Using Critical Thinking to Imagine Sustainable Energy Futures

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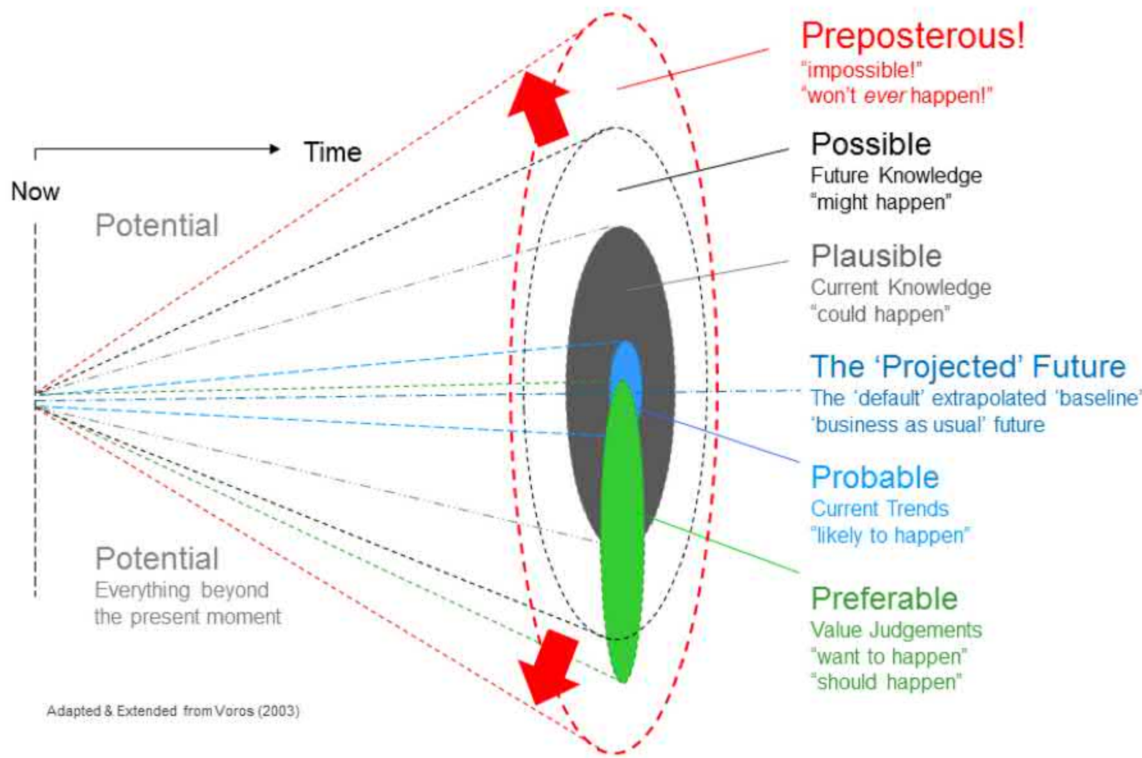
Yangon, Myanmar, September 3rd, 2019

Structure of the presentation

- Futures thinking and energy - a special case
- Energy futures: sustainable or not?
- Sustainable energy target scenarios versus a business-as usual future
- Which sustainable energy target scenario should we choose?
- The use of backcasting from to find transition pathways
- Guiding transition pathways by policy
- Take home messages

FUTURES THINKING AND ENERGY A SPECIAL CASE

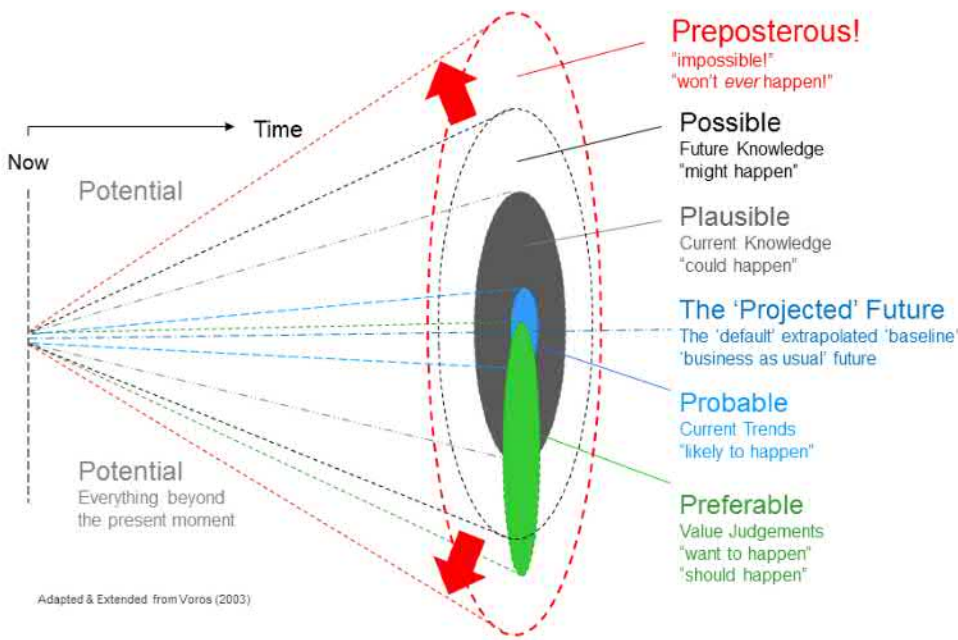
The typical cone of possible futures



Source: https://thevoroscope.com/2017/02/24/the-futures-cone-use-and-history/

Futures Thinking and Energy – A Special Case

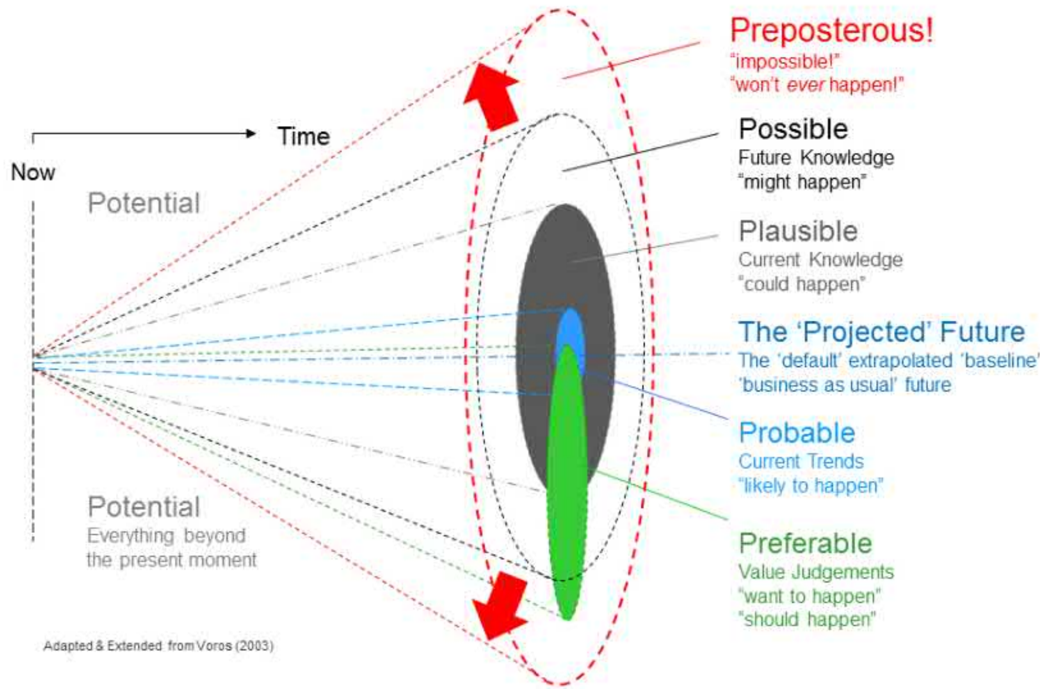
Possible energy futures with growing demand:



- More fossil fuels
- More nuclear energy
- Fossil fuels with CCS (Carbon Capture and Storage)
- More renewable energy
- Energy savings / less use of energy
- Combinations of the above

Source: https://thevoroscope.com/2017/02/24/the-futures-cone-use-and-history/

Not every possible energy future is sustainable!



- Fossil fuels cause climate change and pollution
- Nuclear energy causes long term waste problems and catastrophic accidents
- Bioenergy may compete with food production
- Hydropower may have severe environmental impacts

Source: https://thevoroscope.com/2017/02/24/the-futures-cone-use-and-history/

ENERGY FUTURES SUSTAINABLE OR NOT?

What is sustainable development?

Definition of the Brundtland Commission
(WCED 1987):

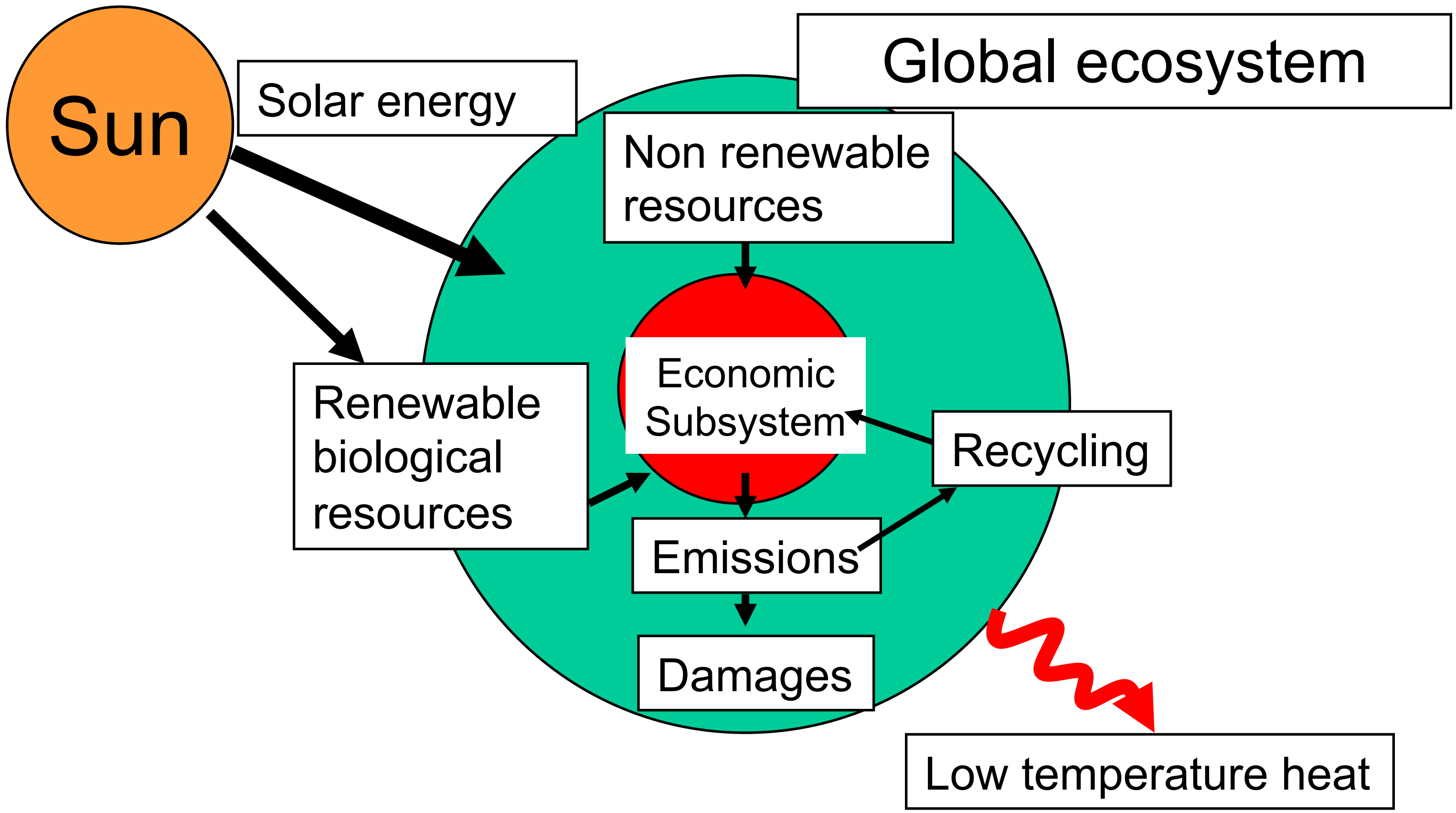
‘A development satisfying the needs of the present generation without impairing the needs of future generations.’

Source: https://thevoroscope.com/2017/02/24/the-futures-cone-use-and-history/

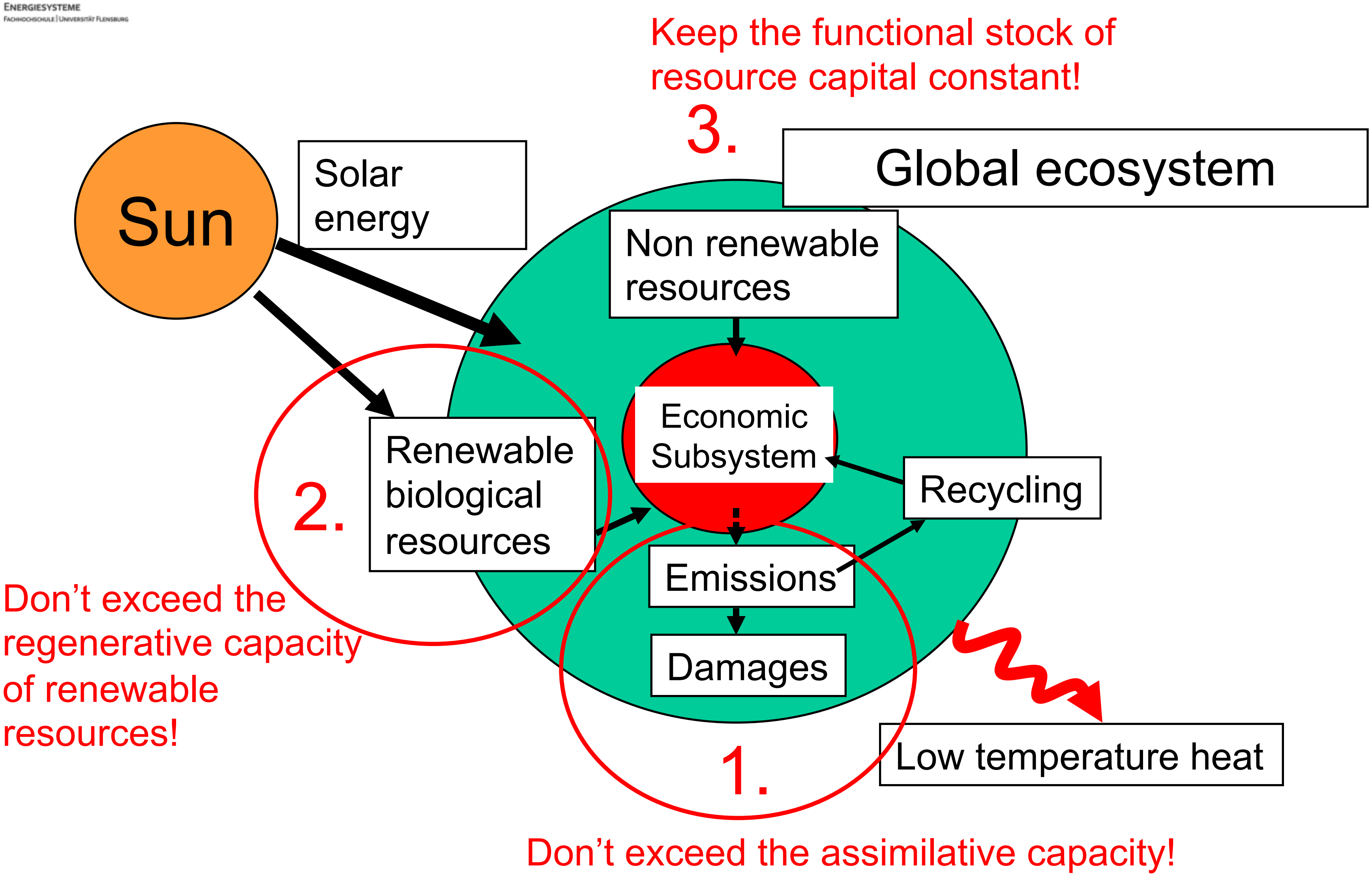
Management rules for sustainable development

- Don’t exceed the assimilative capacity of the ecosystems
- Don’t exceed the regenerative capacity of the renewable resources
- Keep the functional stock of resource capital constant

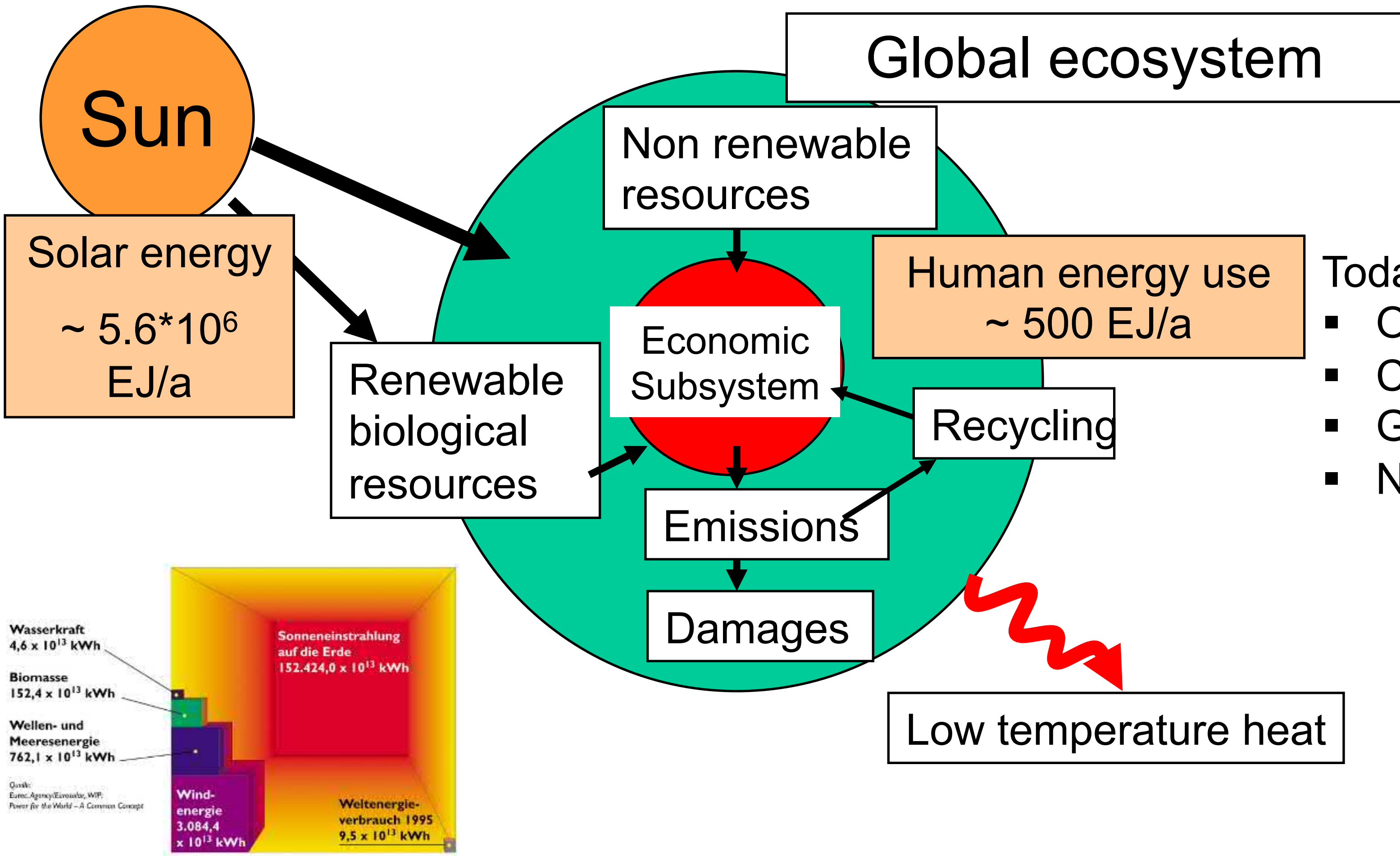
The world economy as subsystem of the global ecosystem



Where do the management rules apply?



