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Courses content

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1 EU Energy Policy

1.1 Introduction to EU Energy Policy

1.1.1 History and Development of EU Energy Policy

Introduction

The European Union (EU) has a comprehensive energy policy designed to ensure a secure, sustainable, competitive, and affordable energy supply. This policy has evolved significantly over the years, adapting to new challenges and priorities such as climate change, energy security, and market integration.

Early Beginnings

- **1951: The European Coal and Steel Community (ECSC)**
 - The ECSC was established by the Treaty of Paris, laying the groundwork for a common energy policy by managing coal and steel production, crucial resources at the time.
- **1957: The European Atomic Energy Community (Euratom)**
 - Established by the Treaty of Rome, Euratom aimed to create a specialized market for nuclear power in Europe, ensuring energy security and reducing dependency on imported fuels.

1970s: The Oil Crisis and Initial Steps towards Energy Policy

- **1973: The First Oil Crisis**
 - The oil crisis highlighted Europe's vulnerability to external energy shocks, prompting the EU to begin developing a coordinated energy policy.
- **1974: The Creation of the International Energy Agency (IEA)**
 - Although not an EU body, the IEA's creation influenced EU energy policy, promoting energy security through coordinated measures among member states.

1980s: Moving Towards a Common Energy Market

- **1985: The White Paper on the Internal Energy Market**
 - This document laid the foundation for creating a single energy market, focusing on liberalizing and integrating national energy markets.

1990s: Liberalization and Environmental Concerns

- **1992: Maastricht Treaty**
 - The Maastricht Treaty formally recognized energy as an area of shared competence, allowing the EU to adopt measures related to energy policy.
- **1996: First Energy Package**
 - Aimed at liberalizing the electricity market, introducing competition, and reducing prices for consumers.
- **1998: Second Energy Package**
 - Extended liberalization to the gas market, further promoting competition and integration.

2000s: Security of Supply and Climate Change

- **2006: Green Paper on a European Strategy for Sustainable, Competitive, and Secure Energy**
 - Addressed concerns about energy supply security, sustainability, and competitiveness, proposing a common approach to energy policy.
- **2007: Third Energy Package**
 - Focused on completing the internal energy market and ensuring non-discriminatory access to networks, enhancing market transparency and consumer protection.
- **2009: The Lisbon Treaty**
 - Reinforced EU energy policy objectives, emphasizing sustainability, security of supply, and market integration.

2010s: Energy Union and Decarbonization

- **2010: Europe 2020 Strategy**
 - Set targets for reducing greenhouse gas emissions, increasing renewable energy use, and improving energy efficiency.
- **2015: Energy Union Framework**
 - Aimed to provide secure, sustainable, competitive, and affordable energy, focusing on five dimensions: energy security, a fully integrated internal energy market, energy efficiency, decarbonizing the economy, and research and innovation.
- **2018: Clean Energy for All Europeans Package**
 - Included revised directives on renewable energy, energy efficiency, and the governance of the Energy Union, aiming to lead the global clean energy transition.

2020s: Accelerating the Energy Transition

- **2021: European Green Deal**
 - A comprehensive plan to make the EU climate-neutral by 2050, proposing significant investments in green technologies and infrastructure.
- **2022: REPowerEU Plan**
 - Introduced in response to the energy crisis exacerbated by geopolitical tensions, focusing on reducing dependency on fossil fuels, particularly from Russia, and accelerating the transition to renewable energy sources.

Conclusion

The development of EU energy policy reflects a dynamic response to evolving challenges and priorities. From its early focus on coal and nuclear energy to the current emphasis on sustainability and decarbonization, the EU's energy policy has continually adapted to ensure a secure, sustainable, and competitive energy future for its member states.

1.1.2 Fundamental Principles of EU Energy Policy

Introduction

The European Union (EU) energy policy is built upon four fundamental principles: decarbonisation, competitiveness, security of supply, and sustainability. These principles guide the EU's approach to ensuring a secure, affordable, and environmentally responsible energy system.

1. Decarbonisation

Definition: Decarbonisation refers to the reduction of carbon dioxide (CO₂) emissions through the transition from fossil fuels to low-carbon and renewable energy sources.

Key Components:

- **Renewable Energy:** Promoting the use of renewable energy sources such as wind, solar, hydro, and biomass
- **Energy Efficiency:** Implementing measures to reduce energy consumption and improve energy efficiency in various sectors
- **Carbon Pricing:** Introducing mechanisms like the EU Emissions Trading System (ETS) to put a price on carbon emissions and incentivize reductions
- **Innovation and Technology:** Investing in research and development of new technologies that facilitate decarbonisation.

EU Initiatives:

- **European Green Deal:** Aims to make the EU climate-neutral by 2050.
- **Fit for 55 Package:** Targets a 55% reduction in greenhouse gas emissions by 2030 compared to 1990 levels.

Impact:

- Reduction of greenhouse gas emissions
- Mitigation of climate change
- Promotion of a cleaner and healthier environment.

2. Competitiveness

Definition: Competitiveness in energy policy refers to creating a market environment where energy prices are affordable and fair, fostering innovation, and ensuring economic growth.

Key Components:

- **Market Liberalization:** Deregulating energy markets to promote competition and lower prices
- **Infrastructure Development:** Investing in modern and efficient energy infrastructure to reduce costs and improve efficiency
- **Energy Innovation:** Encouraging technological advancements and new business models in the energy sector
- **Consumer Choice:** Empowering consumers with more options and control over their energy sources and usage.

EU Initiatives:

- **Third Energy Package:** Aimed at creating a single, competitive internal energy market

- **Clean Energy for All Europeans Package:** Focuses on providing secure, competitive, and sustainable energy.

Impact:

- Lower energy prices for consumers and businesses
- Increased investment and innovation in the energy sector
- Enhanced economic growth and job creation.

3. Security of Supply

Definition: Security of supply ensures that there is a reliable and uninterrupted supply of energy to meet the demands of the EU's population and economy.

Key Components:

- **Diversification of Energy Sources:** Reducing dependence on a single energy source or supplier by diversifying the energy mix
- **Strategic Reserves:** Maintaining reserves of essential energy resources to mitigate the impact of supply disruptions
- **Infrastructure Resilience:** Strengthening and modernizing energy infrastructure to withstand and recover from disruptions
- **International Cooperation:** Collaborating with other countries and regions to ensure a stable and secure energy supply.

EU Initiatives:

- **Energy Security Strategy:** Focuses on diversification, infrastructure, and crisis response mechanisms
- **REPowerEU Plan:** Reduces dependency on Russian fossil fuels and accelerates the transition to renewable energy.

Impact:

- Reduced vulnerability to energy supply disruptions
- Enhanced energy security and reliability
- Greater geopolitical stability.

4. Sustainability

Definition: Sustainability in energy policy ensures that energy production and consumption do not compromise the ability of future generations to meet their needs, integrating environmental, economic, and social dimensions.

Key Components:

- **Environmental Protection:** Minimizing the environmental impact of energy production and consumption
- **Social Equity:** Ensuring that all segments of society have access to affordable and clean energy
- **Economic Viability:** Balancing economic growth with sustainable practices and resource management
- **Resource Efficiency:** Promoting the efficient use of natural resources to reduce waste and environmental degradation.

EU Initiatives:

- **Sustainable Development Goals (SDGs):** Aligning energy policy with global sustainability targets
- **Circular Economy Action Plan:** Encourages the recycling and reuse of materials, including in the energy sector.

Impact:

- Long-term environmental health and resource availability
- Equitable access to energy for all citizens
- Sustainable economic growth and development.

Conclusion

The principles of decarbonisation, competitiveness, security of supply, and sustainability form the cornerstone of the EU's energy policy. Together, they aim to create an energy system that is environmentally friendly, economically viable, secure, and equitable. By adhering to these principles, the EU strives to meet its current energy needs while safeguarding the interests of future generations.

1.2 Legal Basis of EU Energy Policy

Introduction

The Treaty on the Functioning of the European Union (TFEU) provides the legal basis for the EU's energy policy. Key articles within the TFEU outline the principles and objectives of this policy, granting the EU specific competences in the energy sector.

The European Union (EU) has implemented several directives to promote renewable energy and improve energy efficiency. Two key directives in this context are Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources and Directive (EU) 2018/2002 on energy efficiency. These directives are essential components of the EU's strategy to achieve its energy and climate goals.

The Treaty on the Functioning of the European Union (TFEU)**Article 194 TFEU: Energy****Key Provisions:****1. Objectives:**

- Ensure the functioning of the energy market
- Ensure the security of energy supply in the Union
- Promote energy efficiency and energy saving and the development of new and renewable forms of energy
- Promote the interconnection of energy networks.

2. Scope:

- The EU can establish measures necessary to achieve these objectives, while respecting the right of member states to determine their energy sources and the general structure of their energy supply.

Implications:

- Provides a framework for developing a common energy policy
- Balances EU-wide objectives with national sovereignty over energy resources.

Article 122 TFEU: Security of Supply

Key Provisions:

1. Solidarity Clause:

- In cases of severe difficulties in the supply of certain products, notably in the area of energy, the Council, on a proposal from the Commission, may decide upon measures appropriate to the economic situation.

2. Crisis Management:

- Establishes a legal basis for the EU to act collectively in response to emergencies affecting energy supply.

Implications:

- Enables the EU to implement measures to ensure energy security during crises
- Promotes solidarity among member states in addressing supply disruptions.

Articles 170-172 TFEU: Trans-European Networks (TENs)

Key Provisions:

1. Article 170:

- Objectives: Establish and develop trans-European networks in the areas of transport, telecommunications, and energy infrastructures
- Aim: Promote the interconnection and interoperability of national networks and access to such networks.

2. Article 171:

- Implementation: The EU shall support projects of common interest supported by member states
- Guidelines: The EU may establish guidelines for these projects, identifying objectives, priorities, and broad lines of measures
- Financial Assistance: The EU may support these projects financially.

