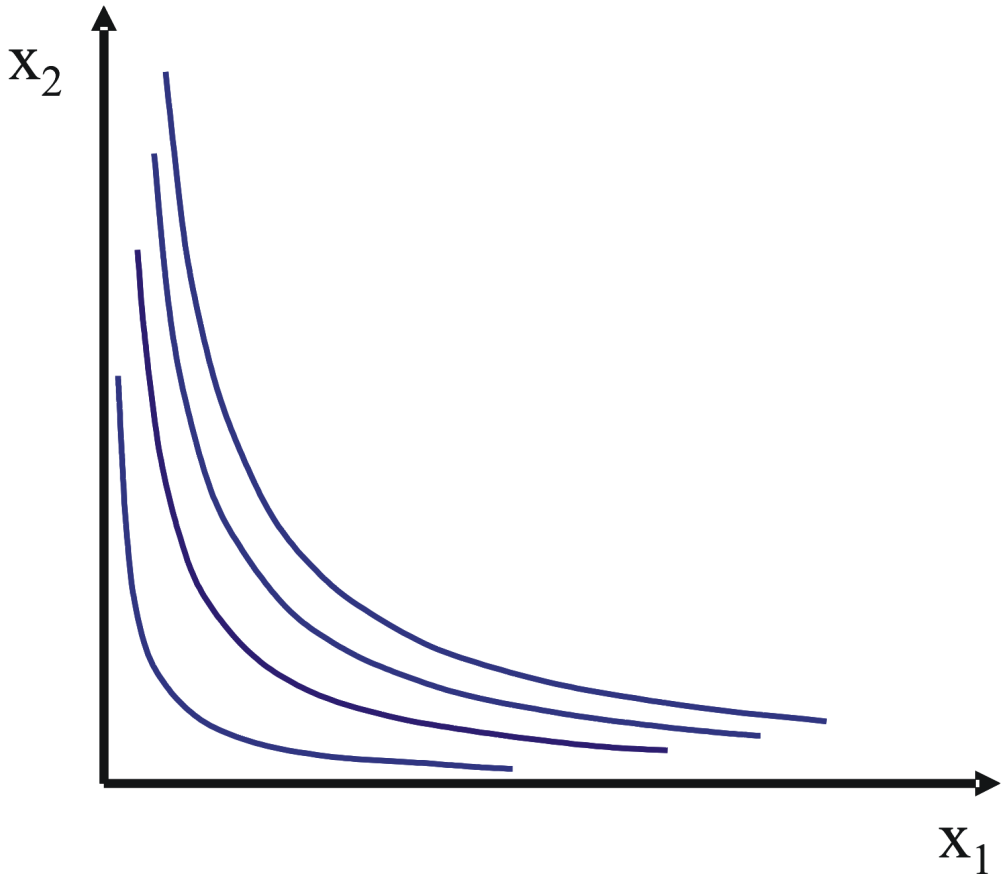
Monotony





When Y is higher in both quantities it is preferred to X. This only applies for a monotonously decreasing slope like in the left graph.

Usual preferences



Preferences are monotonous and convex.

Utility and preferences

- every bundle of goods is assigned with a number

$\rightarrow$ comparison of different bundles possible

- a bundle will be assigned with a higher number if the consumer prefers this bundle over another

$\Rightarrow X \succ Y \quad \Longleftrightarrow \quad u(X) > u(Y)$

- The utility function $u(\cdot)$ reflects the consumer's preferences

Utility function

Example:
preferences shall be $A \succ B \succ C$.
$\Rightarrow$ there is an infinite number of utility functions describing this situation

$$\begin{array}{lll} u_1(A) = 2 & u_2(A) = 8 & u_3(A) = 0 \\ u_1(B) = 1 & u_2(B) = 4 & u_3(B) = -1 \\ u_1(C) = 0 & u_2(C) = 0 & u_3(C) = -24 \end{array}$$

An exemplary utility function:

$$u(x_1, x_2) = x_1 \cdot x_2$$

References

Enerdata (2023). Global energy statistical yearbook. Available at: https://yearbook.enerdata.net/, accessed September 4, 2023.

United Nations (2023). Energy statistics pocketbook 2023. Available at: https://unstats.un.org/unsd/energystats/pubs/documents/2023pb-web.pdf, acessed October 16, 2023.

Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen e.V) (2018). Bruttostromerzeugung in Deutschland ab 1990 nach Energieträgern. Available at: https://ag-energiebilanzen.de/index.php?article_id=29&fileName=20171221_brd_stromerzeugung1990-2017.xlsx, accessed September 4, 2018.