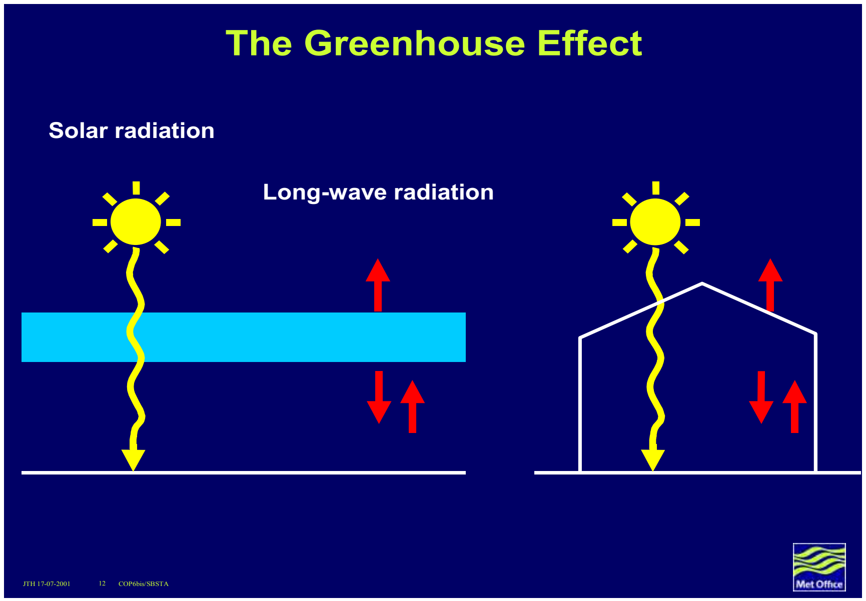
Much more solar energy than needed

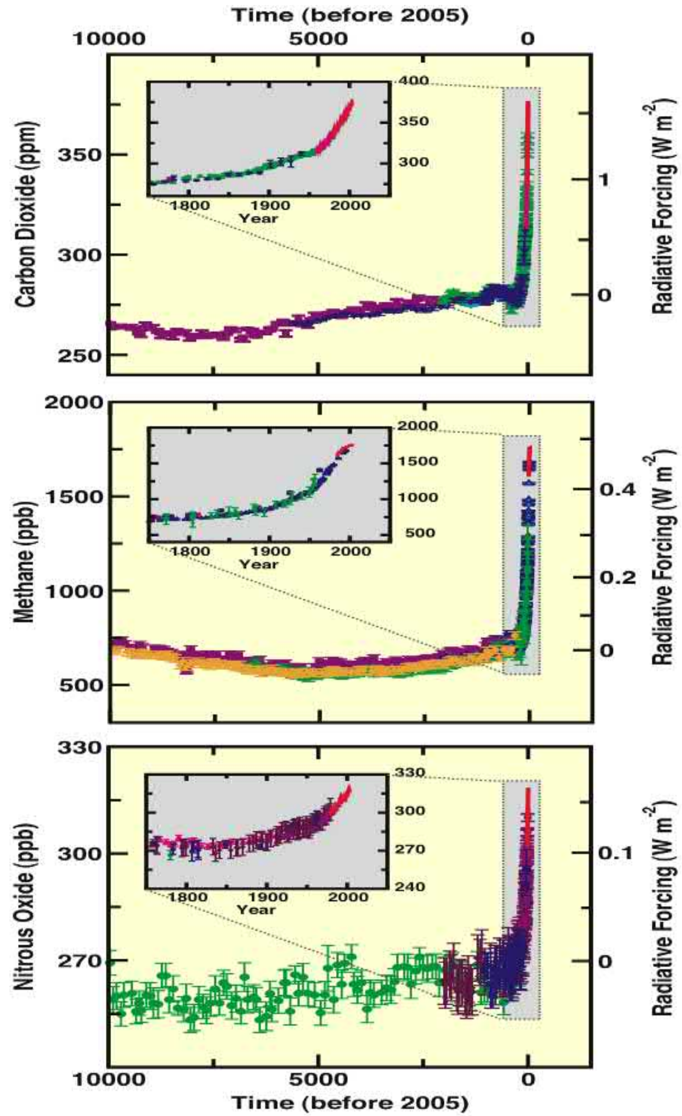


Today mainly:

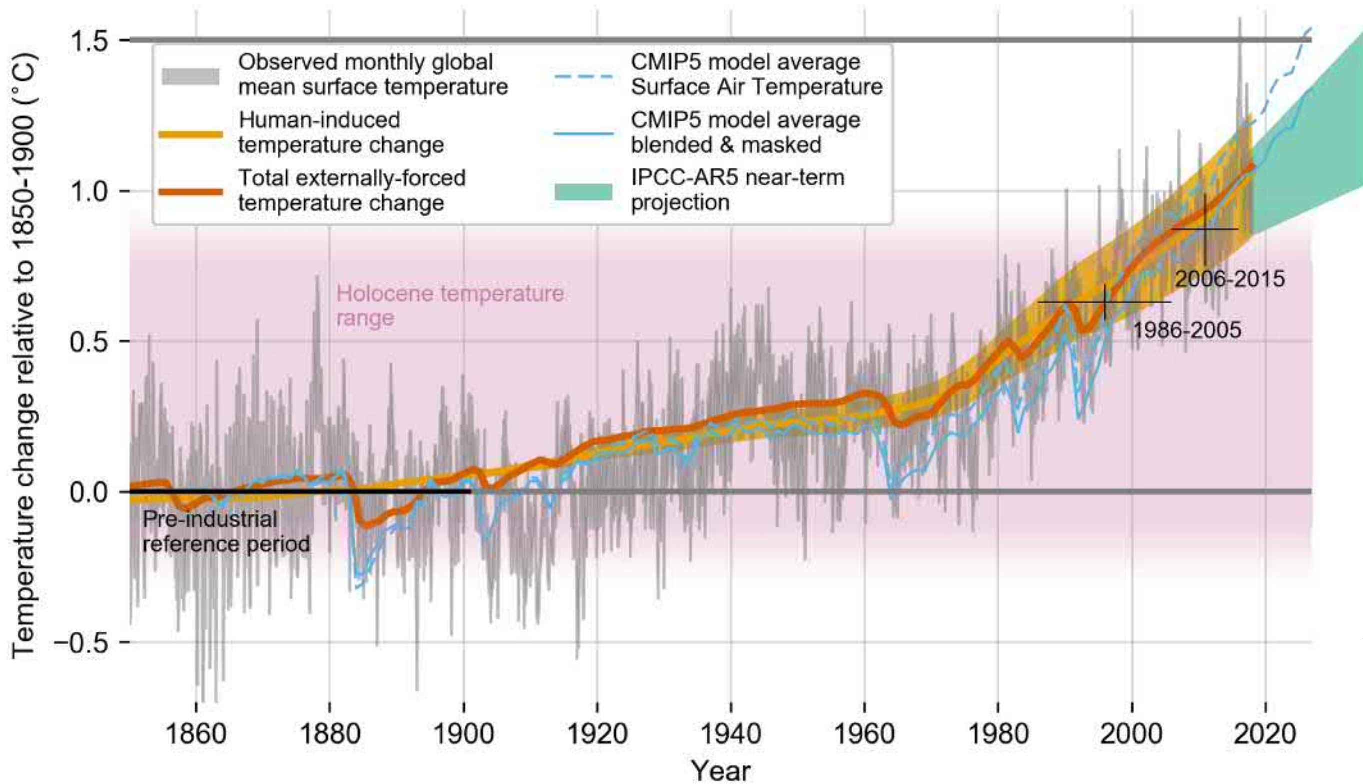
- Oil
- Coal
- Gas
- Nuclear

The problem of climate change





Massive temperature rise because of human GHG emissions

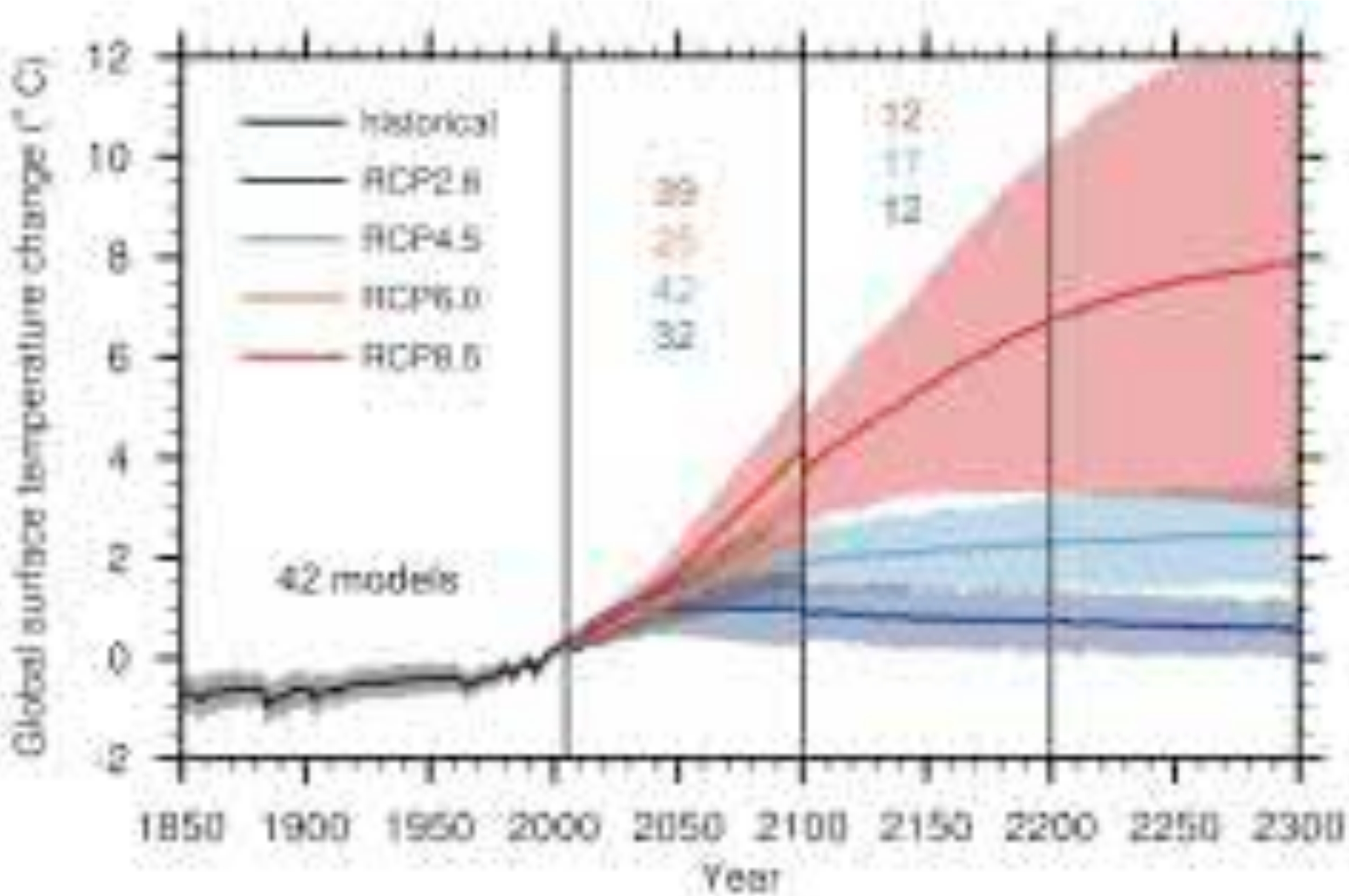


Source: IPCC 2018, p.57

By today + 1.0° warming compared to preindustrial levels

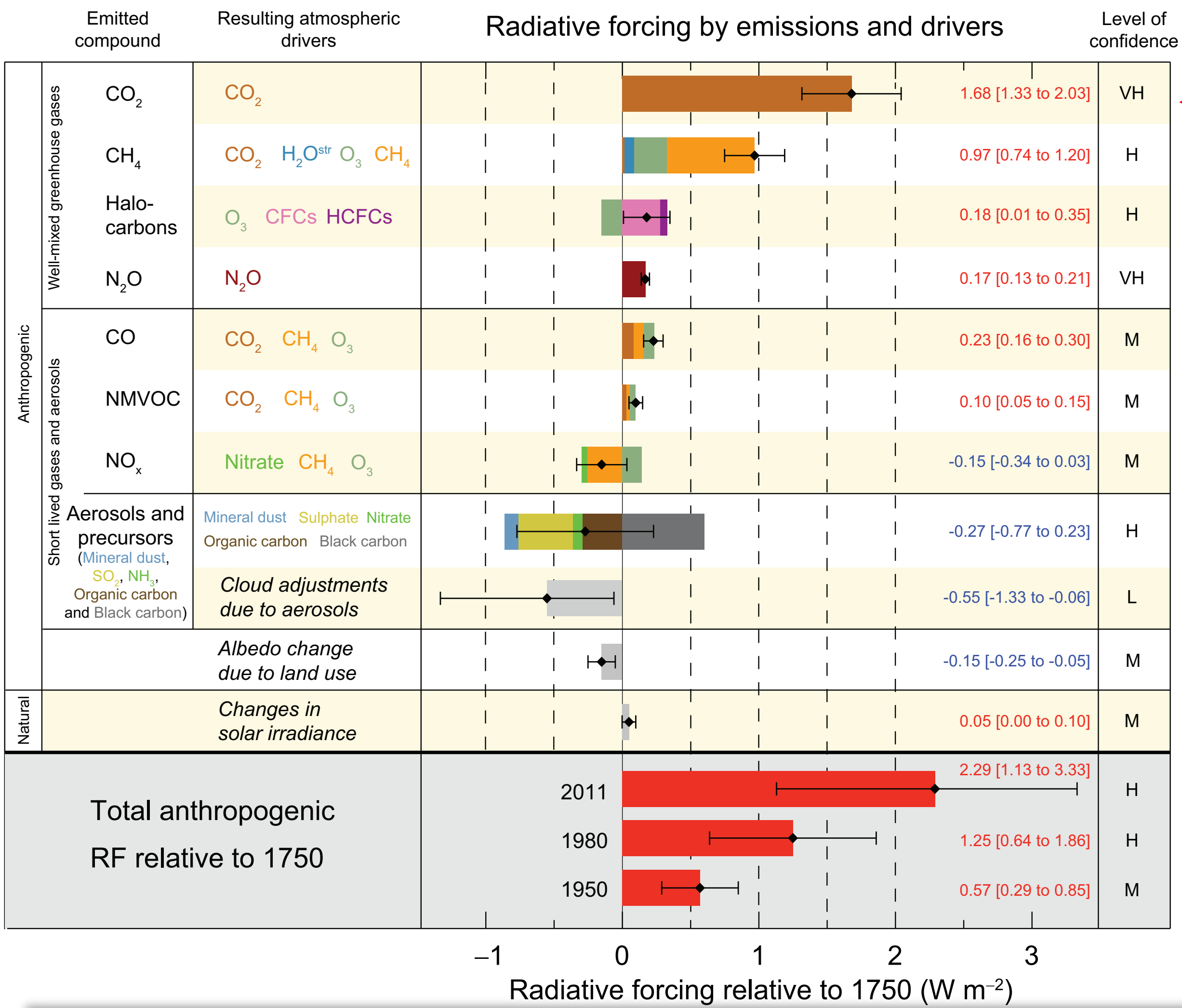
Additional warming of 0.2° per decade at present emission rates

Long temperature rise of 8 degrees by 2300 with high fossil fuel use



Source: IPCC 2013, p.17

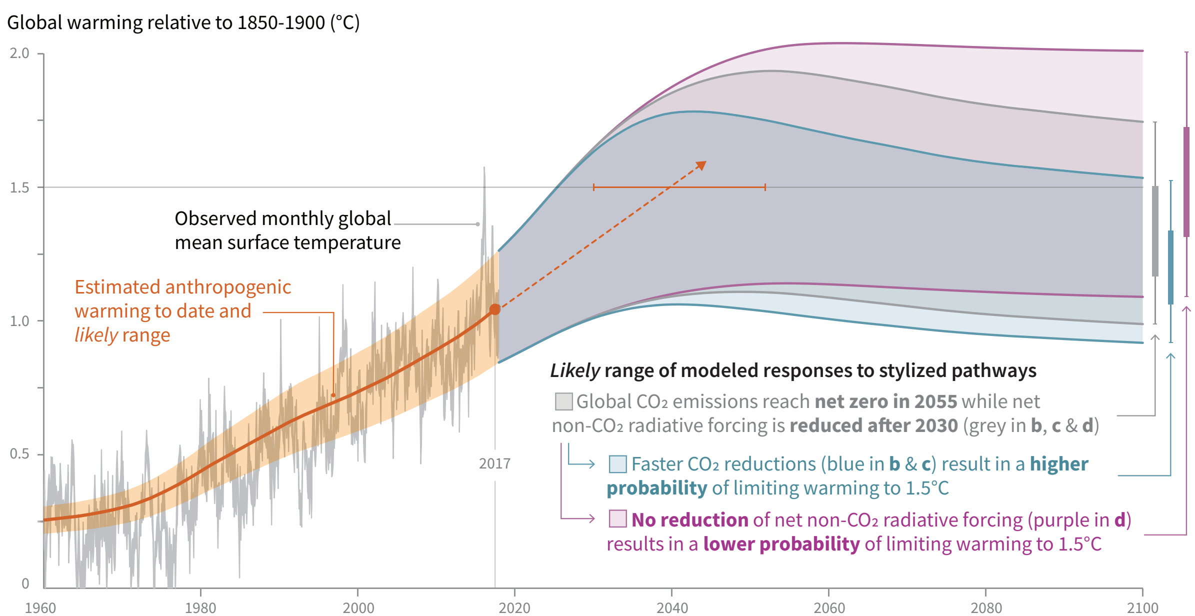
Components of climate change (radiative forcing)

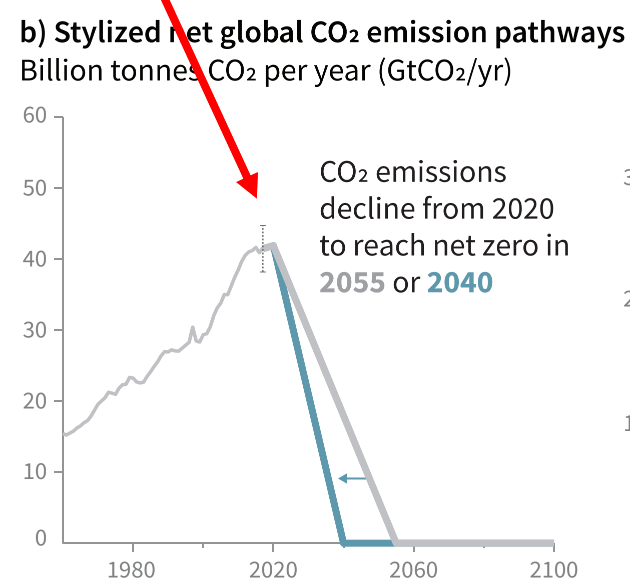


CO_2 is the main contributor to man-made climate change!