3. Article 172:

- Cooperation with Third Countries: Projects of common interest may also involve third countries to ensure the integration and interoperability of networks.

Implications:

- Facilitates the development of cross-border energy infrastructure
- Supports the integration of national energy markets into a single European energy market
- Encourages cooperation with non-EU countries on energy projects.

Practical Applications

1. Energy Market Integration:

- Article 194 enables the creation of an integrated EU energy market, promoting competition and efficiency.

2. Crisis Response:

- Article 122 allows the EU to take collective action during energy crises, ensuring stability and security of supply.

3. Infrastructure Development:

- Articles 170-172 support the development of trans-European energy networks, enhancing connectivity and resilience.

Directive (EU) 2018/2001 on the Promotion of the Use of Energy from Renewable Sources

Overview:

- **Objective:** To establish a common framework for the promotion of energy from renewable sources, aiming to ensure that renewable energy makes up at least 32% of the EU's total energy consumption by 2030.
- **Key Provisions:**
- **National Targets:**
 1. Member states are required to set national targets for the share of renewable energy in their overall energy mix
 2. These targets contribute to the collective EU goal.
- **Sectoral Integration:**
 1. Specific targets for renewable energy usage in heating and cooling, electricity, and transport sectors
 2. Encouragement of sector coupling and the use of renewable energy across different sectors.
- **Support Schemes:**
 1. Member states can implement support schemes to promote renewable energy production and consumption
 2. Guidelines for designing support schemes to ensure market integration and minimize distortions.
- **Simplified Administrative Procedures:**
 1. Streamlining administrative processes for renewable energy projects to reduce bureaucratic barriers
 2. Simplified procedures for small-scale projects and self-consumption installations.
- **Guarantees of Origin:**
 1. System of guarantees of origin for renewable energy to certify and trace the origin of renewable electricity, heating, and cooling.
- **Sustainability Criteria:**
 1. Sustainability and greenhouse gas emission savings criteria for biofuels, bioliquids, and biomass fuels.

Analysis:

- **Impact on Renewable Energy Growth:**
 - Directive (EU) 2018/2001 has significantly contributed to the increase in renewable energy capacity across the EU
 - National targets and support schemes have incentivized investments in renewable energy projects.
- **Sectoral Challenges:**
 - While the electricity sector has seen substantial growth in renewable energy, the heating and cooling and transport sectors face challenges in meeting their specific targets
 - Integration of renewable energy into these sectors requires further innovation and infrastructure development.
- **Administrative Efficiency:**

- Simplified administrative procedures have reduced delays and costs associated with renewable energy projects, particularly benefiting small-scale producers.
- **Market Integration:**
 - The directive promotes market-based support schemes, encouraging the integration of renewable energy into the competitive market framework.
 - Ensures that renewable energy producers can compete on a level playing field.

Directive (EU) 2018/2002 on Energy Efficiency

Objective: To establish measures to promote energy efficiency within the EU, aiming for a 32.5% improvement in energy efficiency by 2030.

Key Provisions:

- **Energy Efficiency Targets:**
 1. Member states are required to set indicative national energy efficiency targets
 2. Collective EU target of a 32.5% improvement in energy efficiency by 2030.
- **Energy Savings Obligations:**
 1. Member states must achieve cumulative end-use energy savings equivalent to new annual savings of 0.8% of final energy consumption over the period 2021-2030.
- **Energy Audits and Management Systems:**
 1. Large enterprises must conduct energy audits every four years
 2. Promotion of energy management systems and the adoption of energy-saving measures.
- **Metering and Billing:**
 1. Requirements for accurate and frequent metering and billing information for consumers.
 2. Enhanced transparency and consumer empowerment to manage energy consumption.
- **Public Sector Role:**
 1. Public bodies are required to lead by example by adopting energy efficiency measures in buildings, equipment, and transport.
 2. Encouragement of public procurement practices that prioritize energy efficiency.
- **Renovation of Buildings:**
 1. Promotion of deep renovations of existing buildings to improve energy performance.
 2. Long-term renovation strategies to decarbonize the building stock by 2050.

Analysis:

- **Impact on Energy Efficiency:**
 - Directive (EU) 2018/2002 has driven significant improvements in energy efficiency across the EU.
 - Energy savings obligations and national targets have encouraged member states to implement effective energy efficiency measures.
- **Challenges in Implementation:**
 - Achieving the cumulative energy savings target requires sustained efforts and investment, particularly in sectors with high energy consumption.

- Compliance and enforcement of energy audits and management systems remain challenging for some member states.
- **Consumer Engagement:**
 - Improved metering and billing practices have empowered consumers to better manage their energy use and reduce consumption.
 - Transparency and regular information updates are key to maintaining consumer engagement and participation.
- **Role of the Public Sector:**
 - Public sector initiatives have set a positive example, driving energy efficiency improvements in public buildings and infrastructure.
 - Public procurement practices that prioritize energy efficiency have created a market for energy-efficient products and services.

Conclusion

The relevant articles of the TFEU provide a robust legal foundation for the EU's energy policy. Article 194 outlines the primary objectives, Article 122 ensures security of supply, and Articles 170-172 facilitate the development of essential infrastructure. Together, these articles enable the EU to pursue a cohesive and comprehensive energy strategy that balances market integration, security, and sustainability.

Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources and Directive (EU) 2018/2002 on energy efficiency are critical components of the EU's strategy to achieve its energy and climate goals. These directives provide a comprehensive framework for increasing the share of renewable energy and improving energy efficiency, contributing to the overall sustainability and resilience of the EU's energy system.

1.3 Objectives and goals of EU Energy policy

1.3.1 Main Objectives of the Energy Union

Introduction

The Energy Union is a strategic initiative launched by the European Union (EU) in 2015 to ensure that Europe has secure, affordable, and sustainable energy. It aims to transform the EU's energy system, addressing major challenges such as energy security, climate change, and market integration. The Energy Union strategy is built around five key dimensions, each with specific objectives to achieve the overall goals.

Five Key Objectives of the Energy Union

1. Energy Security, Solidarity, and Trust

Objective: To enhance the security and resilience of the EU's energy system by diversifying energy sources, suppliers, and routes.

Key Actions:

- **Diversification:** Reduce dependency on a single energy supplier by increasing imports from various countries and regions.
- **Infrastructure:** Develop and modernize energy infrastructure, including cross-border interconnections.
- **Crisis Preparedness:** Improve emergency response mechanisms and mutual assistance between member states.

- **Supply Agreements:** Promote transparency and consistency in intergovernmental energy supply agreements.

Impact:

- Improved resilience against supply disruptions.
- Enhanced energy security and solidarity among member states.

2. A Fully Integrated Internal Energy Market

Objective: To create a single, competitive, and integrated energy market that allows the free flow of energy across the EU.

Key Actions:

- **Market Integration:** Remove technical and regulatory barriers to the free movement of energy.
- **Network Codes:** Implement common rules and standards for energy networks.
- **Consumer Empowerment:** Ensure consumers have access to affordable and reliable energy and can benefit from competitive markets.
- **Retail Markets:** Improve transparency and fairness in retail energy markets.

Impact:

- Increased competition, leading to lower prices and better services for consumers.
- Enhanced market efficiency and investment signals.

3. Energy Efficiency Contributing to Moderation of Demand

Objective: To reduce energy consumption through improved energy efficiency, thereby reducing demand and greenhouse gas emissions.

Key Actions:

- **Energy Efficiency Targets:** Set binding energy efficiency targets for member states.
- **Building Renovation:** Promote the renovation of buildings to improve energy performance.
- **Product Standards:** Enhance energy efficiency standards for appliances and industrial equipment.
- **Energy Audits:** Encourage energy audits and energy management systems in businesses and public institutions.

Impact:

- Lower energy consumption and costs for households and businesses.
- Reduced greenhouse gas emissions and environmental impact.

4. Decarbonising the Economy

Objective:

- To transition to a low-carbon economy by reducing greenhouse gas emissions and increasing the use of renewable energy.

Key Actions:

- **Renewable Energy Targets:** Increase the share of renewable energy in the EU's energy mix.
- **Emissions Trading System (ETS):** Strengthen the EU ETS to provide effective carbon pricing.
- **Research and Innovation:** Invest in research and development of low-carbon technologies.
- **Climate Policies:** Align energy policy with climate goals, including the Paris Agreement commitments.

Impact:

- Significant reduction in greenhouse gas emissions.
- Increased deployment and innovation in renewable energy technologies.

5. Research, Innovation, and Competitiveness**Objective:**

- To foster innovation and maintain the EU's global leadership in clean energy technologies.

Key Actions:

- **Horizon 2020:** Utilize the Horizon 2020 program to fund energy research and innovation.
-
- **Strategic Energy Technology (SET) Plan:** Implement the SET Plan to accelerate the development and deployment of low-carbon technologies.
- **Industrial Leadership:** Support the competitiveness of EU industries in the global clean energy market.
- **Collaboration:** Promote international cooperation in energy research and innovation.

Impact:

- Enhanced global competitiveness of EU clean energy technologies.
- Accelerated innovation and commercialization of low-carbon solutions.

Conclusion

The Energy Union's objectives are designed to ensure that the EU has a secure, sustainable, and competitive energy system. By focusing on energy security, market integration, energy efficiency, decarbonisation, and innovation, the Energy Union aims to address the key challenges facing Europe's energy sector and pave the way for a more resilient and climate-friendly future.

Key Points to Remember

- **Energy Security, Solidarity, and Trust** - Enhance energy security through diversification and crisis preparedness.
- **A Fully Integrated Internal Energy Market** - Create a competitive and integrated energy market across the EU.
- **Energy Efficiency Contributing to Moderation of Demand** - Improve energy efficiency to reduce consumption and emissions.



- **Decarbonising the Economy** - Transition to a low-carbon economy with increased renewable energy use.
- **Research, Innovation, and Competitiveness** - Foster innovation and maintain leadership in clean energy technologies.

1.3.2 Current Goals for 2030

Introduction

The European Union (EU) has set ambitious goals for 2030 to address climate change, enhance energy security, and promote sustainable growth. These goals include a significant increase in the share of renewable energy and a reduction in energy consumption. These targets are part of the broader European Green Deal, which aims to make Europe the first climate-neutral continent by 2050.

1. Increase in the Share of Renewable Energy

Objective:

- To increase the share of renewable energy in the EU's total energy consumption to at least 42.5% by 2030, with an aim to achieve 45%.

Key Components:

1. **Renewable Energy Directive (RED II):**
 - Sets binding targets for renewable energy use in the EU.
 - Requires member states to develop national renewable energy action plans.
2. **Sectoral Targets:**
 - **Electricity:** Increase the share of renewables in electricity generation.
 - **Heating and Cooling:** Promote the use of renewable energy in heating and cooling systems.
 - **Transport:** Increase the share of renewable energy in the transport sector, including advanced biofuels and renewable electricity.
3. **Support Mechanisms:**
 - **Financial Incentives:** Provide subsidies, tax breaks, and grants for renewable energy projects.
 - **Market-Based Mechanisms:** Implement auctions and feed-in tariffs to support renewable energy deployment.
4. **Research and Innovation:**
 - Invest in research and development to improve renewable energy technologies and reduce costs.

Impact:

- **Environmental Benefits:** Reduction in greenhouse gas emissions and pollution.
- **Energy Security:** Diversification of energy sources, reducing dependency on fossil fuels.
- **Economic Growth:** Creation of jobs and growth in the renewable energy sector.

Challenges:

- **Infrastructure:** Upgrading and expanding energy infrastructure to accommodate increased renewable energy.
- **Regulatory Barriers:** Ensuring streamlined and efficient permitting processes for renewable energy projects.

2. Reduction in Energy Consumption

Objective:

- To achieve a 36-39% improvement in energy efficiency by 2030, reducing primary and final energy consumption.

Key Components:

1. **Energy Efficiency Directive (EED):**
 - Sets binding energy efficiency targets for member states.
 - Requires national energy efficiency action plans and regular progress reports.
2. **Energy Savings Obligations:**
 - Member states must achieve annual energy savings of 0.8% of final energy consumption.
3. **Building Renovation:**
 - **Renovation Wave:** Initiative to renovate buildings for improved energy performance.
 - **Minimum Energy Performance Standards:** Implement standards for new and existing buildings.
4. **Industry and Appliances:**
 - **Energy Audits:** Mandatory energy audits for large enterprises.
 - **Efficiency Standards:** Implement energy efficiency standards for appliances and industrial equipment.
5. **Consumer Engagement:**
 - **Smart Metering:** Rollout of smart meters to help consumers manage their energy use.
 - **Information Campaigns:** Educate consumers about energy-saving practices.

Impact:

- **Cost Savings:** Lower energy bills for households and businesses.
- **Reduced Emissions:** Decreased greenhouse gas emissions through reduced energy consumption.
- **Energy Security:** Lower dependency on energy imports.

Challenges:

- **Investment Needs:** Significant investment required for building renovations and energy-efficient technologies.
- **Behavioral Change:** Encouraging consumers and businesses to adopt energy-efficient practices.

Conclusion

The EU's goals for 2030 to increase the share of renewable energy and reduce energy consumption are critical steps towards achieving a sustainable and climate-neutral future. These targets will help the EU reduce its carbon footprint, enhance energy security, and drive economic growth in the green energy sector.

1.4 Instruments of EU Energy Policy (REPowerEU Plan and Fit for 55 Package)

Introduction

The European Union (EU) has implemented two significant strategies to address energy security and climate change: the REPowerEU plan and the Fit for 55 package. These initiatives are central to the EU's efforts to transition to a sustainable energy system and achieve its climate goals.

REPowerEU Plan

Overview:

- **Objective:** To reduce the EU's dependency on Russian fossil fuels and accelerate the transition to renewable energy sources in response to geopolitical tensions and energy supply vulnerabilities.

Key Components:

1. **Diversification of Energy Supplies:**
 - **LNG and Pipeline Imports:** Increase imports of liquefied natural gas (LNG) and diversify pipeline sources from non-Russian suppliers.
 - **International Partnerships:** Strengthen energy partnerships with reliable suppliers.
2. **Boosting Renewable Energy:**
 - **Solar and Wind Energy:** Accelerate the deployment of solar and wind energy projects.
 - **Renewable Hydrogen:** Promote the production and use of renewable hydrogen as a clean energy carrier.
3. **Energy Efficiency:**
 - **Building Renovation:** Enhance energy efficiency in buildings through renovation and retrofitting.
 - **Industrial Efficiency:** Improve energy efficiency in industrial processes and manufacturing.
4. **Infrastructure and Storage:**
 - **Energy Infrastructure:** Develop and modernize energy infrastructure to support the integration of renewable energy.
 - **Energy Storage:** Invest in energy storage solutions to balance supply and demand.
5. **Regulatory Measures:**
 - **Permitting Procedures:** Streamline and expedite permitting procedures for renewable energy projects.
 - **Market Design:** Adapt market design to facilitate the integration of renewable energy.

Impact:

- **Energy Security:** Enhances the EU's energy security by reducing reliance on Russian fossil fuels.
- **Climate Goals:** Supports the EU's climate goals by accelerating the adoption of renewable energy and energy efficiency measures.

Challenges:

- **Implementation:** Ensuring timely and effective implementation of infrastructure projects and regulatory measures.
- **Investment:** Securing sufficient investment and funding for large-scale renewable energy and efficiency projects.

Fit for 55 Package**Overview:**

- **Objective:** To align EU policies with the European Green Deal's target of reducing greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels.

Key Components:**1. Carbon Pricing:**

- **EU Emissions Trading System (ETS):** Strengthening and expanding the ETS to cover more sectors and reduce the number of allowances.
- **Carbon Border Adjustment Mechanism (CBAM):** Introducing a CBAM to prevent carbon leakage and ensure a level playing field for EU industries.

2. Renewable Energy:

- **Renewable Energy Directive:** Revising the directive to increase the share of renewable energy in the EU's energy mix to at least 40% by 2030.
- **Sectoral Targets:** Setting specific targets for renewable energy use in sectors such as transport, heating, and cooling.

3. Energy Efficiency:

- **Energy Efficiency Directive:** Strengthening the directive to achieve a 36-39% improvement in energy efficiency by 2030.
- **Renovation Wave:** Promoting large-scale renovations to improve the energy performance of buildings.

4. Transport:

- **CO2 Standards for Vehicles:** Tightening CO2 emission standards for cars and vans to accelerate the transition to zero-emission vehicles.
- **Alternative Fuels Infrastructure:** Expanding the infrastructure for alternative fuels, including electric vehicle charging stations.

5. Land Use and Forestry:

- **Land Use, Land-Use Change, and Forestry (LULUCF):** Strengthening the LULUCF regulation to enhance carbon sequestration and reduce emissions from land use.

6. Social Climate Fund:

- **Support for Vulnerable Households:** Establishing a fund to support vulnerable households and small businesses affected by the energy transition.

Impact:

- **Emission Reductions:** Provides a comprehensive framework to achieve substantial greenhouse gas emission reductions by 2030.
- **Economic Transition:** Facilitates the transition to a green economy, promoting sustainable growth and job creation.

Challenges:

- **Policy Integration:** Ensuring coherence and integration across different policy areas and member states.

- **Social Equity:** Addressing the social and economic impacts of the transition, particularly for vulnerable groups.

Conclusion

The REPowerEU plan and Fit for 55 package are pivotal initiatives in the EU's strategy to enhance energy security and achieve its climate goals. While REPowerEU focuses on immediate energy security and diversification needs, Fit for 55 provides a long-term framework for deep decarbonisation across all sectors of the economy.

1.5 Financing of EU Green Deal

EU funding programs are set to co-finance energy efficiency investments directly and leverage additional private and public investments through specialized financial instruments and project development support. These programs also bolster research, innovation, technology development, and capacity building in both private and public sectors, addressing non-technological challenges as well.

Co-financing Investments

The Commission's 2021-2027 multi-annual financial framework and the NextGenerationEU instrument will directly fund energy efficiency projects in the EU via three funds: the Recovery and Resilience Facility, cohesion policy funds, and the Modernisation Fund.

Recovery and Resilience Facility

The Recovery and Resilience Facility (RRF) is a cornerstone of the European Union's financial response to the economic challenges posed by the COVID-19 pandemic. It is the largest component of the NextGenerationEU recovery instrument, with a total budget of €672.5 billion, of which €312.5 billion are grants and €360 billion are loans. The RRF is designed to support reforms and investments undertaken by Member States, focusing on areas that will strengthen their economies and make them more sustainable and resilient.

Funding Allocation

The RRF will allocate €184 billion specifically for energy-related measures, with €106.5 billion dedicated to energy efficiency initiatives. This significant investment is aimed at improving the energy performance of buildings, which is a crucial area given that buildings account for 40% of the EU's energy consumption and 36% of its CO₂ emissions. The focus will be on both public buildings and residential buildings, including social housing, to ensure that the benefits of energy efficiency reach a broad spectrum of society.

Objectives and Priorities

The primary objectives of the RRF in the context of energy efficiency are:

1. **Reducing Energy Consumption:** By enhancing the energy performance of buildings, the RRF aims to significantly reduce overall energy consumption.
2. **Lowering CO₂ Emissions:** Improving energy efficiency in buildings will contribute to the EU's goal of reducing greenhouse gas emissions.
3. **Creating Jobs and Economic Growth:** Investments in energy efficiency will stimulate the construction sector and related industries, creating jobs and fostering economic growth.
4. **Enhancing Energy Security:** By reducing dependence on energy imports through better energy management and efficiency, the EU will enhance its energy security.
5. **Promoting Social Equity:** Energy efficiency measures in social housing aim to reduce energy poverty and ensure that vulnerable populations benefit from lower energy costs.