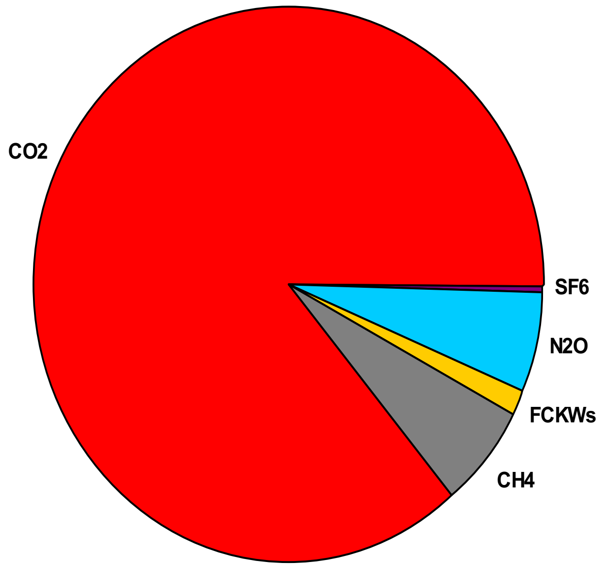
IPCC emission pathways to stay within the 1.5° target agreed at COP 23 in Paris 2018

Global CO_2 emissions need to decline to net zero by 2040 to 2055!





The share of CO_2 from fossil fuels
The example of Germany (2000)



Share of GHGs in the FRG in 2000:

- CO_2: 87%
- CH4: 6%
- N2O: 6%
- HFCS/PFCS: 1%
- SF6: 0,25%

Source: BMU 2003, S. 32 und UBA 2002, S. 31

97% of all CO_2 emissions from energy conversion processes!

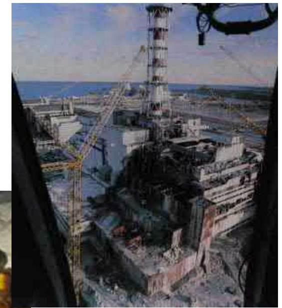
Fossil fuels represent 85% of the problem

The future use of fossil fuels is not sustainable!

Nuclear Energy

- Substantial risk of large scale accidents (e.g. Harrisburg, Chernobyl, Fukushima)

- Long term safety of nuclear waste deposits is still unclear



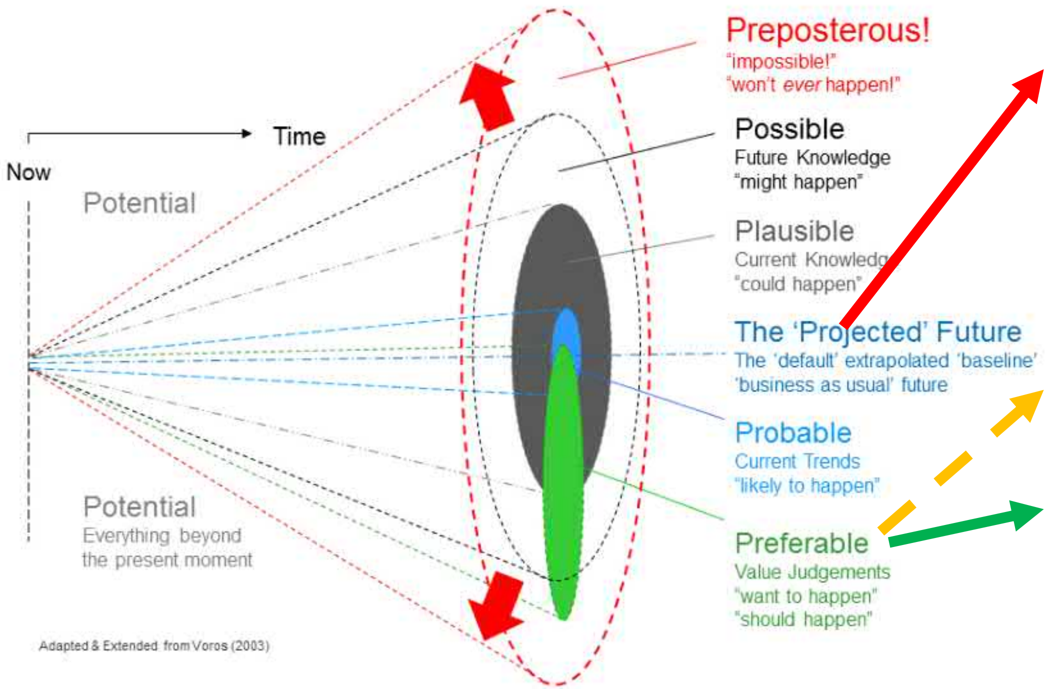
- Massive global use of nuclear energy carries massive risk of nuclear weapons technology proliferation

- In many industrialized societies nuclear energy is faced with massive problems of public acceptance

Nuclear energy is not a sustainable energy option

Not every energy future is sustainable

Only sustainable energy futures are acceptable!



Source: https://thevoroscope.com/2017/02/24/the-futures-cone-use-and-history/

Components of non sustainable energy futures:

- Coal, oil, gas
- Nuclear energy

Components of partially sustainable energy futures:

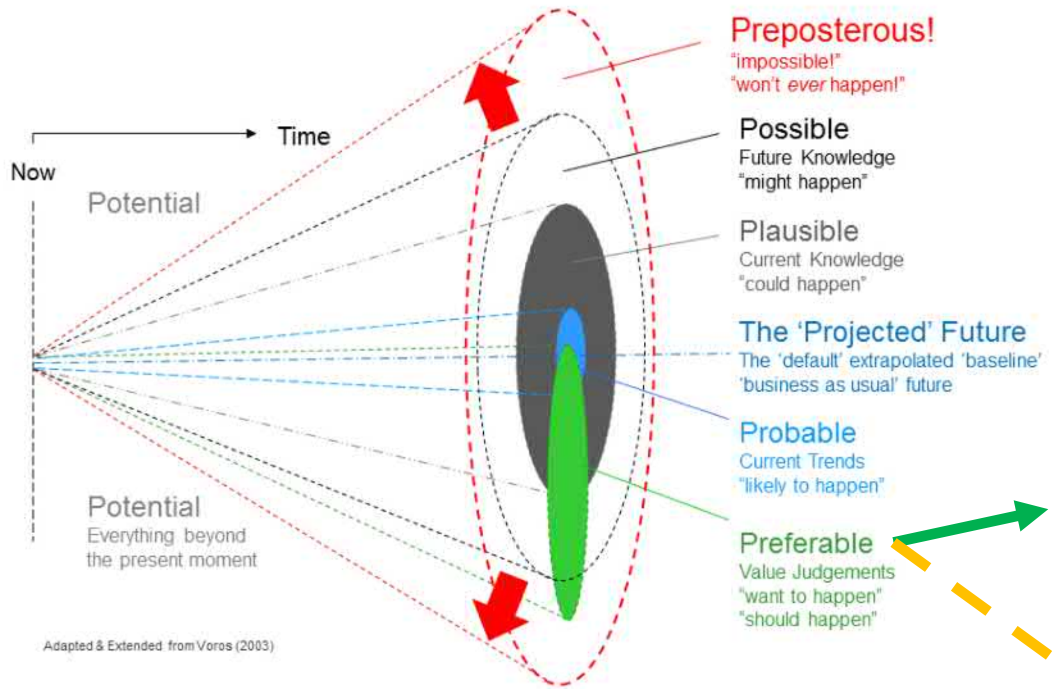
- Hydropower
- Bioenergy

Components of fully sustainable energy future:

- Solar, wind, geothermal and ocean energy
- Energy savings, energy efficiency

Which sustainable energy future should we pick?

Which sustainable energy futures/scenarios can we design for a country?



Source: https://thevoroscope.com/2017/02/24/the-futures-cone-use-and-history/

How much of which component can we envisage?

- energy savings
- energy efficiency

- Solar
- wind
- geothermal
- ocean energy

- Hydropower
- Bioenergy

SUSTAINABLE TARGET SCENARIOS VERSUS BUSINESS AS USUAL

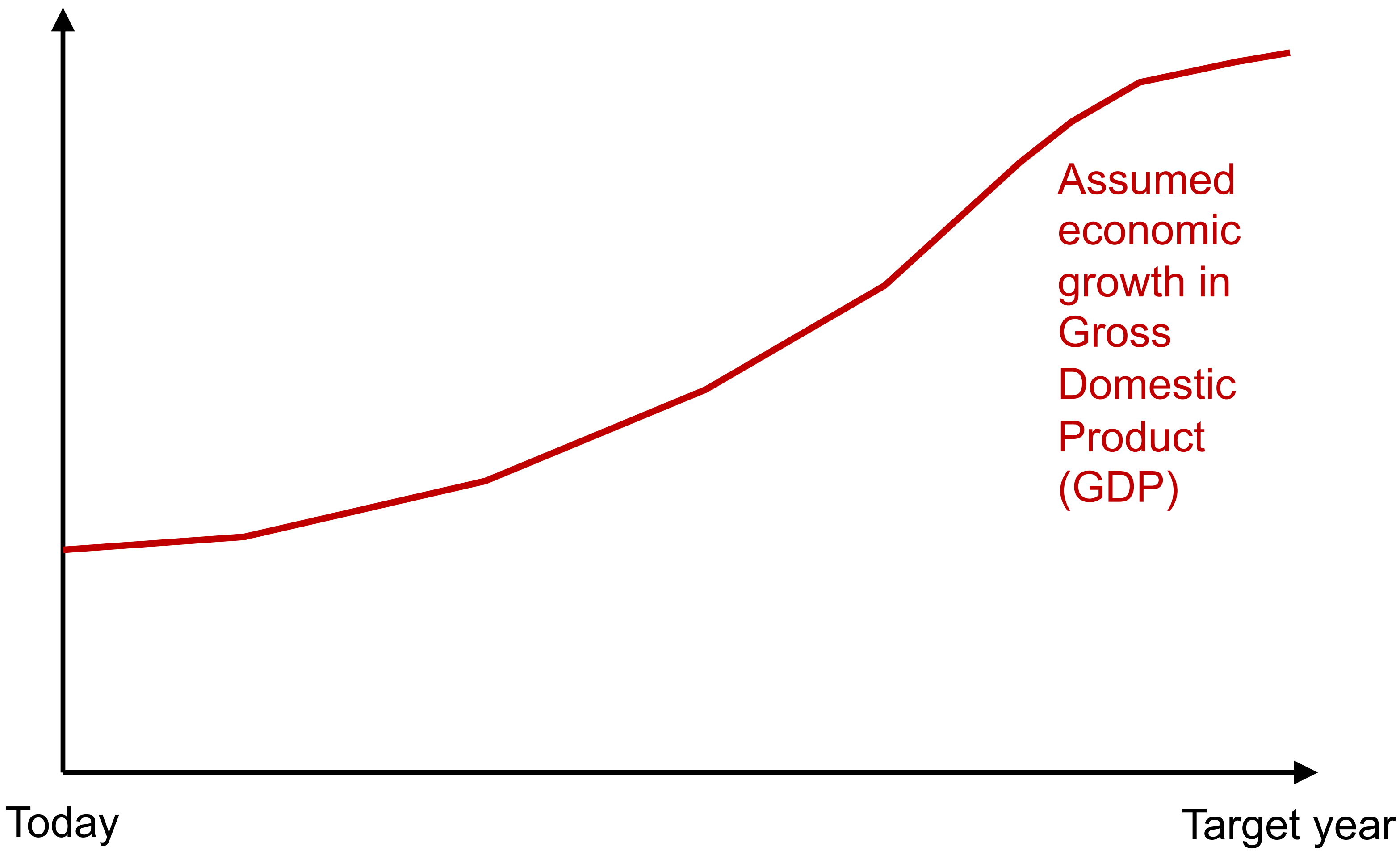
What do we need to look at for sustainable future energy scenarios?

- The likely future energy demand
- The factors driving the future energy demand
  - Economic growth
  - Population growth
  - Energy efficiency improvements
- The possible contributions of different renewable energy sources
- Storage possibilities of a country

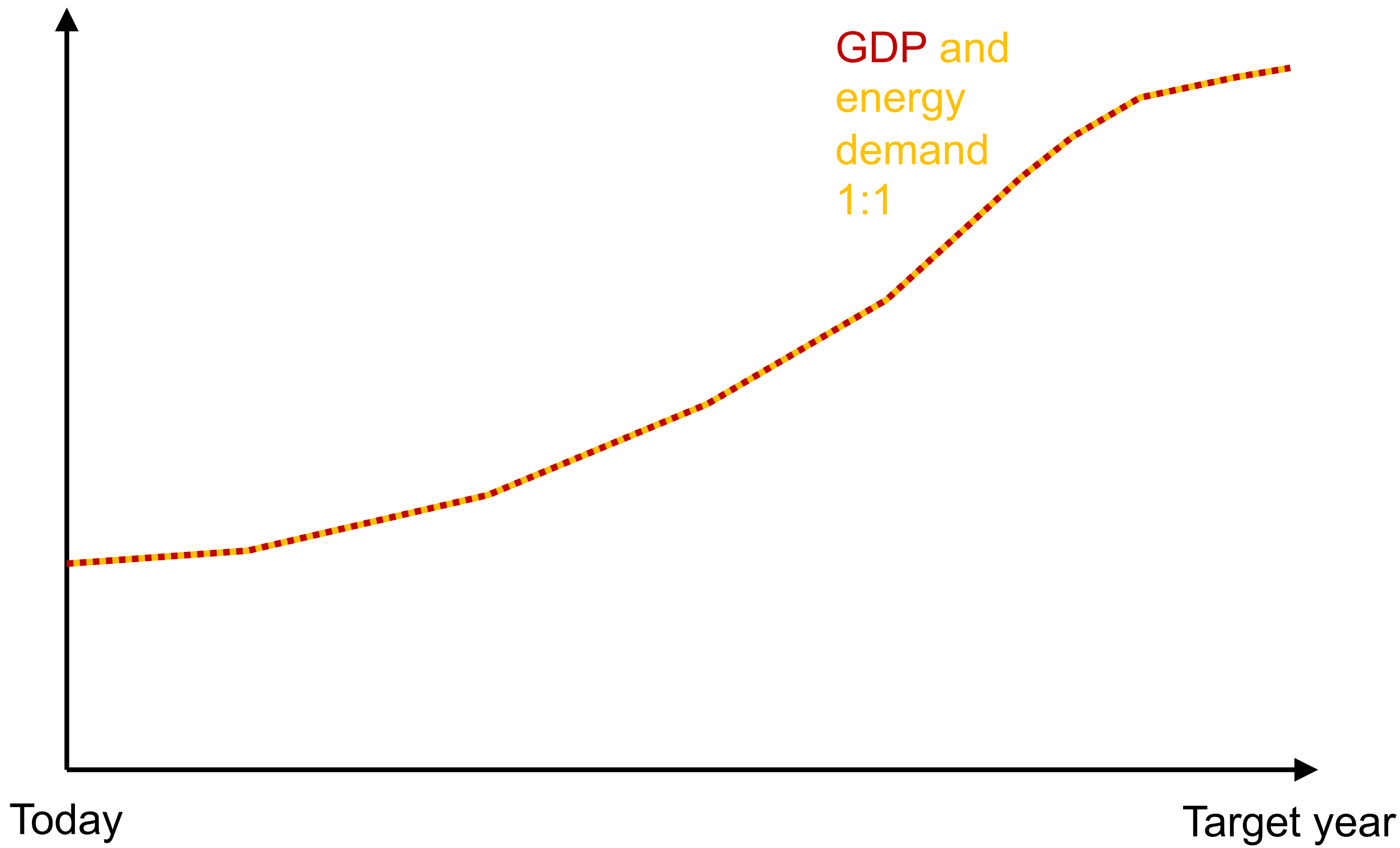
The drivers of future energy demand

- Economic growth
  - In a first approximation energy consumption will grow at a similar path as the economic production (GDP)
- Population growth
  - Strong population growth can lead to even higher growth rates of the energy demand
- Energy efficiency improvements
  – Energy efficiency can lead to a decoupling of energy and economic growth