Key Areas of Investment

1. **Public Buildings:** Significant funding is allocated to retrofit and renovate public buildings, including schools, hospitals, and government offices, to enhance their energy efficiency. These projects will not only reduce energy consumption and emissions but also serve as leading examples of sustainability.
2. **Residential Buildings:** Investments will focus on improving the energy efficiency of residential buildings, with a special emphasis on social housing. This includes measures such as insulation, upgrading heating and cooling systems, and installing energy-efficient windows and doors.
3. **Smart Energy Systems:** Funding will also support the integration of smart energy systems and technologies that optimize energy use in buildings. This includes smart meters, energy management systems, and renewable energy sources like solar panels.

Implementation Mechanisms

To ensure effective implementation, Member States are required to develop national recovery and resilience plans that outline their proposed reforms and investments. These plans must allocate at least 37% of their budget to climate-related projects, including energy efficiency. The European Commission assesses these plans to ensure they meet the criteria and objectives of the RRF.

Cohesion Policy Funds

Cohesion Policy Funds are a vital component of the European Union's strategy to promote economic, social, and territorial cohesion across its Member States. These funds aim to reduce disparities between regions, support economic growth, and enhance overall prosperity. For the 2021-2027 period, the Cohesion Policy Funds have a total budget of €373 billion, which will be a key source of funding for direct investments in energy efficiency.

Key Components of the Cohesion Policy Funds

1. European Regional Development Fund (ERDF)

- The ERDF aims to strengthen economic and social cohesion by correcting imbalances between regions. It supports projects that promote innovation, digitalization, economic transformation, and climate action.
- A significant portion of ERDF funding is allocated to energy efficiency projects, including the renovation of buildings and the development of sustainable urban environments.
- ERDF also supports renewable energy initiatives and the deployment of smart energy systems to optimize energy consumption.

2. European Social Fund Plus (ESF+)

- The ESF+ focuses on improving employment opportunities, enhancing social inclusion, and combating poverty.
- Within the context of energy efficiency, ESF+ supports training programs and initiatives that build the skills required for the green transition. This includes vocational training for energy-efficient construction techniques and the installation of renewable energy technologies.

3. Cohesion Fund

- The Cohesion Fund targets Member States with a Gross National Income (GNI) per capita below 90% of the EU average, helping them to invest in infrastructure and environmental projects.
- It allocates substantial resources to energy efficiency improvements, particularly in the public sector. This includes retrofitting public buildings, modernizing infrastructure, and supporting sustainable transport systems.

4. Just Transition Fund (JTF)

- The JTF is designed to support regions that are most affected by the transition towards a climate-neutral economy, particularly those dependent on fossil fuels and carbon-intensive industries.
- It provides targeted support for energy efficiency projects, helping to mitigate the socio-economic impacts of the green transition. This includes funding for retraining workers, diversifying local economies, and developing green infrastructure.

5. INTERREG

- INTERREG is a European Territorial Cooperation program that promotes cross-border, transnational, and interregional cooperation.
- It supports collaborative projects that improve energy efficiency and sustainability across borders, fostering innovation and sharing best practices between regions.

Objectives and Priorities of Cohesion Policy Funds

1. Reducing Regional Disparities

- The primary goal of the Cohesion Policy Funds is to reduce disparities between more developed and less developed regions. By investing in energy efficiency, these funds help to modernize infrastructure and promote sustainable development in lagging regions.

2. Promoting Sustainable Growth

- Investments in energy efficiency contribute to sustainable economic growth by reducing energy costs, lowering emissions, and creating jobs. Energy-efficient buildings and infrastructure are more resilient and cost-effective in the long run.

3. Enhancing Social Inclusion

- Energy efficiency projects funded by Cohesion Policy Funds aim to improve living conditions, particularly for vulnerable populations. By reducing energy poverty and lowering utility bills, these projects enhance social inclusion and quality of life.

4. Supporting Innovation and Competitiveness

- By funding research, innovation, and the deployment of advanced technologies, the Cohesion Policy Funds help regions to become more competitive. Energy efficiency is a key area where innovation can lead to significant economic and environmental benefits.

5. Fostering Climate Action

- A significant portion of the Cohesion Policy Funds is dedicated to climate action, with energy efficiency being a central component. These investments support the EU's broader climate goals, including the transition to a low-carbon economy and the achievement of climate neutrality by 2050.

Cohesion policy support for energy efficiency and building renovation

Cohesion policy funding planned for renovation and energy efficiency, by member state and building segment in €⁷



Source: Renovate Europe. (April, 2023). 2021-2027 Cohesion policy support for energy efficiency and building renovation

Modernisation Fund

The Modernisation Fund is a crucial element of the European Union's strategy to support lower-income Member States in modernizing their energy systems and improving energy efficiency. Established under the EU Emissions Trading Scheme (ETS) Directive, this fund aims to facilitate the transition towards a low-carbon economy by providing financial assistance for investments in energy infrastructure, energy efficiency, and renewable energy.

Budget and Allocation

The Modernisation Fund has a total budget of around €14 billion for the 2021-2030 period. This budget is derived from the auctioning of carbon allowances under the EU ETS. The fund specifically targets ten lower-income EU countries: Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, and Slovakia. These countries are eligible for support based on their income levels and the specific challenges they face in transitioning to a low-carbon economy.

Objectives and Priorities

1. Modernizing Energy Systems

- The primary goal of the Modernisation Fund is to modernize and upgrade energy systems in eligible countries. This includes improving the efficiency and reliability of energy infrastructure, integrating renewable energy sources, and deploying smart energy technologies.

2. Enhancing Energy Efficiency

- A significant focus of the fund is on enhancing energy efficiency across various sectors. This includes retrofitting existing buildings to improve their energy performance, upgrading industrial processes to reduce energy consumption, and supporting energy efficiency measures in transport and agriculture.

3. Supporting Renewable Energy

- The fund also prioritizes investments in renewable energy projects, such as wind, solar, biomass, and geothermal energy. These projects help to diversify the energy mix, reduce dependence on fossil fuels, and lower greenhouse gas emissions.

4. Fostering Economic Growth and Job Creation

- By investing in modern energy infrastructure and energy efficiency, the Modernisation Fund aims to stimulate economic growth and create jobs. The transition to a low-carbon economy presents significant opportunities for innovation, new business models, and employment in green industries.

Key Areas of Investment

1. Energy Infrastructure

- Investments in energy infrastructure focus on upgrading electricity grids, improving energy storage capacities, and enhancing the resilience of energy systems. This includes projects that facilitate the integration of renewable energy sources and the deployment of smart grid technologies.

2. Building Renovation

- The fund supports the renovation of residential, public, and commercial buildings to improve their energy efficiency. This includes measures such as insulation, efficient heating and cooling systems, and energy-efficient windows and doors.

3. Industrial Modernization

- Industrial projects funded by the Modernisation Fund aim to reduce energy consumption and emissions in manufacturing and production processes. This includes the adoption of energy-efficient technologies and practices, as well as the transition to low-carbon industrial processes.

4. Renewable Energy Projects

- A substantial portion of the fund is allocated to renewable energy projects, including the development of wind farms, solar power plants, and biomass facilities. These projects help to increase the share of renewable energy in the energy mix and reduce reliance on fossil fuels.

Mobilising Investment

InvestEU serves as a unified investment support mechanism with an EU budget of €26.2 billion, aiming to leverage €370 billion by consolidating existing centrally managed financial instruments and technical assistance under its Advisory Hub.

InvestEU seeks to mobilize public and private financing through loans, guarantees, equity, or other market-based instruments for strategic investments supporting EU internal policies. It is structured into four policy windows: sustainable infrastructure (€9.9 billion), research, innovation and digitization (€6.6 billion), SMEs (€6.9 billion), and social investment and skills (€2.8 billion). Energy efficiency projects will be supported mainly under sustainable infrastructure but also under the other windows.

Research and Innovation in Energy Efficiency

Horizon Europe is the European Union's flagship research and innovation program for the 2021-2027 period, with a budget of €95.5 billion. The program aims to boost scientific and technological advancements, drive economic growth, and tackle global challenges such as climate change, digital transformation, and public health. One of the key areas of focus for Horizon Europe is energy efficiency, which is crucial for achieving the EU's climate neutrality goals by 2050.

Key Features of Horizon Europe

1. Funding and Budget Allocation

- Horizon Europe has a substantial budget of €95.5 billion, making it the largest research and innovation funding program in the world. This budget is allocated across various thematic clusters, with significant funding dedicated to energy efficiency and climate action.

2. Strategic Objectives

- Horizon Europe aims to strengthen the EU's scientific and technological base, boost its innovation capacity, and deliver solutions to global challenges. The program supports research and innovation projects that contribute to the EU's policy priorities, including the European Green Deal, digital transformation, and health resilience.

Focus on Energy Efficiency

Energy efficiency is a central theme within Horizon Europe, with several initiatives and funding streams dedicated to improving energy use across different sectors. The program supports projects that develop innovative technologies, enhance energy efficiency in buildings and industry, and promote sustainable urban development.

1. Cluster 5: Climate, Energy, and Mobility

- Cluster 5 of Horizon Europe focuses on climate, energy, and mobility, with a significant emphasis on energy efficiency. The cluster aims to accelerate the transition to a sustainable and climate-neutral economy by 2050.
- The first two years of the work program have earmarked €244 million for projects that improve energy efficiency in buildings and industry, develop sustainable urban environments, and promote clean energy technologies.

2. Built4People Partnership

- The Built4People co-programmed partnership, established in 2021, aims to drive the transition towards a sustainable and climate-resilient built environment. This partnership involves collaboration between the European Commission, industry stakeholders, and research organizations.

- The partnership focuses on developing and implementing innovative solutions for energy-efficient buildings and neighborhoods. It supports projects that enhance building performance, integrate renewable energy systems, and improve the overall sustainability of the built environment.
 - Additional details and strategic directions for this partnership are outlined in the Strategic Research & Innovation Agenda adopted in February 2022.
3. **100 Climate-Neutral and Smart Cities**
- Horizon Europe includes a mission to achieve 100 climate-neutral and smart cities by 2030. This initiative aims to showcase how cities can become more sustainable and resilient through integrated energy efficiency measures.
 - The mission supports projects that focus on building renovation, sustainable urban infrastructure, and green transportation. By promoting energy efficiency and smart city technologies, this mission aims to create replicable models for other cities across Europe and beyond.
4. **Innovation Fund**
- The Innovation Fund, one of the world's largest funding programs for low-carbon technologies, is supported by Horizon Europe. The fund focuses on demonstrating innovative solutions in energy-intensive industries, renewable energy, energy storage, and carbon capture and storage.
 - Projects funded by the Innovation Fund aim to significantly reduce greenhouse gas emissions by replacing high-energy processes with more efficient alternatives. The fund supports the commercialization of breakthrough technologies that have the potential to transform energy systems and contribute to climate goals.

Implementation Mechanisms

Horizon Europe implements its projects through various funding instruments, including grants, loans, and equity investments. These instruments are designed to support different stages of research and innovation, from fundamental research to market deployment.

1. **Research and Innovation Actions (RIA)**
 - RIA provides funding for collaborative research projects that aim to generate new knowledge and develop innovative technologies. These projects typically involve partnerships between academia, industry, and other stakeholders.
2. **Innovation Actions (IA)**
 - IA supports projects that demonstrate and validate innovative solutions in real-world settings. These projects aim to bring new technologies closer to the market and accelerate their adoption.
3. **Coordination and Support Actions (CSA)**
 - CSA funds activities that enhance cooperation and networking among research and innovation actors. These actions support the dissemination and exploitation of project results, capacity building, and policy development.
4. **European Innovation Council (EIC)**
 - The EIC is a new initiative under Horizon Europe that supports high-risk, high-impact innovation projects. It provides funding and support for startups, SMEs, and researchers to develop and scale up breakthrough technologies.

Built4People Initiated by the European Commission in 2021, the Built4People partnership aims to drive the transition towards a sustainable society and economy. Funded by Horizon Europe and partner contributions, it focuses on sustainable building and urban development,

with additional information detailed in the Strategic Research & Innovation Agenda adopted in February 2022.

100 Climate-neutral and Smart Cities This mission within Horizon Europe aims for 100 European cities to achieve climate neutrality by 2030, promoting investments in energy efficiency, building renovation, urban infrastructure, and transport.

Innovation Fund The Innovation Fund is among the world's largest funding programs for demonstrating innovative low-carbon technologies in energy-intensive industries, renewable energy, energy storage, and carbon capture and storage. It supports innovations that significantly reduce emissions by replacing high-energy processes with more efficient alternatives.

LIFE Clean Energy Transition With a budget of €1 billion for 2021-2027, the LIFE Clean Energy Transition program aims to support energy efficiency by addressing structural and organizational barriers, creating favorable frameworks, and building capacity among public and private stakeholders. It continues to fund initiatives that remove market barriers and promote best practices for energy efficiency policy implementation across the EU.

Conclusion

The Recovery and Resilience Facility represents a historic opportunity for the EU to accelerate its transition to a greener, more sustainable, and resilient economy. By prioritizing energy efficiency investments, the RRF will not only help the EU recover from the economic impacts of the COVID-19 pandemic but also lay the foundation for long-term prosperity and environmental sustainability.

Cohesion Policy Funds are essential for promoting balanced and sustainable development across the EU. By prioritizing energy efficiency investments, these funds not only help to bridge regional disparities but also contribute to the EU's climate goals, economic resilience, and social cohesion. The targeted support provided by these funds ensures that all regions, particularly those most in need, can participate in and benefit from the transition to a greener, more sustainable future.

The Modernisation Fund is an essential instrument for facilitating the transition to a low-carbon economy in lower-income EU Member States. By targeting investments in energy infrastructure, energy efficiency, and renewable energy, the fund supports these countries in overcoming the specific challenges they face in the energy transition. The financial assistance provided by the Modernisation Fund not only contributes to climate action but also promotes economic growth, job creation, and social cohesion, ensuring a just and inclusive transition for all.

Horizon Europe is a pivotal program for advancing research and innovation in energy efficiency. By supporting a wide range of projects and initiatives, it contributes to the EU's climate goals, fosters economic growth, and enhances the quality of life for citizens. The program's comprehensive approach ensures that energy efficiency remains at the forefront of the EU's efforts to achieve a sustainable and climate-neutral future.

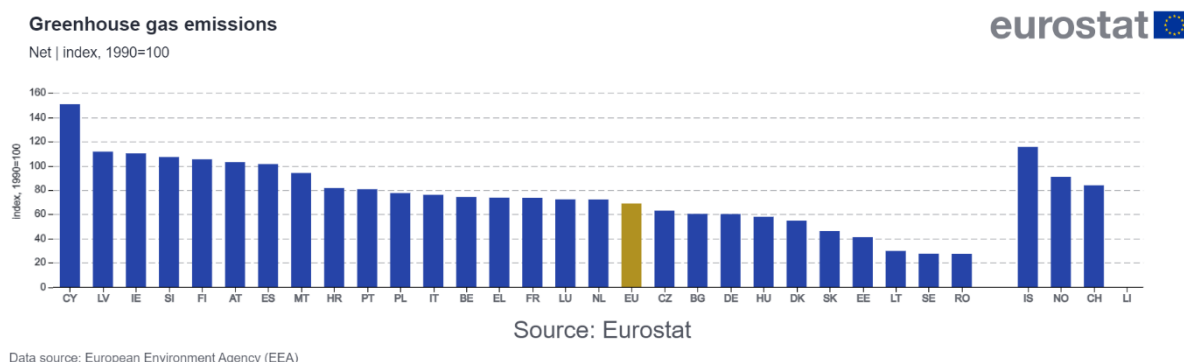
1.6 The current state of meeting the goals of the EU Green Deal energy policy - European Green Deal

Greenhouse Gas Emissions in the EU

Analysis of the Graph

Graph Overview:

- The graph shows greenhouse gas emissions indexed to 1990 levels for various EU countries.
- Index (1990=100):** Represents the change in emissions relative to 1990. An index above 100 indicates an increase in emissions since 1990, while an index below 100 indicates a decrease.



Key Observations:

- Cyprus (CY)** has the highest increase in emissions, reaching an index of about 160.
- Lithuania (LT)** shows the largest reduction in emissions, with an index well below 100.
- The EU average is highlighted, indicating overall progress in reducing emissions, though some countries lag behind.

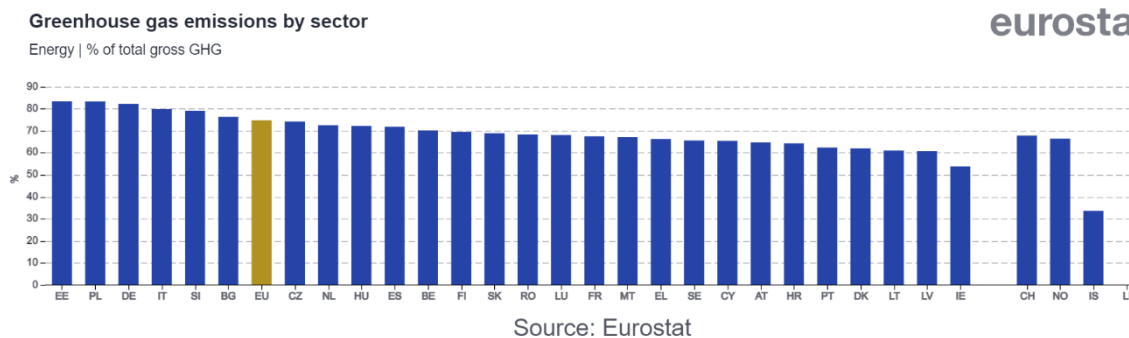
Implications for Policy:

- Countries with increasing emissions need targeted policies to accelerate reductions.
- Successful countries like Lithuania can serve as models, showcasing effective strategies for emission reductions.

Greenhouse Gas Emissions by Sector

Graph Overview

The graph shows the percentage of total greenhouse gas emissions attributed to the energy sector across various EU countries and neighbouring regions. This data is crucial for understanding the impact of the energy sector on overall emissions and identifying key areas for improvement.



Key Observations

1. High Emission Countries:

- **Estonia (EE), Poland (PL), and Germany (DE)** are among the countries with the highest percentage of greenhouse gas emissions from the energy sector, all hovering around or above 80%. This indicates a significant reliance on fossil fuels for energy production.
- These countries may face challenges in transitioning to cleaner energy sources and will need focused policies to reduce emissions.

2. EU Average:

- The EU average shows that approximately 75% of total greenhouse gas emissions are from the energy sector, highlighting the sector's critical role in the EU's overall emissions profile.

3. Lower Emission Countries:

- **Lithuania (LT), Latvia (LV), and Ireland (IE)** have lower percentages of energy-related emissions, indicating a better integration of renewable energy sources or energy efficiency measures.
- These countries can serve as models for best practices in energy transition and decarbonization.

4. Non-EU Observations:

- **Switzerland (CH) and Norway (NO)** also have significant emissions from the energy sector, but countries like **Iceland (IS)** have much lower percentages, reflecting their reliance on renewable energy such as geothermal and hydropower.

Implications for EU Energy Policy

- **Focus on Energy Transition:** Countries with high energy-related emissions need to prioritize the transition to renewable energy sources such as wind, solar, and hydropower. Investments in clean energy infrastructure and technologies will be crucial.
- **Policy Implementation:** Strong policy measures, including carbon pricing, subsidies for renewable energy, and stricter emissions regulations, are essential to drive change.
- **Cross-Country Collaboration:** Sharing best practices and technologies between countries with low emissions and those with high emissions can facilitate faster transitions across the EU.