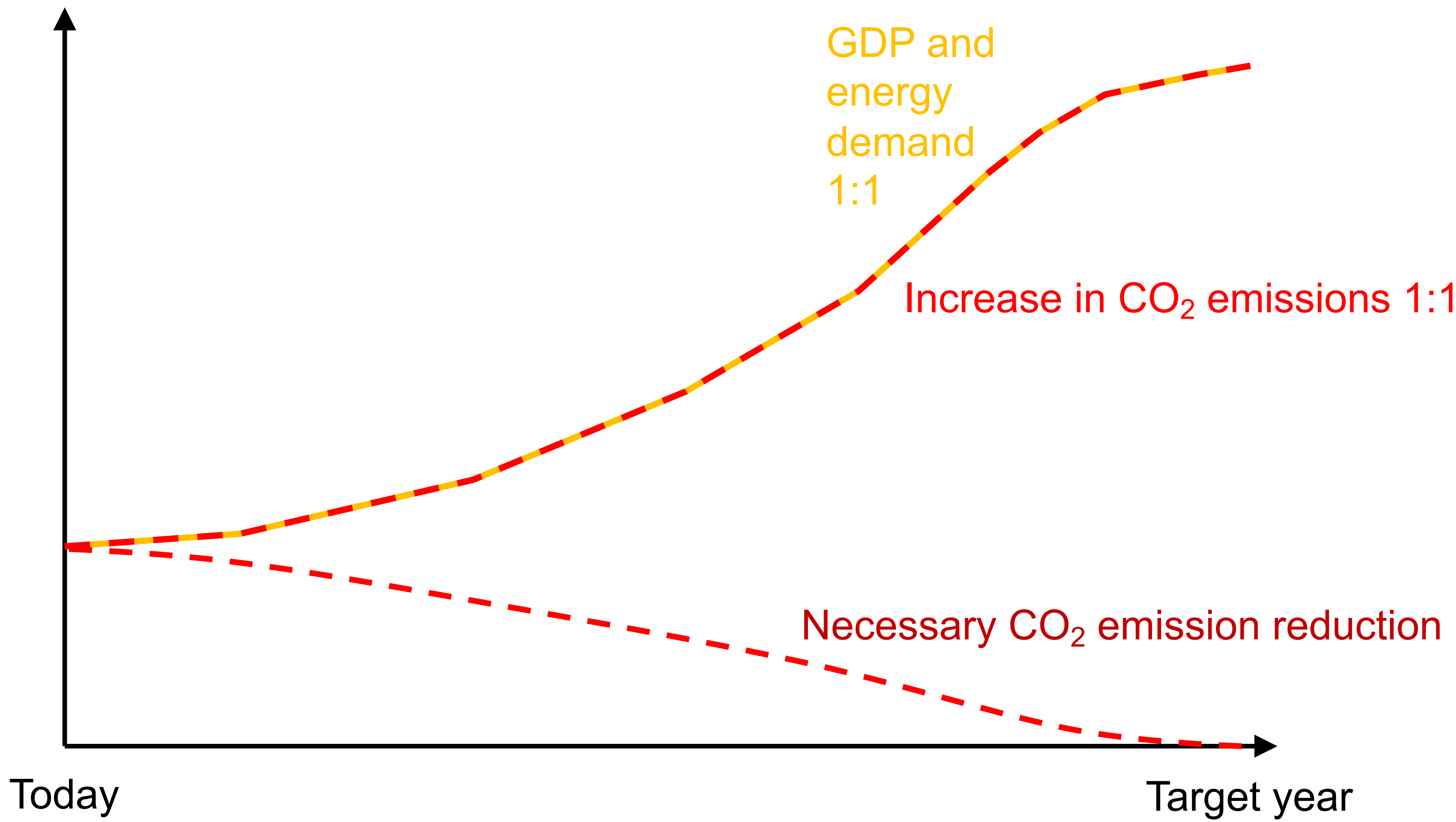
Possible future energy demand
Economic growth as the main driver



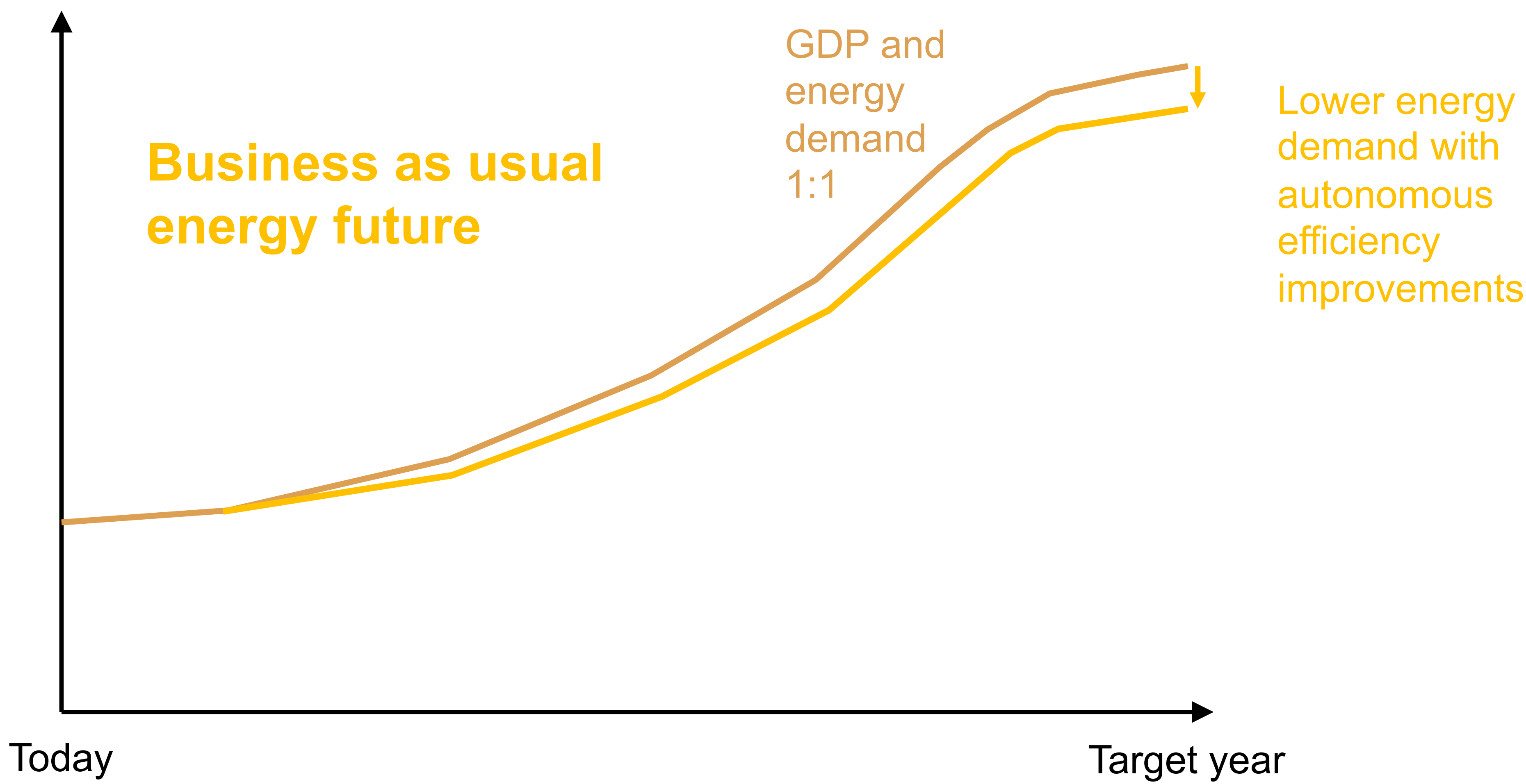
Possible future energy demand
First approximation GDP and energy 1:1



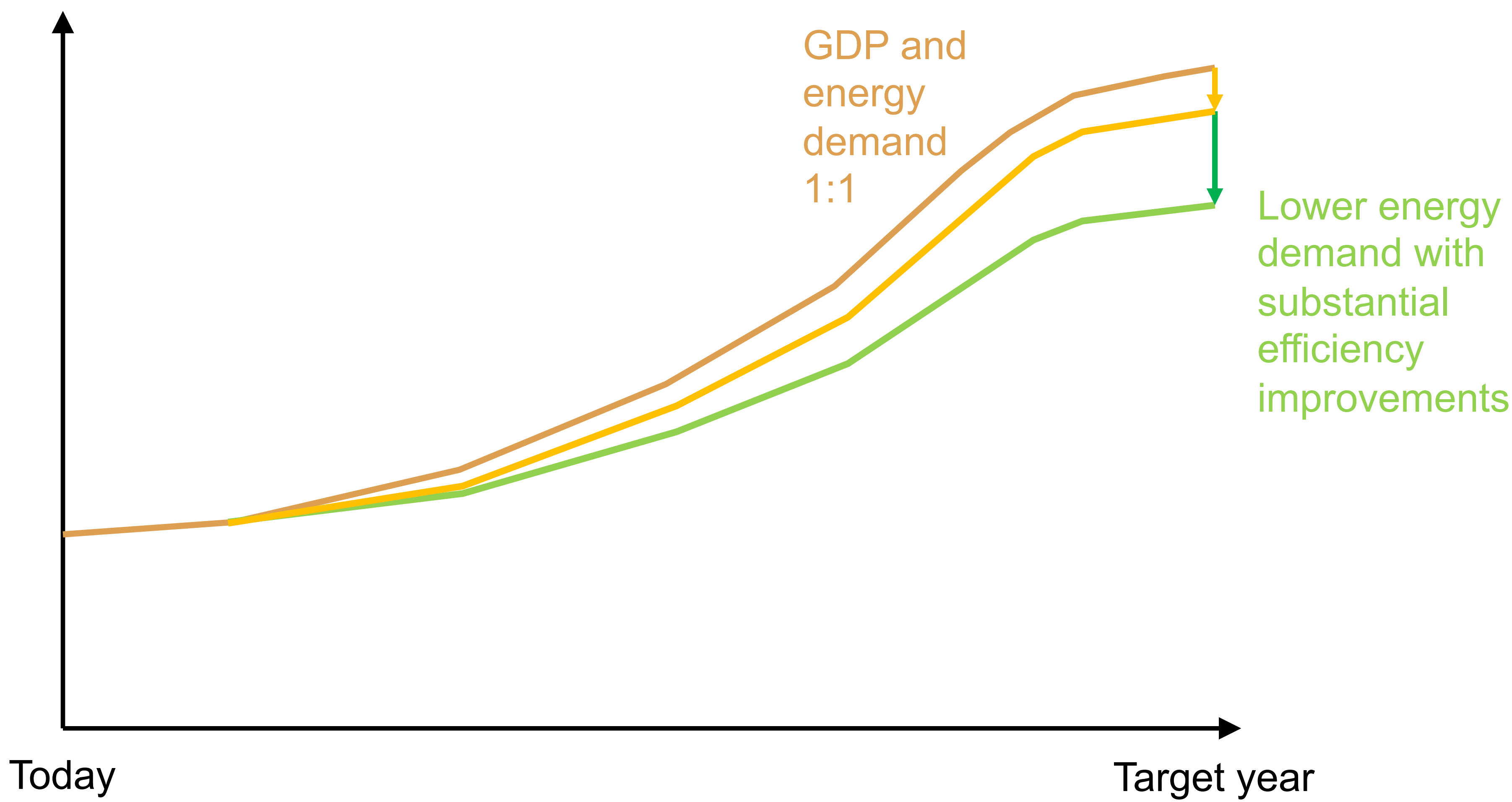
Possible future energy demand CO_2 emissions 1:1



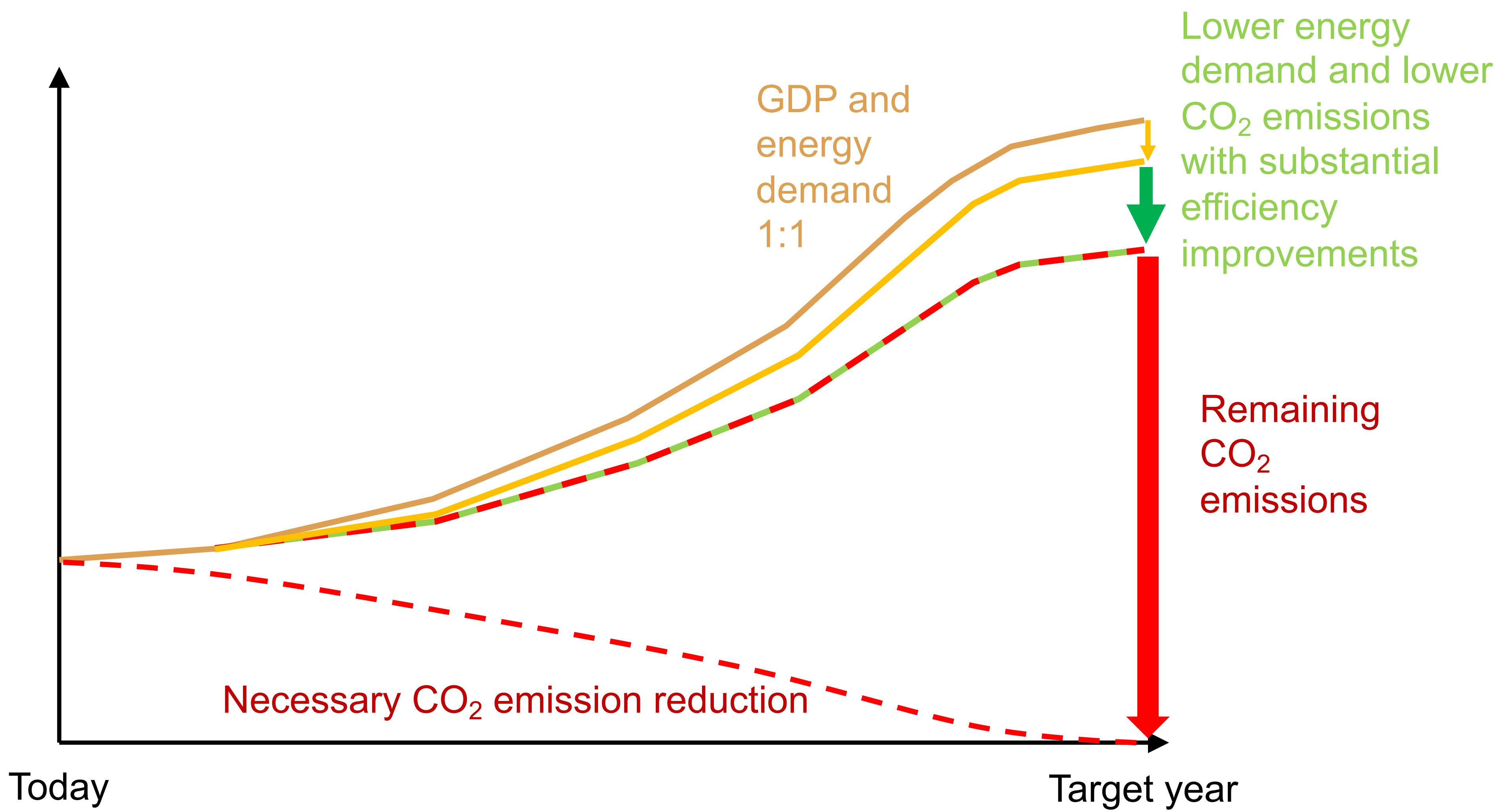
Possible future energy demand with autonomous improvements in energy efficiency



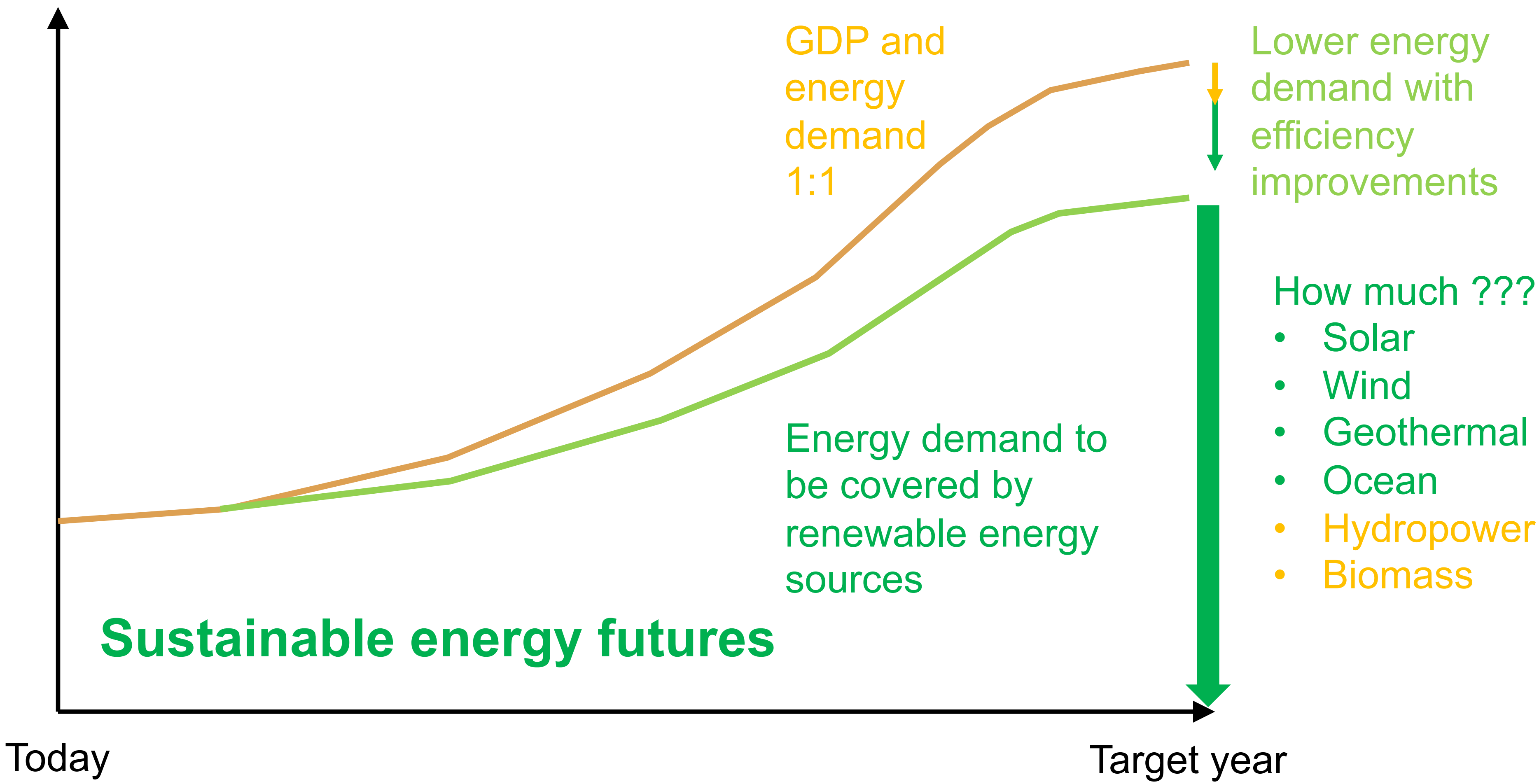
Possible future energy demand with forced improvements in energy efficiency