Recommendations for Future Strategies

1. **Invest in Renewables:**
 - Increasing investment in renewable energy projects is vital. The EU should focus on expanding wind and solar capacity, especially in countries heavily reliant on fossil fuels.
2. **Enhance Energy Efficiency:**
 - Implementing energy efficiency measures across industries and residential areas can significantly reduce energy demand and emissions.
3. **Develop Infrastructure:**
 - Building and upgrading energy infrastructure, including smart grids and energy storage systems, will support the integration of renewable energy and improve grid stability.
4. **Promote Innovation:**
 - Encouraging research and development in clean energy technologies and carbon capture solutions can provide new ways to reduce emissions.
5. **Public Engagement:**
 - Raising awareness and engaging the public in energy-saving practices and renewable energy adoption will help drive societal shifts towards sustainability.

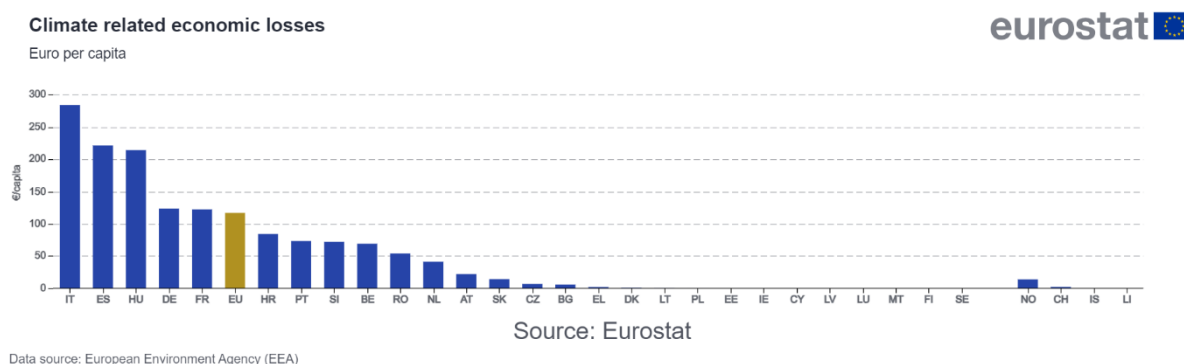
Conclusion

The EU's decarbonization efforts are critical to achieving climate neutrality by 2050. By addressing the challenges highlighted by these graphs and implementing effective strategies, the EU can significantly reduce greenhouse gas emissions and lead the global transition to a sustainable energy future.

Climate-Related Economic Losses in the EU

Graph Overview

The graph illustrates the economic losses per capita attributed to climate-related events for various countries within the EU and neighboring regions. This is measured in euros per capita, reflecting the financial impact of climate change on different populations.



Key Observations

1. **Highest Economic Losses:**
 - Italy (IT), Spain (ES), and Hungary (HU) have the highest climate-related economic losses per capita, with Italy leading at nearly €300 per person. This indicates significant vulnerability to climate impacts such as extreme weather events.
2. **EU Average:**

- The EU average shows a climate-related economic loss of approximately €100 per capita. This reflects the widespread economic impacts of climate change across member states.
- 3. **Lower Economic Losses:**
 - **Greece (EL), Denmark (DK), and Lithuania (LT)** show much lower economic losses per capita. This could be due to a variety of factors, including geographical location, climate resilience measures, and economic structure.
- 4. **Non-EU Observations:**
 - **Norway (NO) and Switzerland (CH)** have minimal economic losses compared to the EU average, possibly due to effective climate adaptation strategies and economic resilience.

Implications for EU Policy

- **Risk Assessment and Management:** Countries with high per capita losses should prioritize climate risk assessment and implement comprehensive adaptation strategies to mitigate future economic impacts.
- **Investment in Resilience:** Investments in climate resilience infrastructure and early warning systems can reduce the financial burden of climate-related disasters.
- **Regional Cooperation:** Sharing best practices and resources among EU countries can enhance collective resilience and reduce economic losses.

Recommendations for Future Strategies

1. **Enhance Climate Resilience:**
 - Implement infrastructure upgrades and land-use planning to protect against floods, heatwaves, and other climate impacts.
2. **Promote Insurance and Risk Transfer:**
 - Encourage the development of insurance products that cover climate risks, helping to distribute financial burdens more equitably.
3. **Strengthen Policy Frameworks:**
 - Develop robust policies that incorporate climate risk into economic planning and development strategies.
4. **Increase Public Awareness:**
 - Educate citizens about climate risks and resilience measures to foster community-led adaptation efforts.

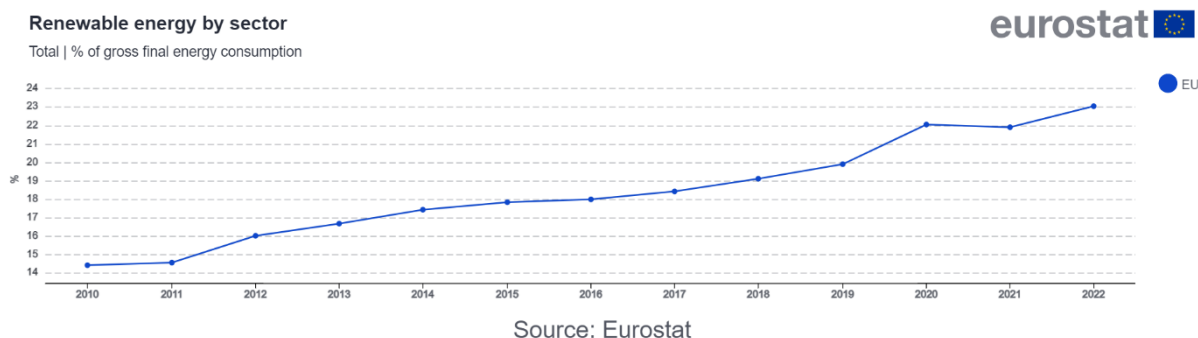
Conclusion

The graph highlights significant disparities in climate-related economic losses across Europe, emphasizing the need for targeted policies and investments to enhance climate resilience. By addressing these challenges, the EU can better protect its economies and populations from the growing impacts of climate change.

Renewable Energy by Sector in the EU

Graph Overview

The graph illustrates the percentage of renewable energy in the EU's gross final energy consumption from 2010 to 2022. It highlights the progress made in increasing the share of renewables within the EU's energy mix.



Key Observations

1. Steady Increase in Renewables:

- The share of renewable energy has grown consistently from approximately 14% in 2010 to about 23% in 2022. This indicates a strong commitment to transitioning to cleaner energy sources.

2. Growth Trends:

- The increase from 2010 to 2022 demonstrates a steady upward trend, with noticeable accelerations after 2019. This reflects the impact of EU policies promoting renewable energy and technological advancements in this sector.

3. Stagnation and Challenges:

- While there is steady growth, the pace of increase between certain years (e.g., 2016-2018) appears slower, highlighting potential challenges in scaling up renewable deployment rapidly.

Implications for EU Energy Policy

- **Policy Effectiveness:** The growth in renewable energy share underscores the effectiveness of EU directives such as the Renewable Energy Directive and the European Green Deal in encouraging investment and deployment of renewables.
- **Investment in Infrastructure:** Continued investment in renewable energy infrastructure, such as wind farms, solar panels, and energy storage systems, is crucial for maintaining this growth trajectory.
- **Technology Innovation:** Advances in renewable technologies, including improved efficiency and cost reductions, have played a significant role in facilitating this increase.
- **Regulatory Support:** The role of supportive regulatory frameworks cannot be understated, as they provide stability and incentives for investment in renewable energy.

Recommendations for Future Strategies

1. Accelerate Renewable Adoption:

- Implement measures to further accelerate the adoption of renewable energy technologies, especially in sectors lagging behind, such as transportation and heating.

2. Enhance Grid Integration:

- Invest in smart grid technologies and energy storage solutions to enhance the integration of renewables into the energy system and improve grid stability.

3. Foster Research and Development:

- Encourage research and development to drive innovation in renewable technologies, making them more efficient and cost-effective.

4. Supportive Policies:

- Maintain and expand supportive policies and incentives for renewable energy projects to ensure sustained growth and achievement of climate targets.

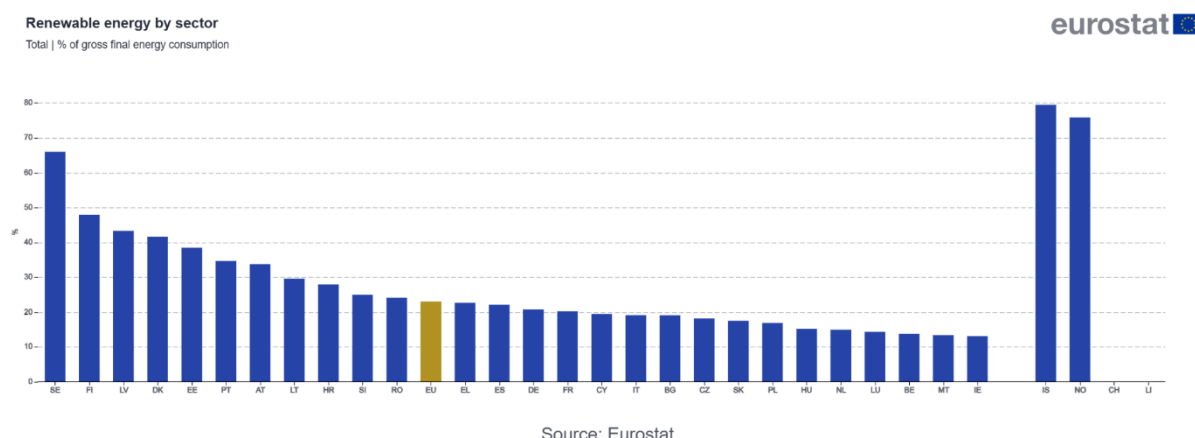
5. Public Engagement:

- Increase public awareness and engagement in renewable energy initiatives to foster community support and participation in the transition.