Energy efficiency alone can't do the trick

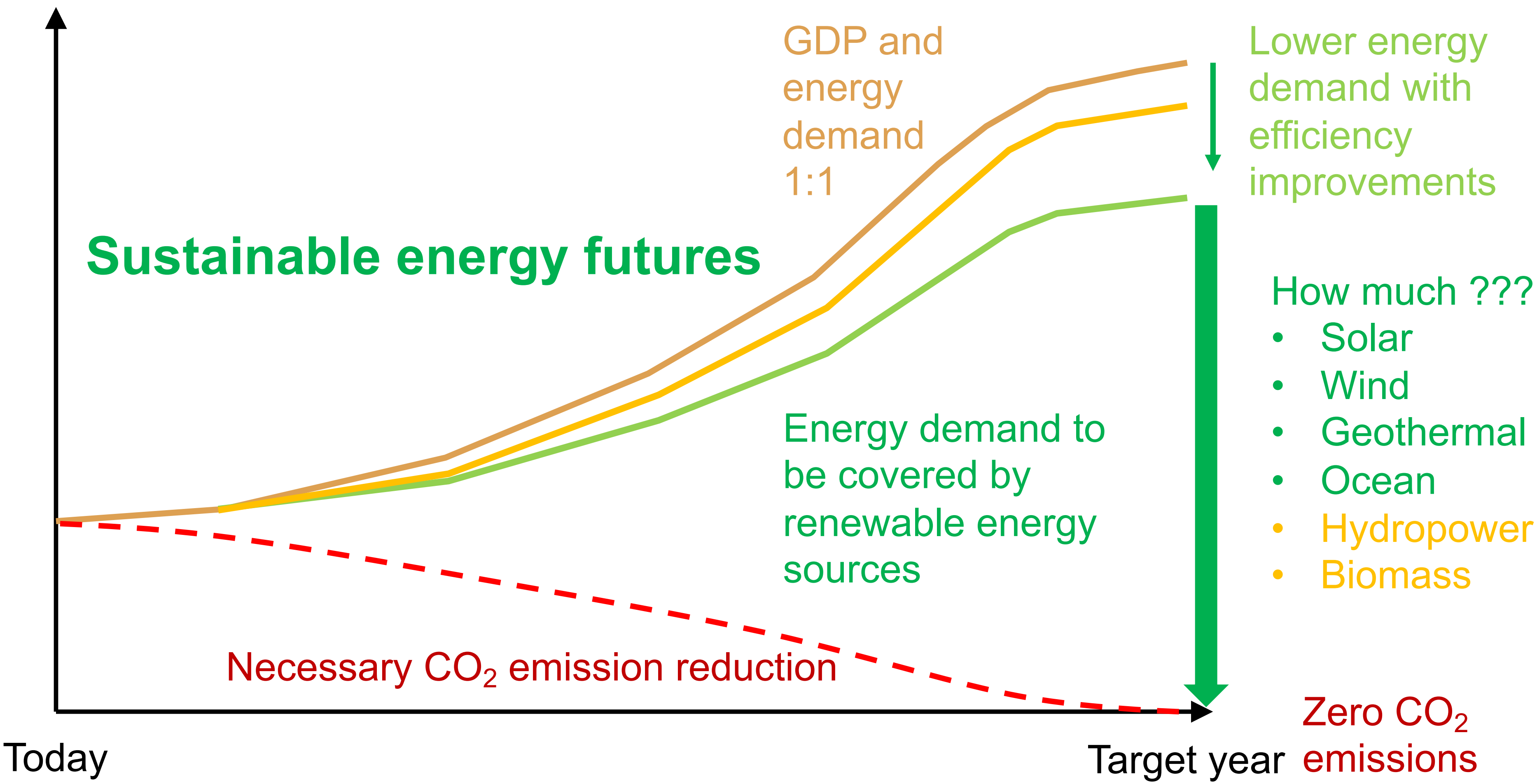


Possible future energy demand to be covered by renewable energy sources



WHICH SUSTAINABLE TARGET SCENARIO SHOULD WE CHOOSE?

How much energy efficiency and how much of each renewable energy source?



How to design sustainable energy scenarios for a country

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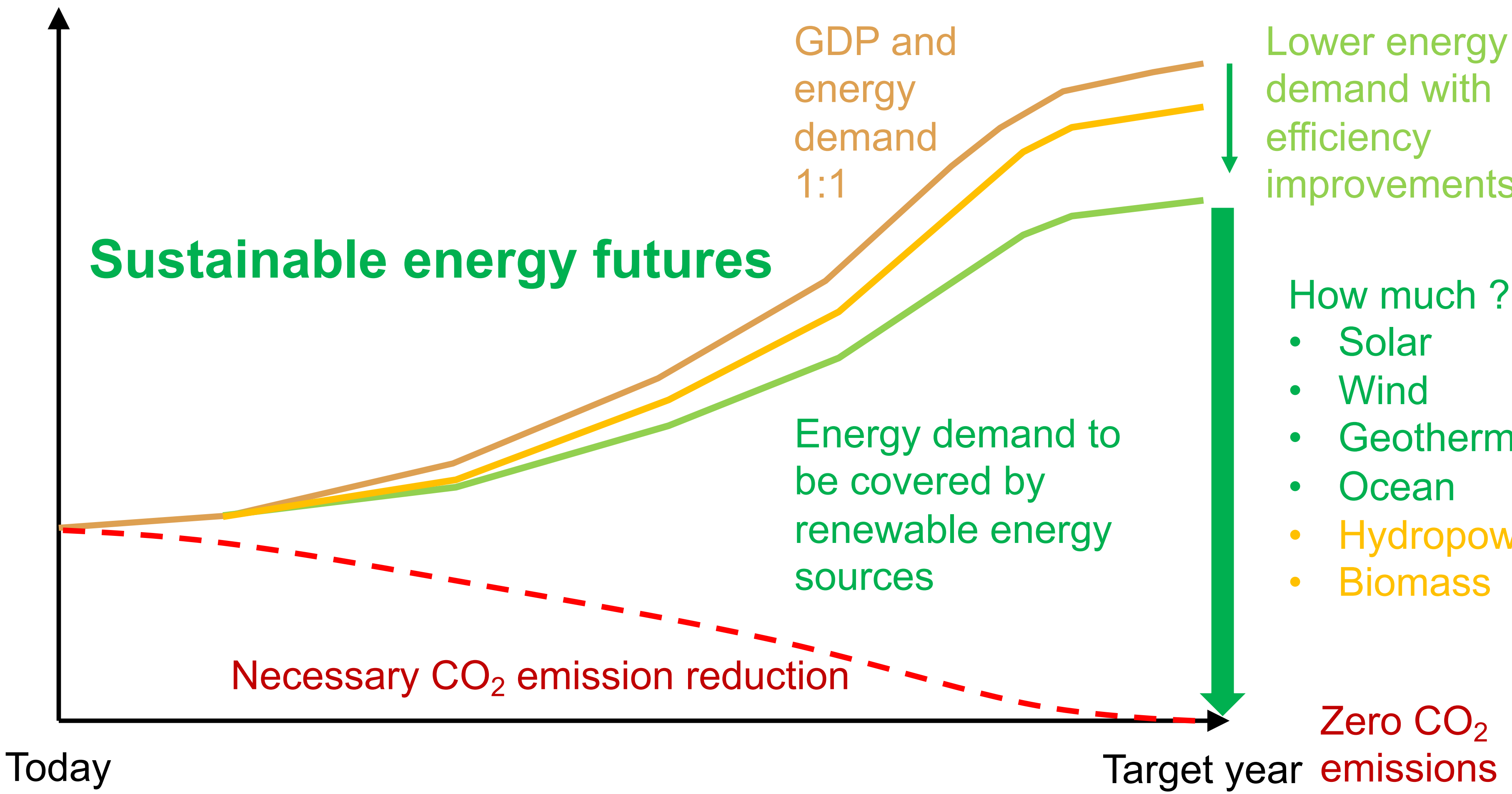
Yangon, Myanmar, September 4th, 2019

How much energy efficiency and how much of each renewable energy source?



How much ???

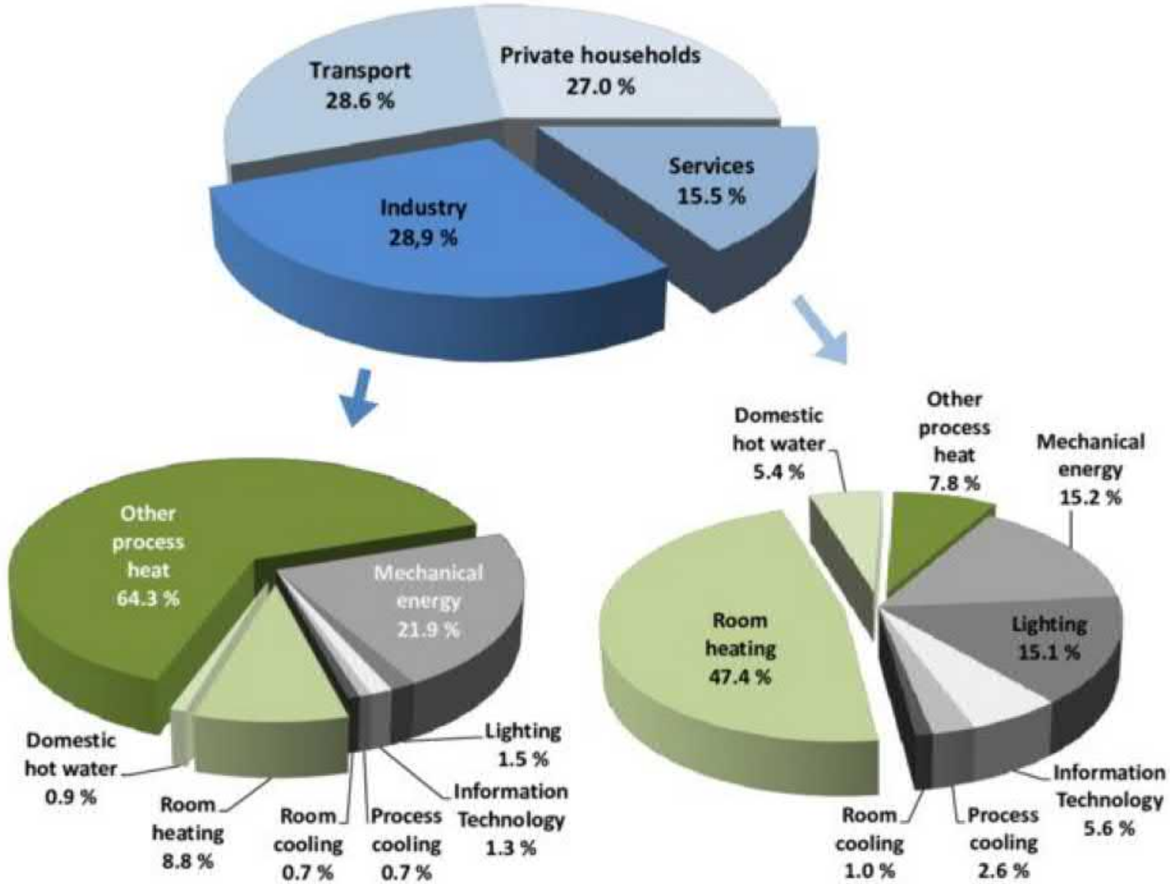
- Solar
- Wind
- Geothermal
- Ocean
- Hydropower
- Biomass

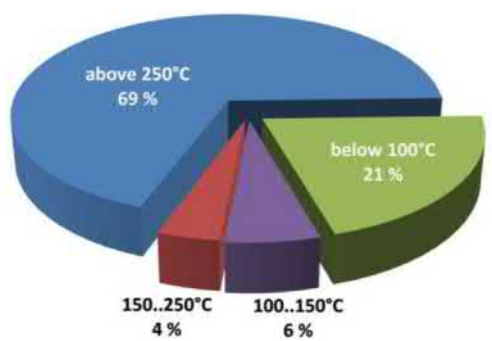
HOW TO BUILD A SUSTAINABLE TARGET SCENARIO?

A CLOSER LOOK AT ENERGY DEMAND

The structure of energy demand
The example of German

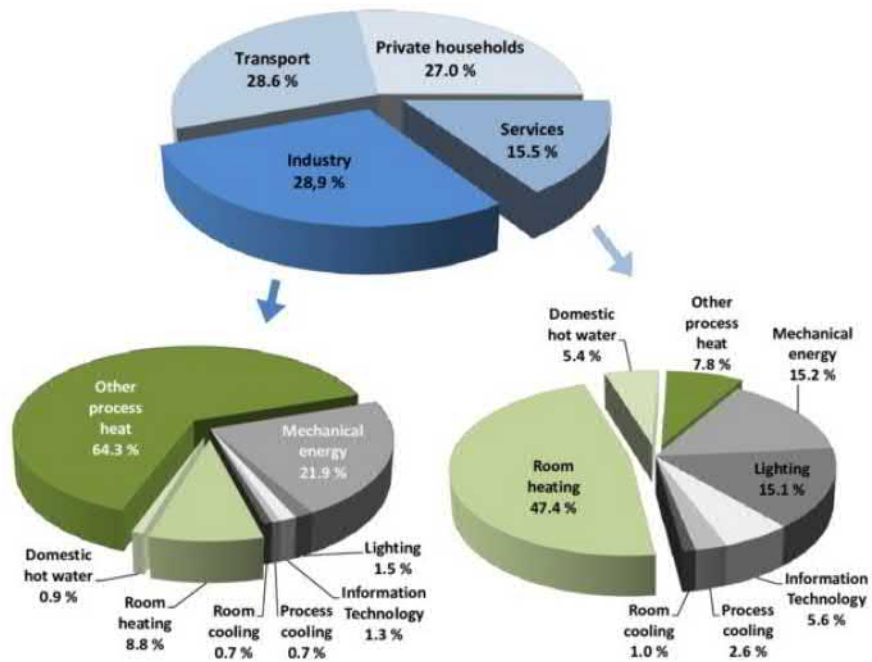
Mechanical energy
Stationary
Mobile
Heat
High Temperature
Low Temperature
Cooling
Lighting
Information Technology



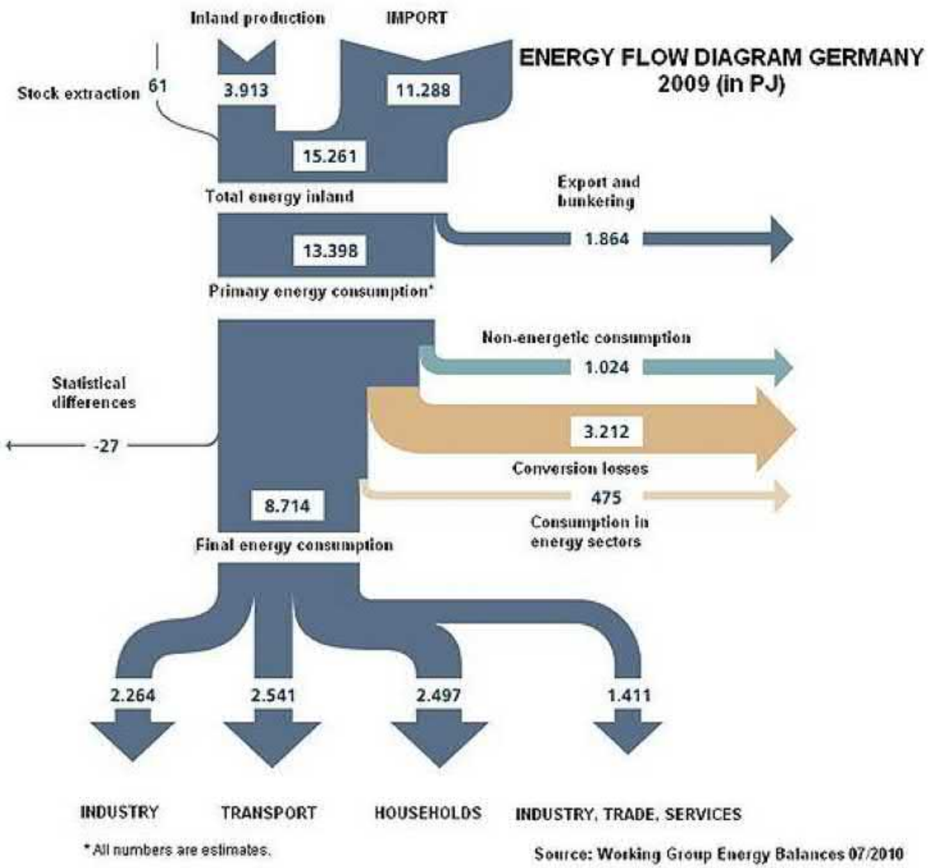


The structure of energy demand by energy service

- Mechanical energy
  - Stationary
  - Mobile (Transport)
- Heat
  - High Temperature
  - Low Temperature
- Cooling
- Lighting
- Information Technology



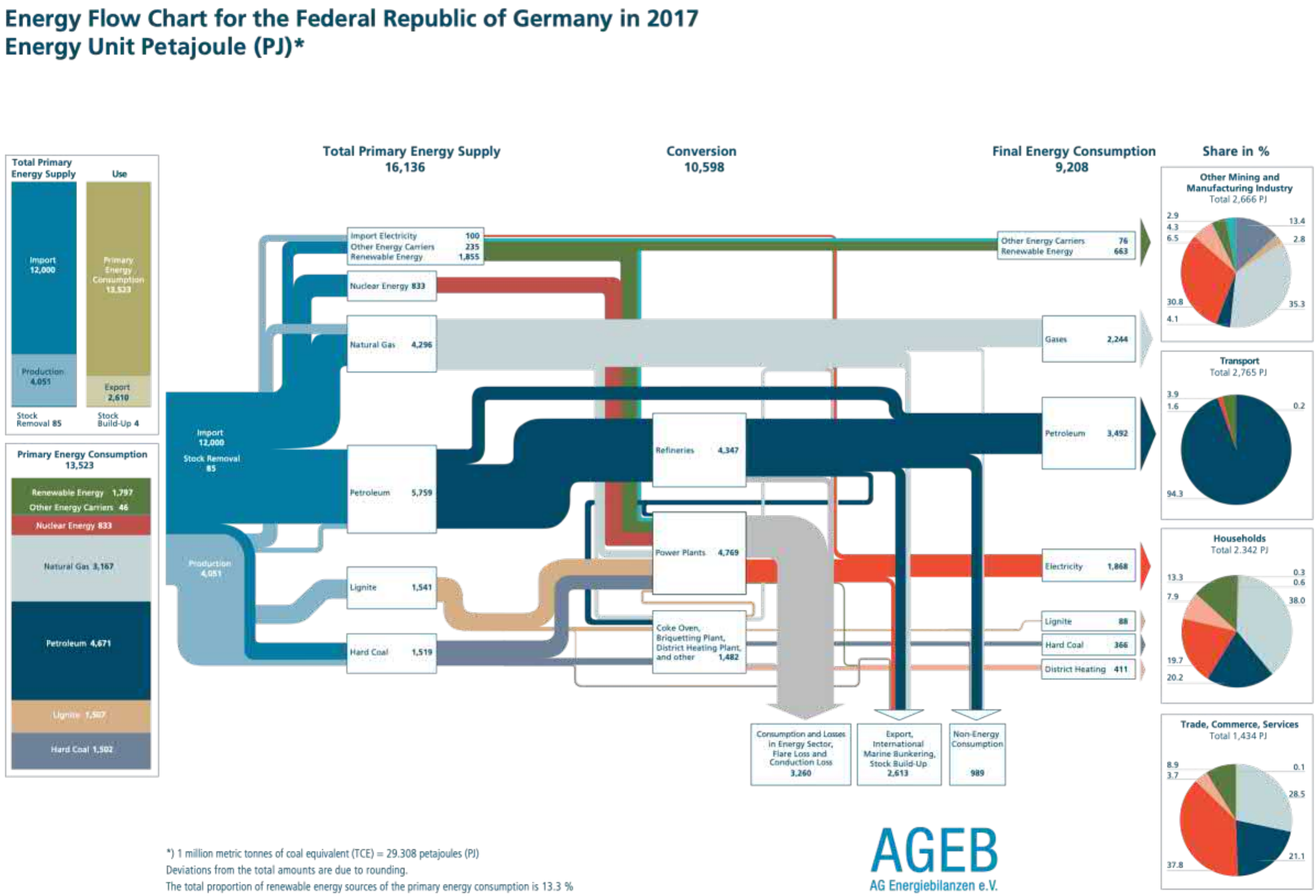
The structure of energy demand as flow chart