Conclusion

The increasing share of renewable energy in the EU's gross final energy consumption reflects significant progress towards climate goals and highlights the success of policy measures. To achieve further advancements, continued focus on infrastructure, technology, and policy support is essential. The EU can build on this momentum to meet its ambitious climate targets and lead the global transition to a sustainable energy future.

This graph depicts the share of renewable energy as a percentage of gross final energy consumption across various EU countries. It shows how different countries are progressing in integrating renewable energy into their energy mix.



Key Observations

1. Top Performers:

- **Sweden (SE)** leads the EU with over 60% of its energy coming from renewable sources, followed by **Finland (FI)** and **Latvia (LV)**, all above 40%.

2. EU Average:

- The EU average sits at around 22%, reflecting the collective progress towards the EU's renewable energy goals.

3. Lower Percentages:

- Countries like **Belgium (BE)**, **Ireland (IE)**, and **Malta (MT)** have the lowest shares of renewable energy, indicating a need for accelerated renewable energy deployment.

4. Non-EU Observations:

- **Iceland (IS)** and **Norway (NO)** stand out with exceptionally high shares, well above 70%, due to their extensive use of hydropower and geothermal energy.

Implications for EU Policy

- **Leadership in Renewables:** Countries like Sweden and Finland serve as models for integrating renewable energy, particularly through hydropower and bioenergy.
- **Challenges for Low-Performers:** Countries with lower shares must enhance their policies, investments, and infrastructure to meet EU renewable energy targets.

- **Non-EU Contributions:** Iceland and Norway demonstrate how geography and natural resources play a significant role in renewable energy success, serving as examples for strategic resource utilization.

Recommendations for Future Strategies

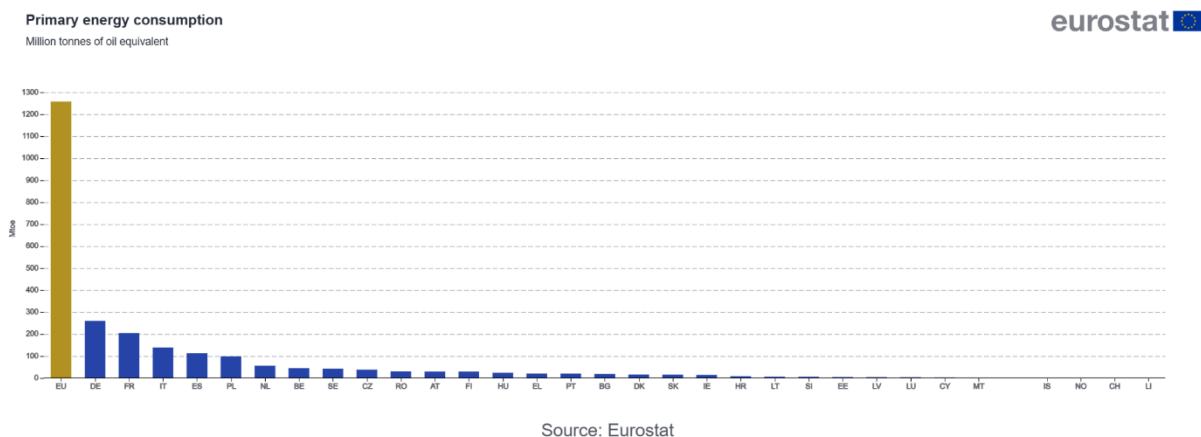
1. **Accelerate Renewable Integration:**
 - Enhance financial incentives and remove regulatory barriers to expedite renewable energy adoption in countries with low shares.
2. **Regional Cooperation:**
 - Foster partnerships between high and low performers to share best practices and technologies.
3. **Invest in Diverse Technologies:**
 - Encourage investment in diverse renewable technologies such as wind, solar, and biomass to complement hydropower and boost energy resilience.
4. **Public Engagement and Awareness:**
 - Educate the public about the benefits of renewable energy to foster community-driven renewable projects.

Conclusion

The progress shown in this graph highlights the EU's ongoing efforts to transition to renewable energy but underscores the disparities between member states. To meet future climate targets, the EU must continue supporting lagging countries while strengthening its leadership in renewables globally.

Primary Energy Consumption in the EU

The graph displays the primary energy consumption in million tonnes of oil equivalent (Mtoe) for EU member states, highlighting the significant differences in energy usage across the region.



Key Observations

1. **EU Aggregate Consumption:**
 - The EU's total primary energy consumption is depicted by the largest bar, significantly higher than any individual member state.
2. **Top Consumers:**
 - **Germany (DE)** leads individual countries with the highest primary energy consumption, followed by **France (FR)**, **Italy (IT)**, and **Spain (ES)**.
 - These countries represent the largest economies in the EU, correlating with their higher energy demands.
3. **Lower Consumption Countries:**

- Smaller member states like **Luxembourg (LU)**, **Cyprus (CY)**, and **Malta (MT)** exhibit the lowest energy consumption, reflective of their smaller populations and industrial bases.

Implications for EU Energy Policy

- Focus on Energy Efficiency:** High consumption in leading economies emphasizes the need for increased energy efficiency measures, particularly in Germany, France, Italy, and Spain.
- Support for Lower Consumers:** Countries with lower consumption may require tailored policies that support sustainable growth without drastically increasing energy demand.

Recommendations for Future Strategies

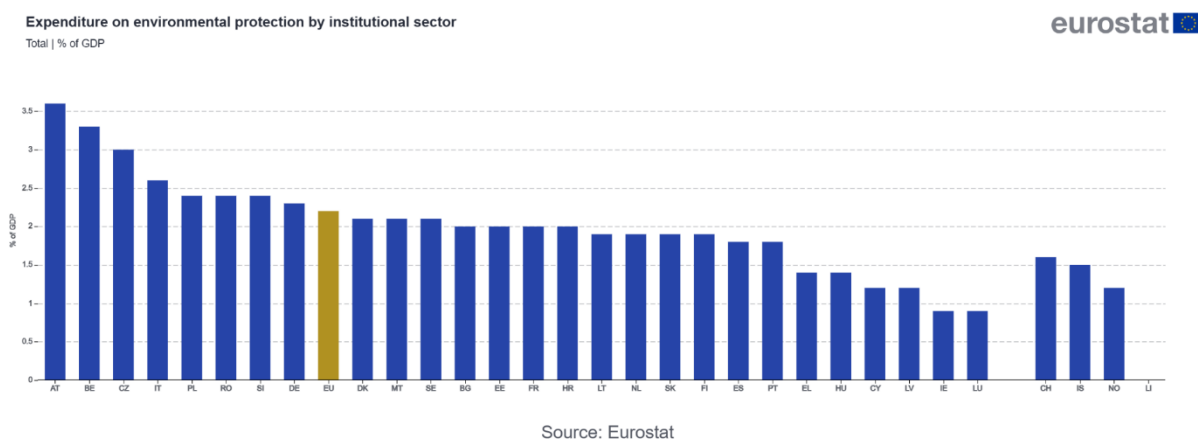
- Enhance Energy Efficiency:**
 - Prioritize energy efficiency programs in the highest consuming countries to reduce overall EU energy demand.
- Promote Renewable Energy:**
 - Increase the share of renewable energy within high consumption countries to reduce dependence on fossil fuels.
- Energy Transition Support:**
 - Provide financial and technical support for energy transitions in lower consumption countries, ensuring they grow sustainably.

Conclusion

Primary energy consumption across the EU reflects economic and industrial disparities between member states. By focusing on energy efficiency and promoting renewables, the EU can manage its energy needs while progressing towards its climate goals.

Expenditure on Environmental Protection in the EU

This graph shows the expenditure on environmental protection as a percentage of GDP across different EU countries and several non-EU countries.



Key Observations

- Highest Expenditure:**
 - Austria (AT)**, **Belgium (BE)**, and **Czech Republic (CZ)** lead in environmental protection spending, with over 3% of GDP allocated to this area.
- EU Average:**
 - The EU average expenditure stands around 2% of GDP.
- Lower Expenditure:**

- Latvia (LV), Cyprus (CY), and Ireland (IE) have the lowest expenditure on environmental protection, highlighting potential areas for increased investment.

Implications for Policy

- Prioritize Environmental Spending:** Countries with lower spending should focus on increasing investments in environmental protection to meet climate targets.
- Supportive Measures for High-Spenders:** Countries leading in environmental expenditure can serve as models, sharing best practices for efficient environmental protection.

Recommendations for Future Strategies

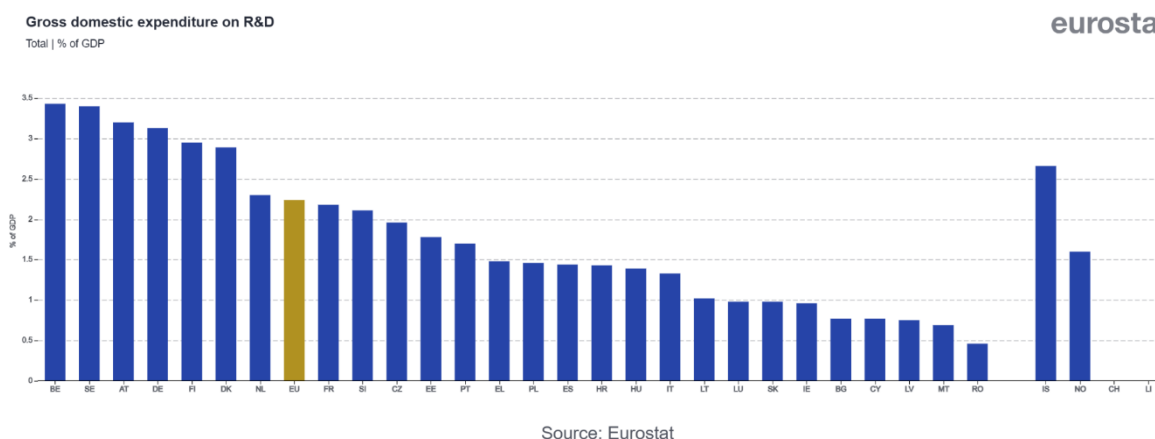
- Increase Investments in Environmental Protection:**
 - Countries with lower expenditure percentages should increase their financial commitments to meet sustainability goals.
- Promote Sustainable Practices:**
 - Encourage industrial sectors to adopt green practices, which can contribute to reducing environmental damage and promoting a green economy.
- Incentivize Public and Private Sectors:**
 - Provide tax breaks and subsidies to private sectors contributing to environmental protection initiatives.