Sectors of final demand

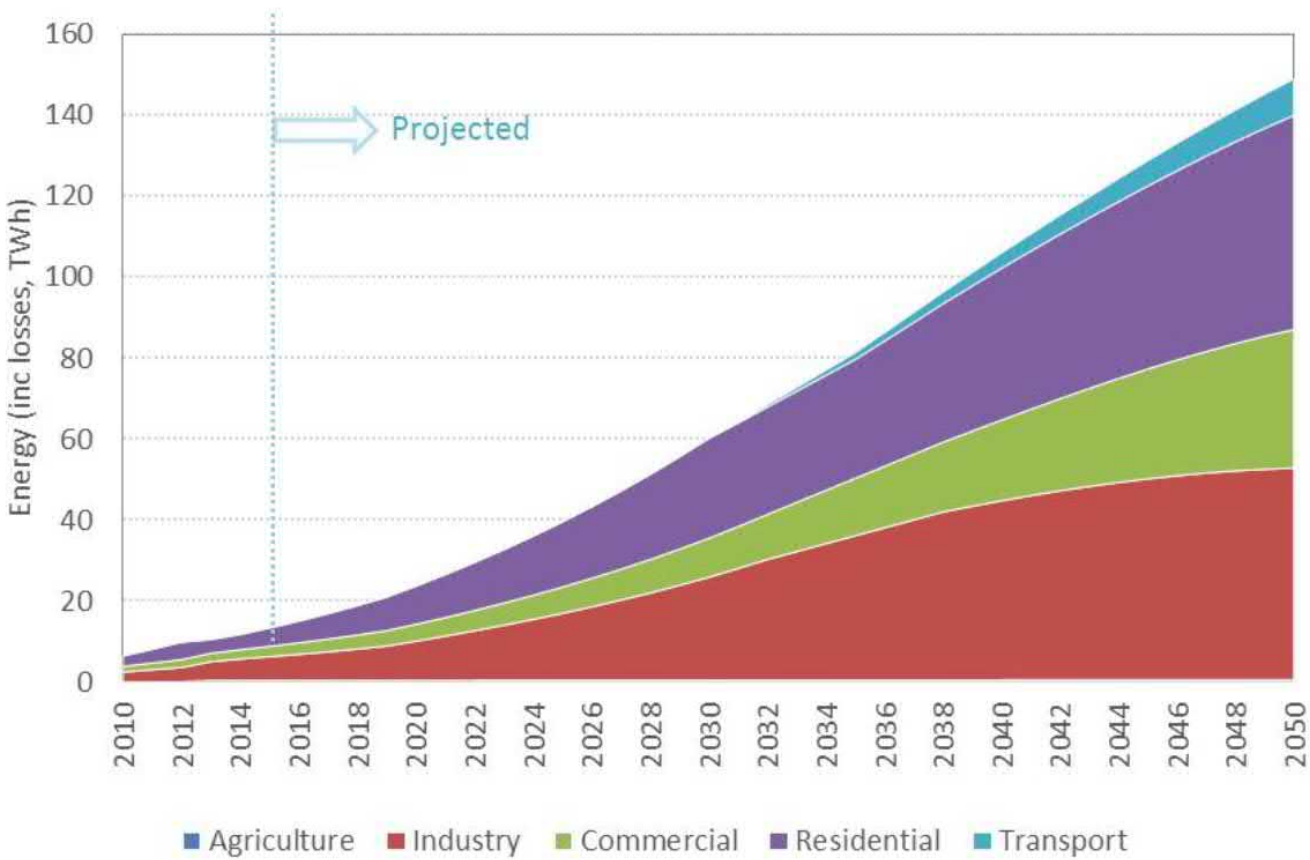
- Industry
- Transport
- Households
- Service sector

The structure of energy demand as flow chart



Projected future energy demand of Myanmar until 2050

Figure 31 **Myanmar Projected Electricity Demand (2015-50, BAU)**



Source: IES and MKE 2017

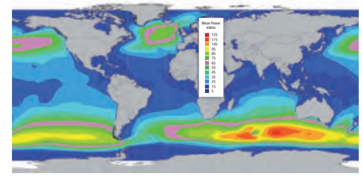
A sevenfold increase in electricity demand will need to be met by 2050

A CLOSER LOOK AT RENEWABLE ENERGY SOURCES

Analyse the national renewable energy potentials

- Size (GW) and quality (cost per kWh) of the renewable resources of the country?
  - Solar energy (PV and solar thermal)
  - Wind energy (onshore and offshore)
  - Geothermal energy (deep and shallow)
  - Ocean energy (wave, tidal, ocean currents)
  - Hydropower
  - Bioenergy (waste and energy crops)



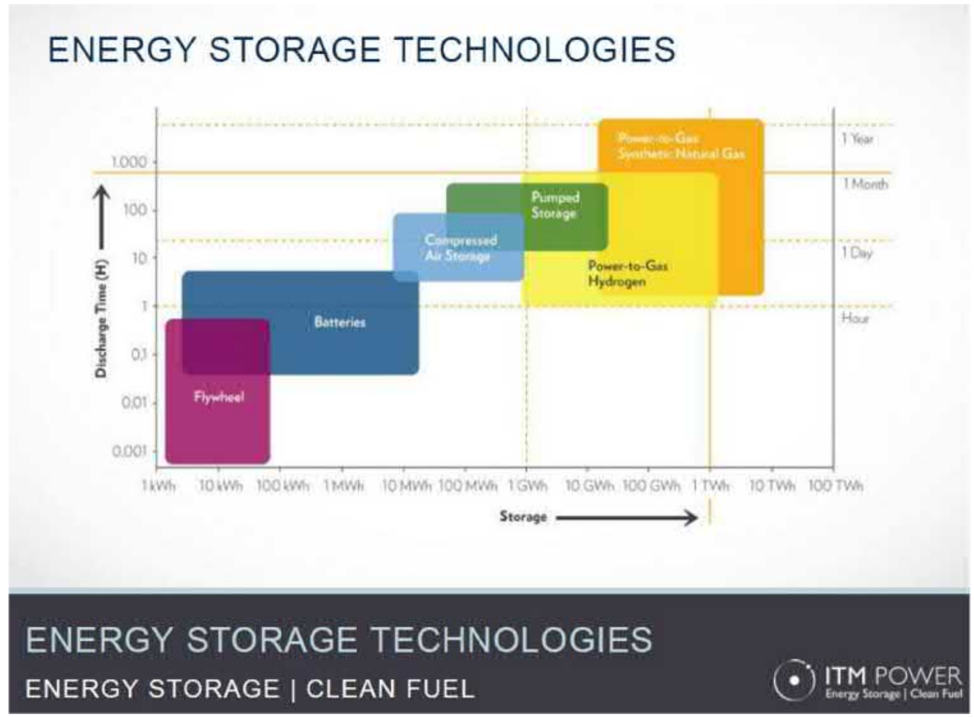



- In the first round of scenario building rough estimates will suffice.

A CLOSER LOOK STORAGE

Analyse the national storage potentials

- Size (GW) and quality (cost per kWh) of the storage options of the country?
  - Pump hydro storage
  - Compressed air storage
  - Power to gas to power storage
  - Battery storage



CHOOSING THE TARGET SCENARIO

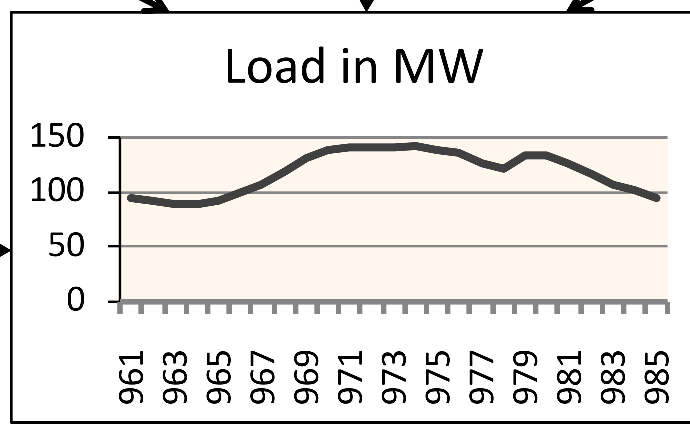
Simulate possible target scenarios

195 MW PV

3 GWh PSH

200 MW wind

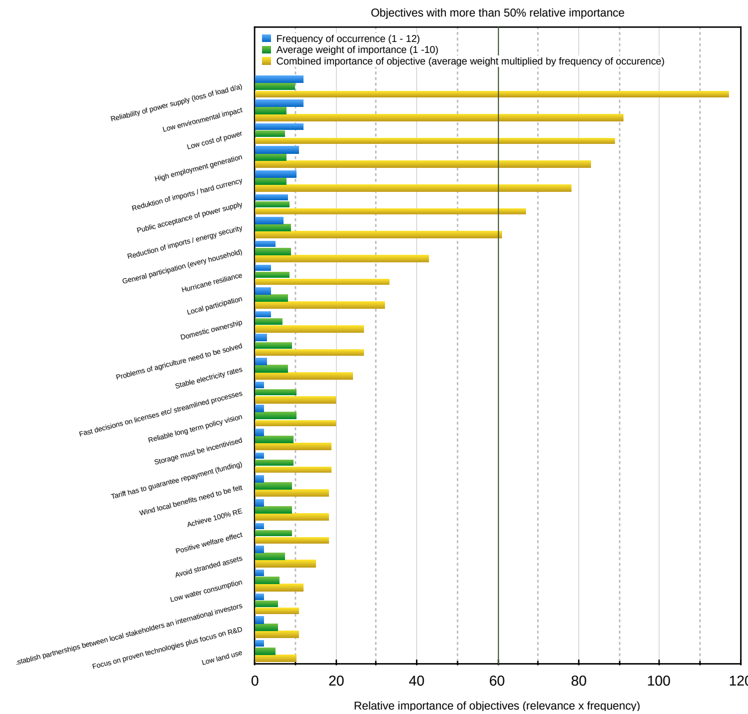
25 GWh biomass



Compare results and select possible target scenarios (Barbados 2017)

Scenario		LCOE
No.	Name	BBD/ kWh
11	100% RE / Wind / PV / Solid waste combustion	0.3883
7	100% RE Wind and PV plus storage	0.3999
13	100% RE / Wind / PV / King Grass / WTE combustion	0.4004
6	100% RE Wind and storage alone	0.4013
17	100% RE / Wind / PV / King Grass / Bagasse / WTE combustion	0.4128
14	100% RE / Wind / PV / Bagasse / WTE combustion	0.4143
12	100% RE / Wind / PV / King Grass / WTE gasification	0.4209
8	100% RE / Wind / PV / King Grass	0.4212
9	100% RE / Wind / PV / Bagasse	0.4233
10	100% RE / Wind / PV / WTE gasification	0.4356
18	100% RE / Wind / PV / King Grass / Bagasse / WTE gasification /WTE combustion	0.4361
13a	100% RE / Wind / PV / King Grass / WTE combustion	0.4386
1	New diesel only (base line)	0.4495
16	100% RE / Wind / PV / King Grass / Bagasse / WTE gasification	0.4584
15	100% RE / Wind / PV / Bagasse / WTE gasification	0.4614
2	Bagasse and river tamarind only	0.4810
3	King grass gasification only	0.4886
5	100% RE PV and storage alone	0.5100
4	Waste to energy gasification only	0.5126

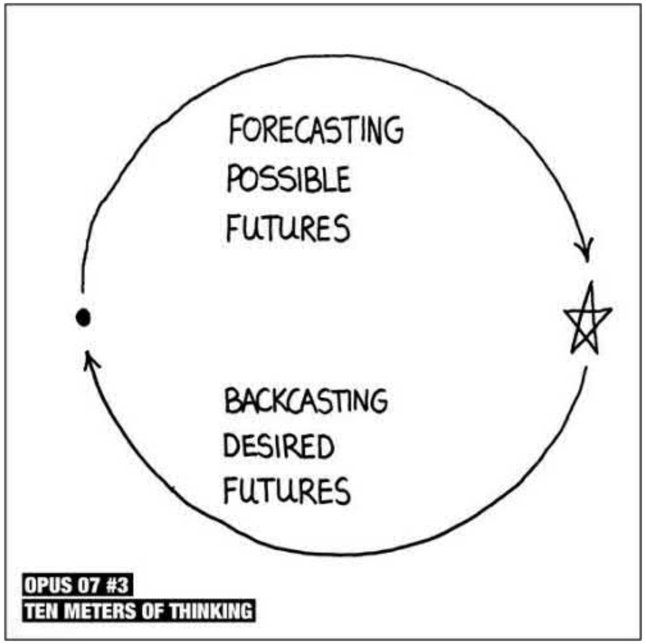
A multi-criteria decision process



Source: Hohmeyer 2017, p.17 and 19

USE OF BACKCASTING TO FIND TRANSITION PATHWAYS

Moving from today to sustainable future scenarios and backcasting the way to the future



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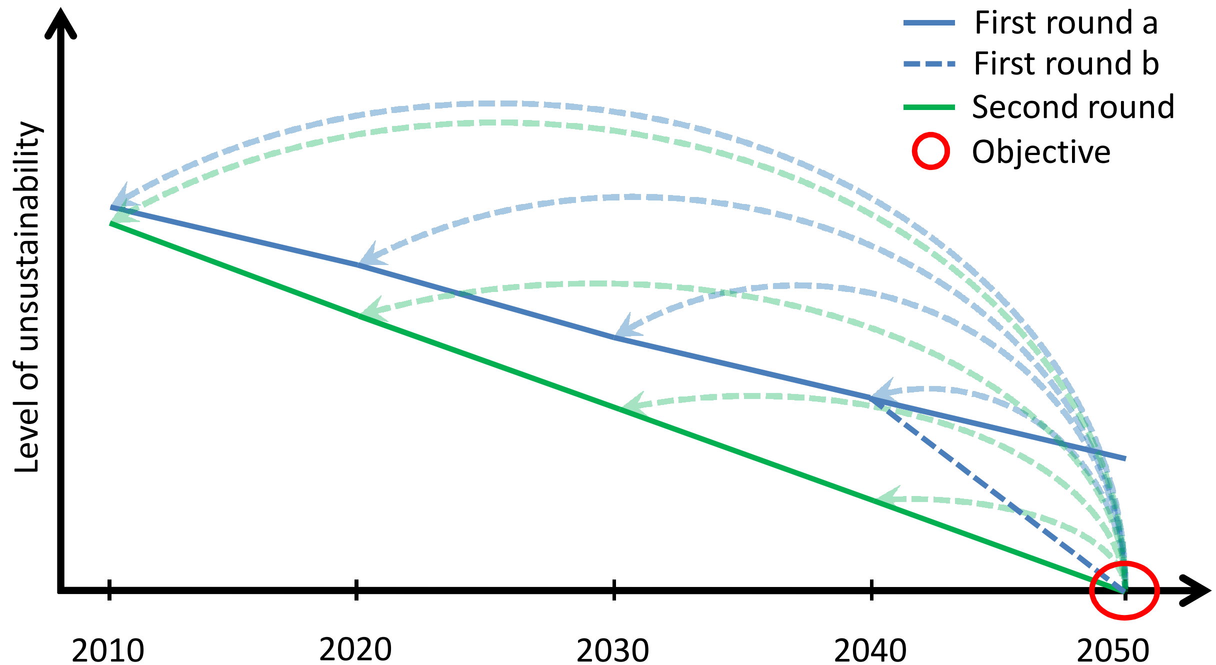


Figure 4.9: *Construction of a scenario with its pathway in a sequence of development rounds*

Source: Maas 2014, p. 129

Example of a simple transition pathways for a selected target scenario (Barbados), Part 1

Transition pathway

Scenario / Wind year 2011		Year	Annual power demand	LCOE	Installed capacities and annual generation									
					Wind		PV		King Grass		Bagasse and river tamarind combustion		Solid wate combustion	
No.	Name			BBD/ kWh	MW	GWh/ a	MW	GWh/ a	MW	GWh/ a	MW	GWh/ a	MW	GWh/a
11	100% RE / Wind / PV / WTE combustion	2015	950		0		10	19					0	
		2020	1050	0.3664	25	114	55	113					5	34
		2025	1150	0.3002	105	481	125	258					11	74
		2030	1250	0.3123	185	847	195	403					11	74
		2035	1350	0.3883	265	1213	265	547					11	74

Target scenario 11

Source: Hohmeyer 2017, p.22

Example of a simple transition pathways for a selected target scenario (Barbados), Part 2

Transition pathway

Scenario / Wind year 2011		Year	Annual power demand	LCOE	Installed capacities and annual generation								Share of RE	Total overproduction
					Diesel/ Biodiesel		Storage volume	Storage generation		Storage pumping				
No.	Name			BBD/ kWh	MW	GWh/ a	MWh	MW	GWh/ a	MW	GWh/ a		%	GWh/a
11	100% RE / Wind / PV / WTE combustion	2015	950		239	950								
		2020	1050	0.3664	140.9	789							24.9 %	0
		2025	1150	0.3002	148.8	354	3000	150.5	60	90	80		69.2 %	17
		2030	1250	0.3123	162.2	118	5000	186.3	176	220.7	202		90.6 %	192
		2035	1350	0.3883	166.7	50	5000	196.8	205	307	238		96.3 %	400

Target scenario 11

Source: Hohmeyer 2017, p.23

Backcasting simple transition pathways for four selected target scenarios (Barbados)

No.	Scenario / Wind year 2011 – Name	Year	Annual power demand	LCOE (BBD/kWh)	Wind MW	Wind GWh/a	PV MW	PV GWh/a	King Grass MW	King Grass GWh/a	Bagasse and river tamarind combustion MW	Bagasse and river tamarind combustion GWh/a	Solid wate combustion MW	Solid wate combustion GWh/a
					Installed capacities and annual generation									
11	100% RE / Wind / PV / WTE combustion	2015	950		0		10	19					0	
		2020	1050	0.3664	25	114	55	113					5	34
		2025	1150	0.3002	105	481	125	258					11	74
		2030	1250	0.3123	185	847	195	403					11	74
		2035	1350	0.3883	265	1213	265	547					11	74
13	100% RE / Wind / PV / King Grass / WTE combustion	2015	950		0	0	10	19	0	0			0	0
		2020	1050	0.3696	20	92	65	134	2	5			5	34
		2025	1150	0.3253	90	412	120	248	10	30			11	74
		2030	1250	0.3161	160	733	175	361	18	75			11	74
		2035	1350	0.4004	232	1062	232	479	26	120			11	74
13 a	100% RE / Wind / PV / King Grass / WTE combustion	2015	950		0		10	19	0	0			0	
		2020	1050	0.3749	20	92	50	103	2	5			5	34
		2025	1150	0.3354	80	366	100	206	14	45			11	74
		2030	1250	0.3451	140	641	150	310	27	150			11	74
		2035	1350	0.4331	200	916	200	413	40	300			11	74
14	100% RE / Wind / PV / Bagasse / WTE combustion	2015	950		0	0	10	19			0	0	0	0
		2020	1050	0.3807	20	92	65	134			25	169	5	34
		2025	1150	0.3452	85	389	120	248			25	169	11	74
		2030	1250	0.3609	170	778	175	361			25	169	11	74
		2035	1350	0.4143	219	1003	219	452			25	169	11	74

No.	Scenario / Wind year 2011 – Name	Year	Annual power demand	LCOE (BBD/kWh)	Diesel/ Biodiesel MW	Diesel/ Biodiesel GWh/a	Storage volume MWh	Storage generation MW	Storage generation GWh/a	Storage pumping MW	Storage pumping GWh/a	Share of RE %	Total overproduction GWh/a
					Installed capacities and annual generation								
11	100% RE / Wind / PV / WTE combustion	2015	950		239	950							
		2020	1050	0.3664	140.9	789						24.9 %	0
		2025	1150	0.3002	148.8	354	3000	150.5	60	90	80	69.2 %	17
		2030	1250	0.3123	162.2	118	5000	186.3	176	220.7	202	90.6 %	192
		2035	1350	0.3883	166.7	50	5000	196.8	205	307	238	96.3 %	400
13	100% RE / Wind / PV / King Grass / WTE combustion	2015	950		239	950	0	0	0	0	0	0.0 %	0
		2020	1050	0.3696	140.2	785						25.2 %	0
		2025	1150	0.3253	148	422						63.3 %	36
		2030	1250	0.3161	155.6	164.4	5000	178	142	162.8	163	86.8 %	157.4
		2035	1350	0.4004	144.8	50	5000	172.9	163	253.4	190	96.3 %	435
13 a	100% RE / Wind / PV / King Grass / WTE combustion	2015	950		239	950						0.0 %	
		2020	1050	0.3749	140.2	816						22.3 %	0
		2025	1150	0.3354	140.5	469						59.2 %	10
		2030	1250	0.3451	135.3	168	5000	156	97	131.5	110	86.6 %	93
		2035	1350	0.4331	131.6	50	5000	156.8	129	199.8	151	96.3 %	403
14	100% RE / Wind / PV / Bagasse / WTE combustion	2015	950		239	950	0	0	0	0	0	0.0 %	0
		2020	1050	0.3807	121.7	621						40.9 %	0
		2025	1150	0.3452	129.9	286	5000	138.4	56	85.3	75	75.1 %	16
		2030	1250	0.3609	139.4	133	5000	165	157	181.4	181	89.4 %	265
		2035	1350	0.4143	151.9	50	5000	180.6	176	248.3	205	96.3 %	398

Source: Hohmeyer 2017, p.22/23

Different scenarios may need to build storage at different times

Scenario / Wind year 2011		Year	Annual power demand	LCOE	Installed capacities and annual generation							Share of RE	Total overproduction
					Diesel/ Biodiesel		Storage volume	Storage generation		Storage pumping			
No.	Name			BBD/ kWh	MW	GWh/a	MWh	MW	GWh/a	MW	GWh/a	%	GWh/a
11	100% RE / Wind / PV / WTE combustion	2015	950		239	950							
		2020	1050	0.3664	140.9	789						24.9 %	0
		2025	1150	0.3002	148.8	354	3000	150.5	60	90	80	69.2 %	17
		2030	1250	0.3123	162.2	118	5000	186.3	176	220.7	202	90.6 %	192
		2035	1350	0.3883	166.7	50	5000	196.8	205	307	238	96.3 %	400
13	100% RE / Wind / PV / King Grass / WTE combustion	2015	950		239	950	0	0	0	0	0	0.0 %	0
		2020	1050	0.3696	140.2	785						25.2 %	0
		2025	1150	0.3253	148	422						63.3 %	36
		2030	1250	0.3161	155.6	164.4	5000	178	142	162.8	163	86.8 %	157.4
		2035	1350	0.4004	144.8	50	5000	172.9	163	253.4	190	96.3 %	435

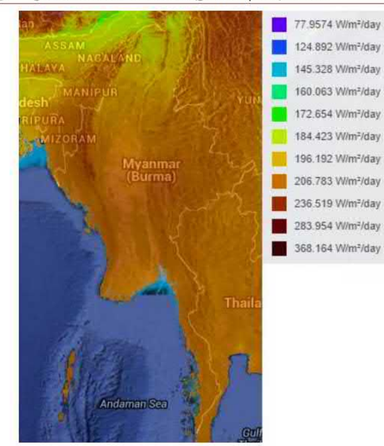
Source: Hohmeyer 2017, p.23

GUIDING TRANSITION PATHWAYS BY POLICY

Where to find information on national renewable energy potentials

- Size (GW) and quality (cost per kWh) of the renewable resources of the country?
  - Solar energy (PV and solar thermal)
  - Wind energy (onshore and offshore)
  - Geothermal energy (deep and shallow)
  - Ocean energy (wave, tidal, ocean currents)
  - Hydropower
  - Bioenergy (waste and energy crops)

Figure 19 3TIER's Global Solar Dataset (3km in W/m^2) for GHI



Source: IRENA Global Atlas for Renewable Energy (3TIER Global Solar Dataset)

Guiding the transition: Why policy has to step in

- Markets don’t steer towards sustainable energy futures due to massive externalities (climate, health, environment), which are not included in market prices!

- Policy has to set the guardrails / framework for markets to steer towards sustainable energy futures

Guiding the transition: The policy framework

- Prohibit the use of non sustainable energy sources (phase out):
  - Phase out of nuclear energy by set target year in many countries after Fukushima
  - Phase out of coal in a number of countries to reach climate targets
- Mandate the use of sustainable energy sources (phase in)
  - Renewable energy quota (portfolio standards) in different countries
- Make non sustainable energy sources very expensive (taxes or emission charges)
  - CO_2 taxes in some countries
  - CO_2 emission rights in trading systems
- Make sustainable energy sources cheap (subsidies)
  - Feed-in tariffs
  - Investment subsidies

TAKE HOME MESSAGES

Sustainable future energy systems
Take home message

- Energy futures need to fulfill sustainability criteria
- Energy is the main cause and solution of global warming
- Projecting past trends into the future will not lead to a sustainable energy future
- A sustainable energy future has three main components:
  - Energy efficiency to decrease demand
  - 100% renewable energy supply
  - Storage to allow time shift of electricity from wind and solar production to times of demand
- Every country will have its own sustainable energy future
- Policy needs to set the framework to guide the transition

How to design sustainable energy scenarios for a country

Prof. Dr. Olav Hohmeyer

Europa-Universität Flensburg

Yangon, Myanmar, September 4th, 2019

What do we need to look at for sustainable future energy scenarios?

- The likely future energy demand
- The factors driving the future energy demand
  - Economic growth
  - Population growth
  - Energy efficiency improvements
- The possible contributions of different renewable energy sources
- Storage possibilities of a country

A 100% renewable energy supply
A chance for Myanmar?

Prof. Dr. Olav Hohmeyer
Europa-Universität Flensburg

Langon, Myanmar, October 9th, 2017

Results of a first 100% RE study on Myanmar

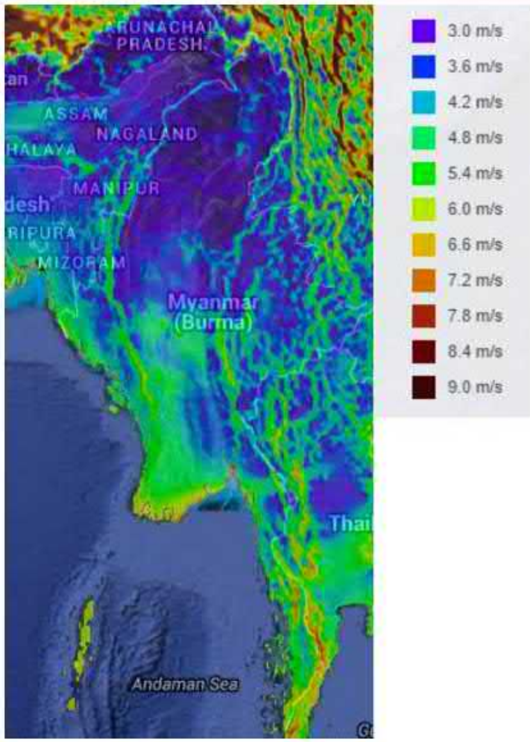
Prof. Dr. Olav Hohmeyer

Europa-Universität Flensburg

Langon, Myanmar, October 9th, 2017

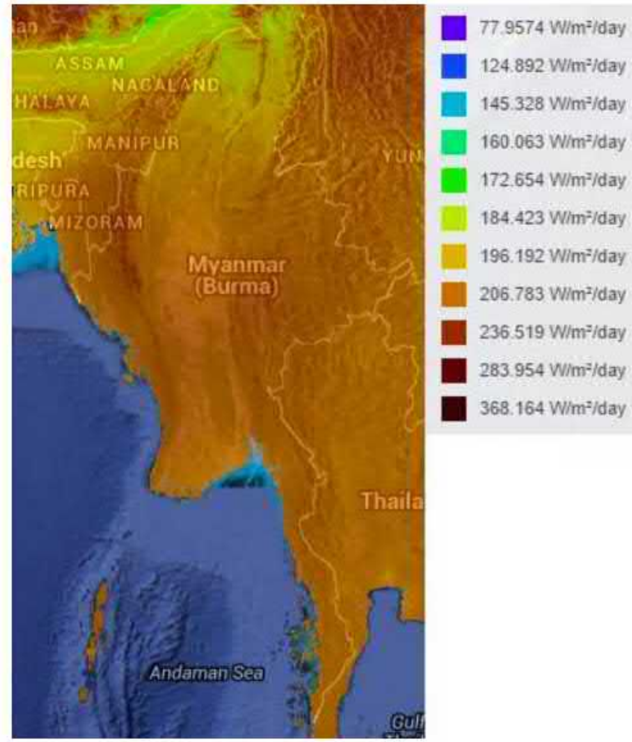
Myanmar has very good wind and solar energy resources

Figure 15 3TIER's Global Wind Dataset 5km onshore wind speed at 80m height[6]



Source: IRENA Global Atlas for Renewable Energy (3TIER Global Wind Dataset)

Figure 19 3TIER's Global Solar Dataset (3km in W/m^2) for GHI



Source: IRENA Global Atlas for Renewable Energy (3TIER Global Solar Dataset)

Source: IES and MKE 2017

Myanmar's hydropower resource is excellent and biomass can contribute substantially

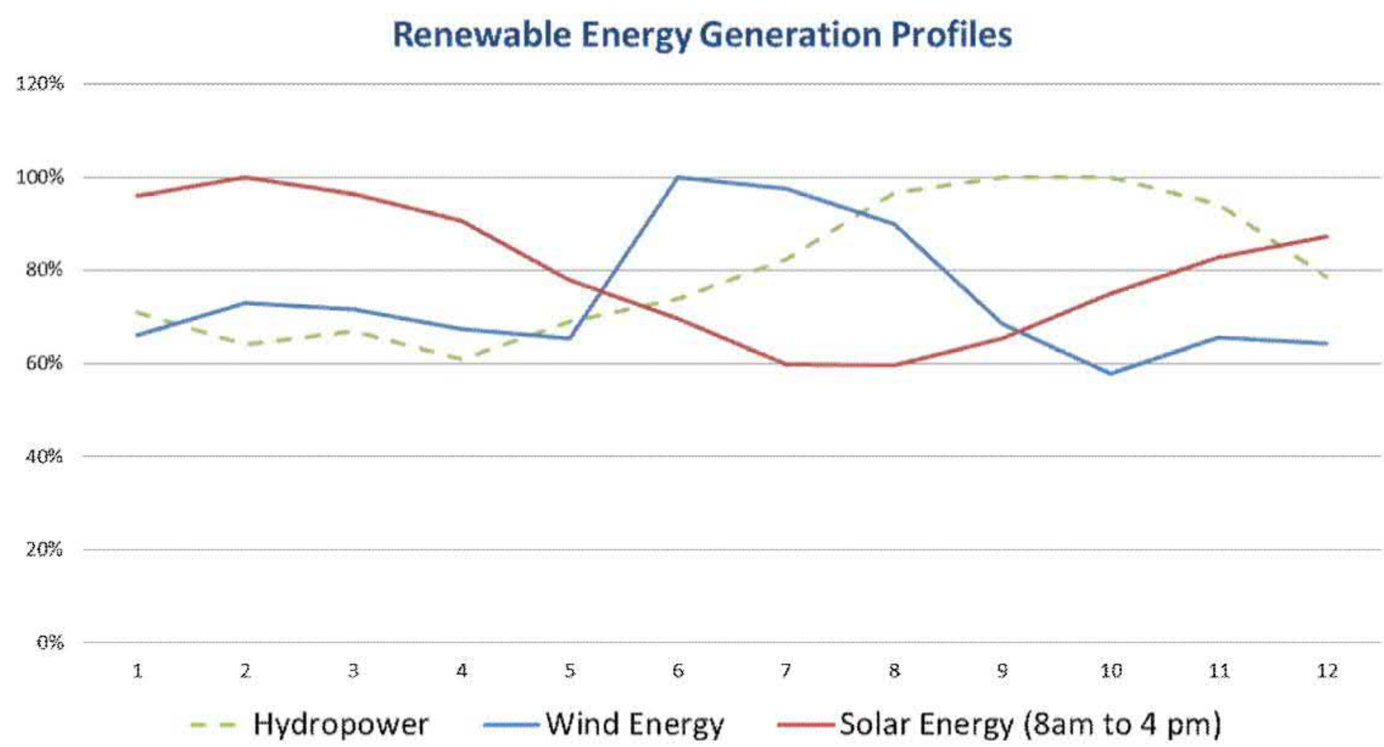
Table 5 Summary of Estimated Renewable Energy Potential (Compiled from Various Sources and Analysis)

Myanmar	Potential (MW)	Source and comments
Hydro (Large)	46,000	See Section 3.4
Hydro (Small)	231	See Section 3.4
Pump Storage	0	Lack of studies available
Solar	26,962 MW	Renewable Energy Developments and Potential in the Greater Mekong Subregion (ADB, 2015)
Wind Onshore	33,829	Renewable Energy Developments and Potential in the Greater Mekong Subregion (ADB, 2015)
Wind Offshore	No information available	Lack of studies available
Biomass	6,899	IES projections based on data from Renewable Energy Developments and Potential in the Greater Mekong Subregion (ADB, 2015)
Biogas	4,741	IES projections based on data from Renewable Energy Developments and Potential in the Greater Mekong Subregion (ADB, 2015)
Geothermal	400	See Section 3.7
Ocean	1,150	Ocean renewable energy in Southeast Asia: A review (2014), based on 5kW/m wave potential, 2300km coastline, 10% efficiency

Source: IES and MKE 2017

The seasonality of solar, wind and hydropower fits very well together

Figure 23 Seasonal Renewable Energy Generation Profiles

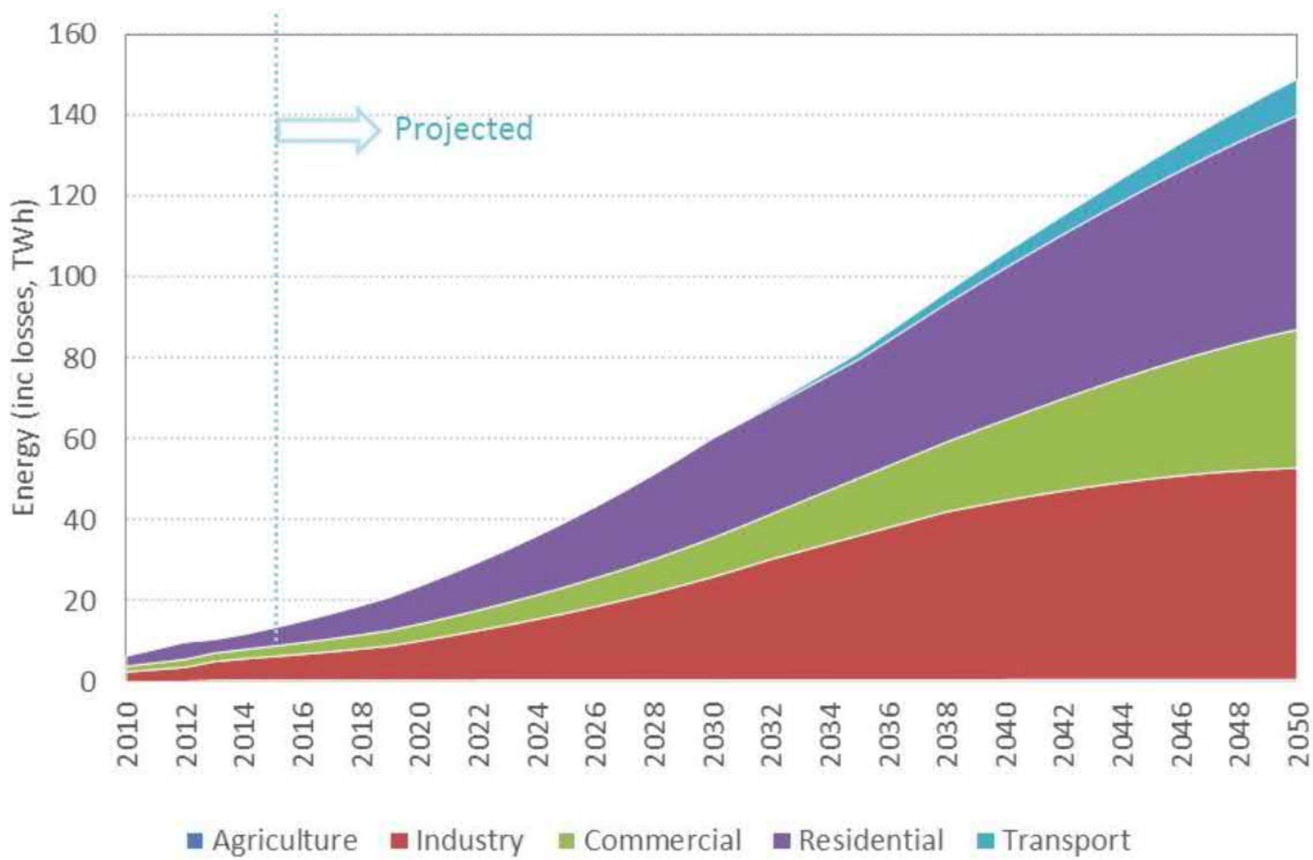


Source: Consultant analysis

Source: IES and MKE 2017

A sevenfold increase in electricity demand will need to be met by 2050

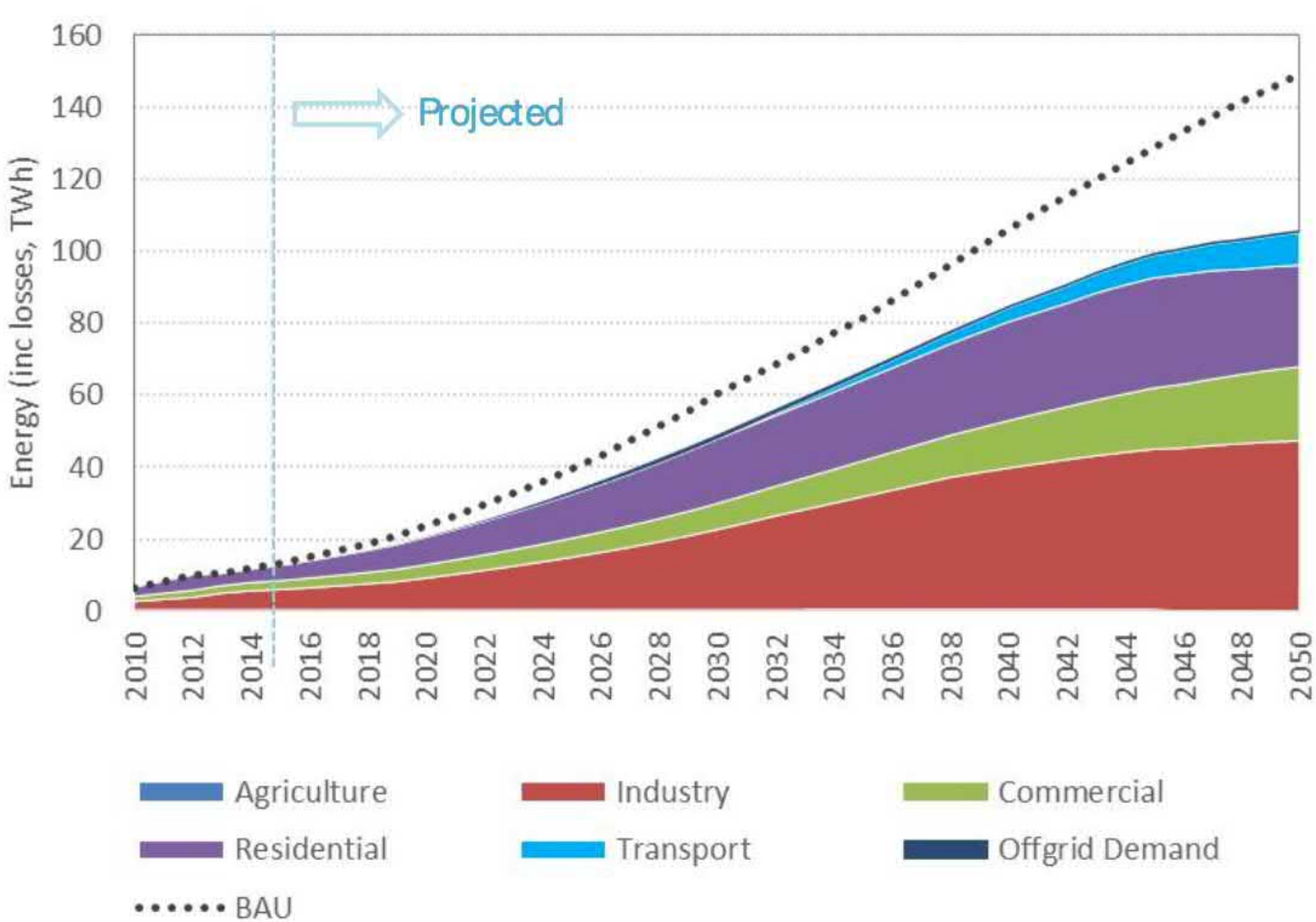
Figure 31 **Myanmar Projected Electricity Demand (2015-50, BAU)**



Source: IES and MKE 2017

Increased efficiency may reduce power demand by about 20%

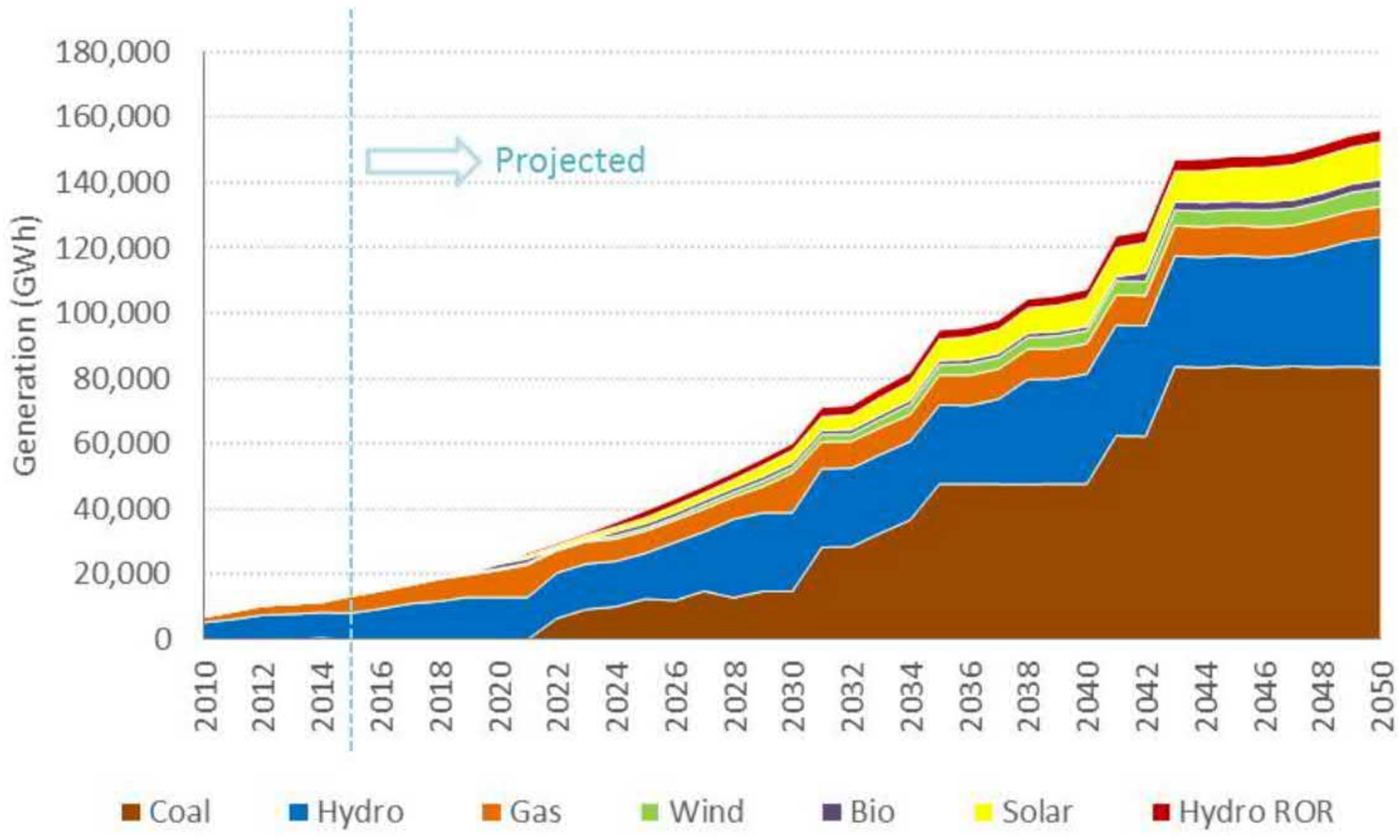
Figure 44 **Myanmar Projected Electricity Demand (2015-2050, SES)**



Source: IES and MKE 2017

In the business-as-usual case coal is supposed to cover about 60% of the future power demand

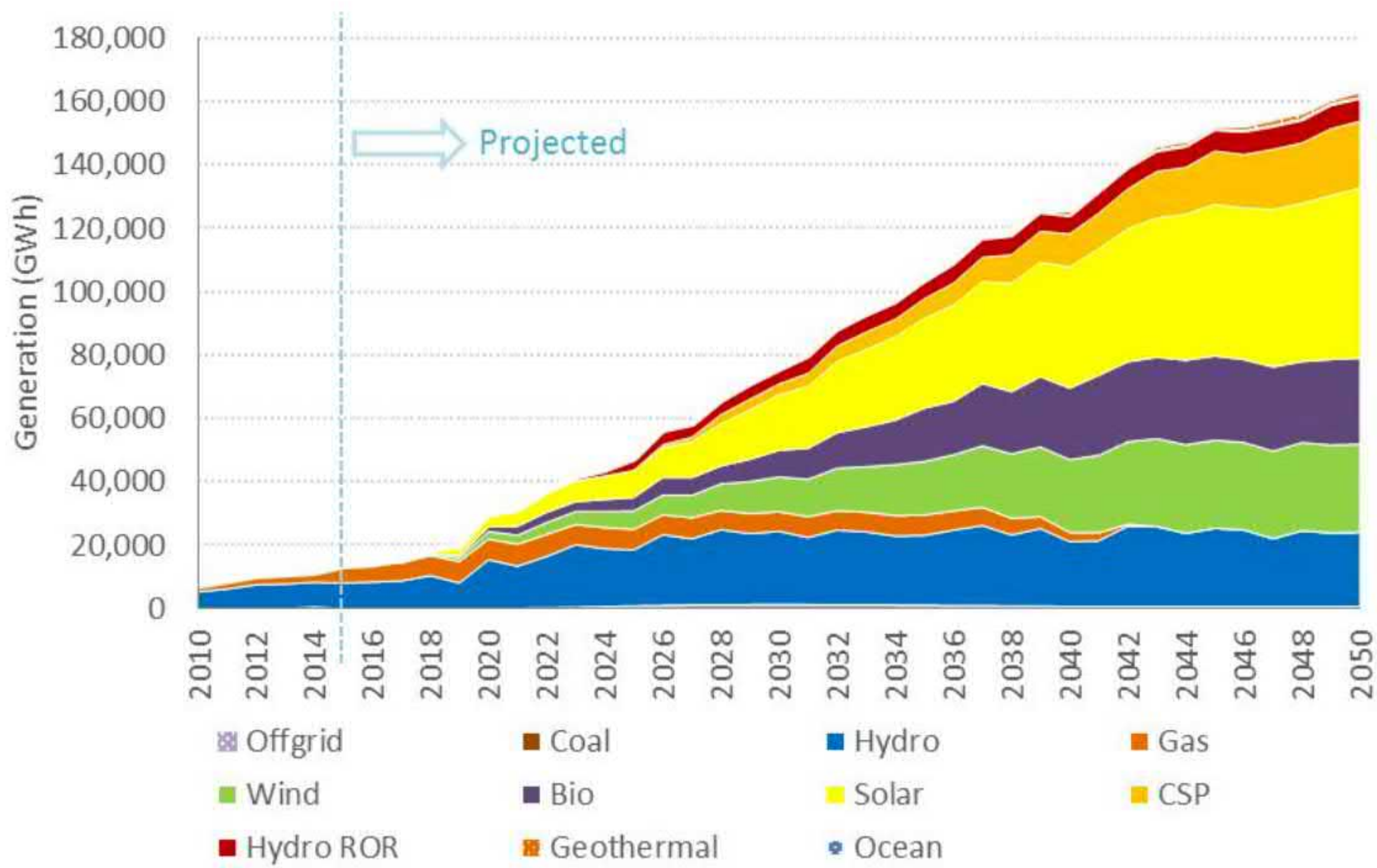
Figure 35 **Myanmar Generation Mix (BAU, GWh)**



Source: IES and MKE 2017

A mix of solar, wind, biomass and hydropower can supply 100% RE

Figure 48 **Myanmar Generation Mix (SES, GWh)**



Source: IES and MKE 2017

A mix of solar, wind, biomass and hydropower can supply 100% RE

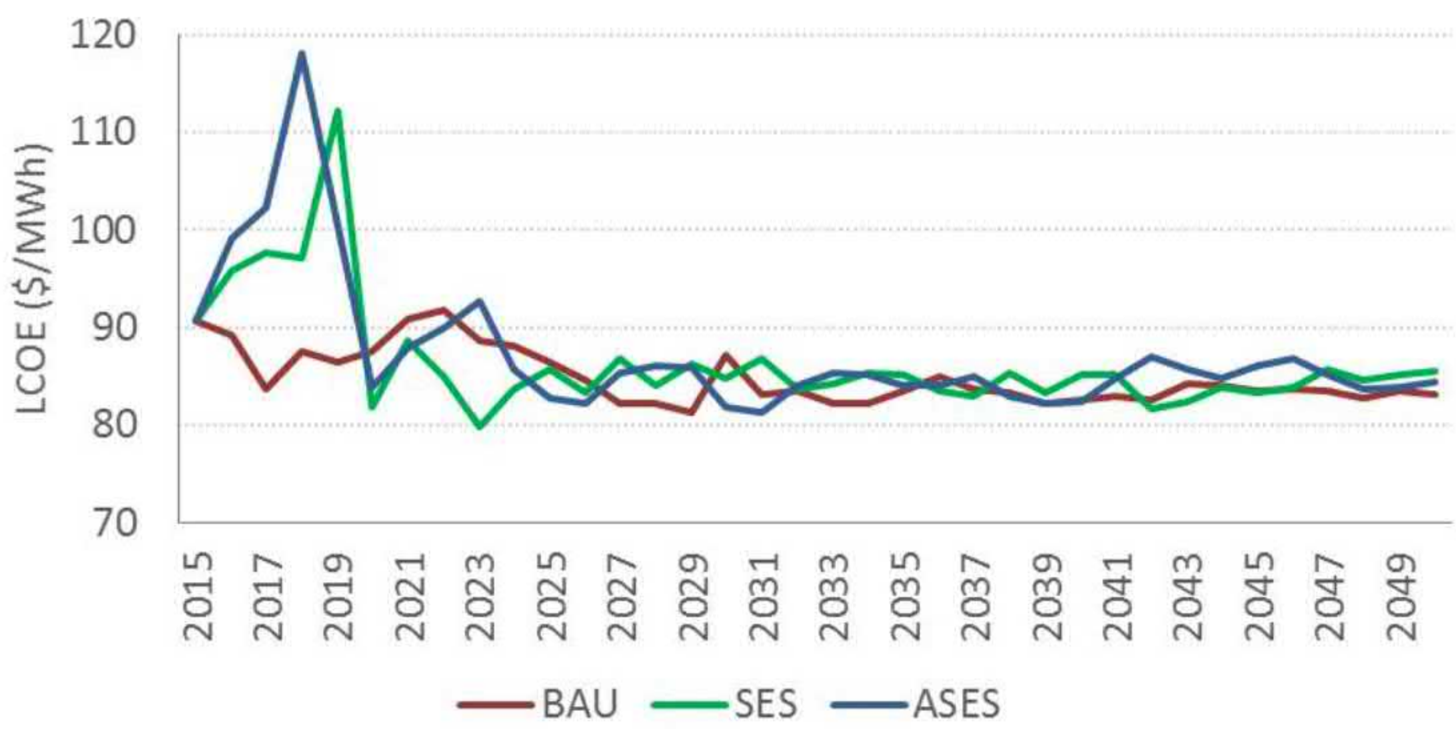
Table 16 Myanmar Generation by Fuel (SES, GWh)

Generation	2010	2015	2020	2030	2040	2050
Coal	0	0	0	0	0	0
CCS	0	0	0	0	0	0
Diesel	30	0	0	0	0	0
Fuel Oil	0	0	0	0	0	0
Gas	1,678	5,233	6,502	6,174	2,923	0
Nuclear	0	0	0	0	0	0
Hydro	5,263	8,099	15,308	23,125	20,402	23,362
Onshore Wind	0	0	2,435	10,980	22,981	27,800
Offshore Wind	0	0	0	0	0	0
Biomass	0	0	1,441	8,445	22,522	27,187
Biogas	0	0	0	0	0	0
Solar	0	0	3,836	17,501	38,141	53,640
CSP	0	0	0	3,381	10,525	21,085
Battery	0	0	0	0	0	0
Hydro ROR	0	0	0	4,415	5,925	7,358
Geothermal	0	0	0	333	1,651	2,304
Pump Storage	0	0	0	0	0	317
Ocean	0	0	0	0	132	526
Off-grid	0	2	112	1,268	725	716

Source: IES and MKE 2017

The levelized cost of electricity remains at a similar level

Figure 88 Myanmar LCOE for Generation



Source: IES and MKE 2017

Conclusions

- Myanmar can shift to 100% RE without higher costs
- Myanmar will benefit by higher jobs and less pollution
- International climate money can pave the way
- A 100% RE strategy will help mitigate global climate change
- A 100% RE strategy can avoid substantial future payments for CO_2 emission charges
- We know how to do it and how to get the funding and financing
- 100% RE power supply may be an interesting option for Myanmar

Thank you very much for your attention

Thank you very much for your attention