Conclusion

Environmental protection expenditure varies significantly across the EU, with certain countries making substantial investments while others lag behind. Strengthening financial commitments across all member states is crucial for achieving EU-wide climate and environmental goals.

Gross Domestic Expenditure on R&D in the EU

This graph presents the gross domestic expenditure on research and development (R&D) as a percentage of GDP across EU countries, including some non-EU nations.



Key Observations

- Top Spenders:**
 - Belgium (BE), Sweden (SE), and Austria (AT) lead the EU with R&D spending exceeding 3% of GDP.
- EU Average:**
 - The EU average is around 2%, highlighting a collective commitment to innovation and research.
- Lower Spenders:**
 - Latvia (LV), Cyprus (CY), and Bulgaria (BG) have the lowest R&D expenditures, reflecting room for growth in innovation investments.

Implications for Innovation

- **Encouraging Innovation:** Higher R&D spending fosters technological advances and competitiveness, critical for addressing climate and energy challenges.
- **Supporting Low-Investment Countries:** Increased funding and support for R&D initiatives in lower-spending countries can accelerate their economic and technological development.

Recommendations

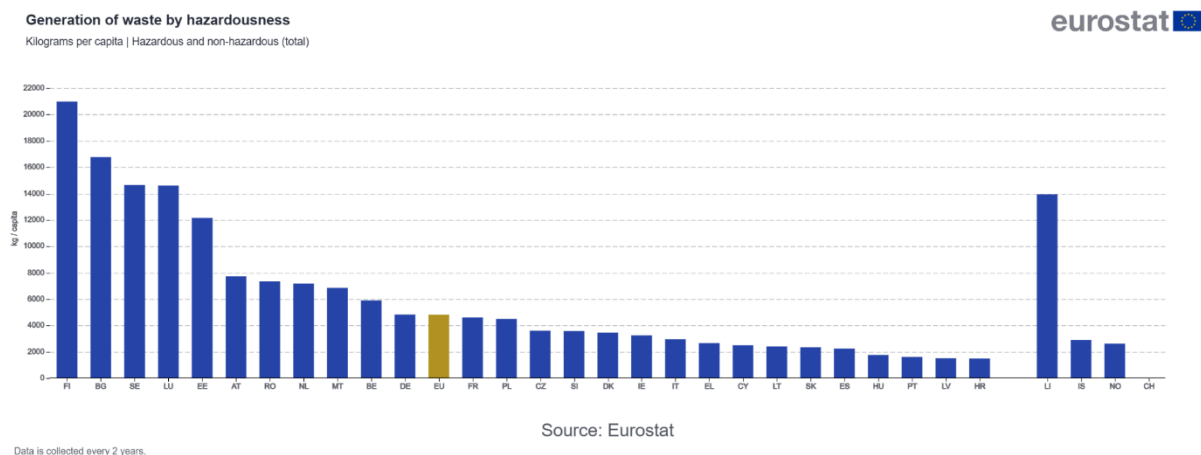
1. **Boost R&D Investments:**
 - Encourage countries with low R&D spending to allocate more resources towards research to drive innovation and competitiveness.
2. **Public-Private Partnerships:**
 - Foster collaborations between governments and private sectors to share the financial burden of R&D.
3. **Prioritize Green Technology:**
 - Align R&D spending with sustainability goals by promoting innovation in renewable energy, energy efficiency, and carbon reduction technologies.

Conclusion

The graph highlights disparities in R&D investment across the EU, with some countries leading in innovation while others lag behind. Increasing R&D spending across the EU, particularly in green technologies, will be crucial for meeting future sustainability and economic goals.

Generation of Waste by Hazardousness in the EU

This graph displays the generation of hazardous waste per capita (in kilograms) across EU countries, with Finland (FI) and Bulgaria (BG) leading in waste generation.



Key Observations

1. **Highest Waste Generation:**
 - **Finland (FI)** generates the most waste per capita, with over 20,000 kg, followed by **Bulgaria (BG)** and **Sweden (SE)**.
2. **EU Average:**
 - The EU average is around 6,000 kg per capita, significantly lower than the leading countries.
3. **Lower Waste Generators:**
 - Countries like **Hungary (HU)**, **Portugal (PT)**, and **Croatia (HR)** generate much less waste per capita.

Implications and Recommendations

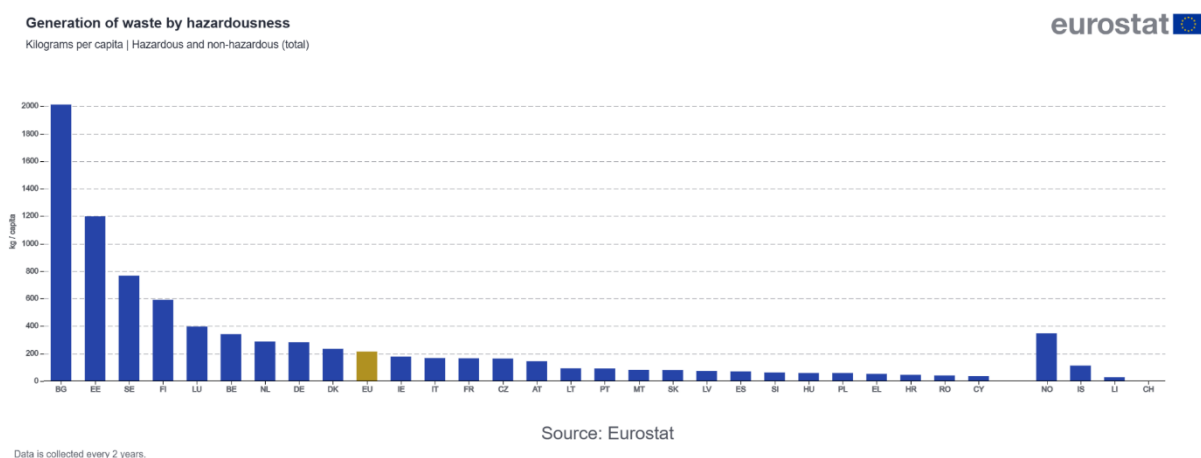
- **Waste Reduction:** High waste generation in certain countries suggests the need for improved waste management and recycling initiatives.
- **Focus on Circular Economy:** Promote policies that emphasize reducing waste and improving resource efficiency across industries.

Conclusion

The wide disparities in waste generation highlight the need for targeted waste management strategies in high-generating countries, while promoting sustainable practices across all member states to reduce overall waste output.

Generation of Waste by Hazardousness in the EU

This graph illustrates the per capita generation of non-hazardous waste across EU countries, measured in kilograms. Bulgaria (BG) leads with the highest waste generation per capita, followed by Estonia (EE) and Sweden (SE).



Key Observations

1. Highest Waste Generators:

- **Bulgaria (BG)** shows an exceptionally high waste generation of nearly 2,000 kg per capita.
- **Estonia (EE)** and **Sweden (SE)** also have significant per capita waste generation.

2. EU Average:

- The EU average is substantially lower, reflecting more moderate waste generation across most member states.

3. Lower Waste Generation:

- Countries like **Croatia (HR)**, **Romania (RO)**, and **Cyprus (CY)** generate much less waste per capita, indicating better waste management practices or less industrial activity.

Implications for Waste Management

- **Focus on High-Generating Countries:** Countries with high waste generation need to prioritize waste reduction strategies, including improved recycling, resource efficiency, and waste-to-energy conversion.
- **Support for Circular Economy:** Promote a circular economy model to reduce waste generation by maximizing the reuse, recycling, and recovery of materials.

Conclusion

The significant variation in waste generation across EU countries highlights the need for tailored waste management strategies. High-generating countries must adopt stricter waste

reduction measures, while all member states can benefit from embracing circular economy principles to minimize waste output and enhance sustainability.

1.7 European Commission Decarbonization Scenarios

The European Commission Decarbonization Scenarios are strategic frameworks developed to guide the European Union (EU) in its transition towards a climate-neutral economy by 2050. These scenarios outline various pathways and policy measures that can be adopted to achieve deep decarbonization across all sectors of the economy, ensuring that the EU meets its ambitious climate targets while maintaining economic growth and social equity.

Key Objectives of Decarbonization Scenarios

1. **Achieving Climate Neutrality by 2050:** The primary goal of these scenarios is to reach net-zero greenhouse gas (GHG) emissions by mid-century, in line with the EU's commitment under the Paris Agreement to limit global warming to well below 2°C, preferably to 1.5°C.
2. **Ensuring Economic Growth and Social Fairness:** The scenarios aim to demonstrate that it is possible to decouple economic growth from GHG emissions, ensuring a just transition that supports all regions and sectors, particularly those most affected by the shift to a low-carbon economy.
3. **Promoting Technological Innovation:** By exploring different technological pathways, the scenarios emphasize the role of innovation in achieving decarbonization. This includes advancements in renewable energy, energy efficiency, electrification, and carbon capture and storage.

Main Decarbonization Scenarios

The European Commission has developed several decarbonization scenarios, each exploring different combinations of technologies, policies, and societal changes. Key scenarios include:

1. Baseline Scenario (Reference Scenario)

- The baseline scenario projects the future based on existing policies and measures. It serves as a reference point to compare the impact of additional decarbonization efforts.
- Under this scenario, the EU is expected to fall short of its 2050 climate goals, highlighting the need for more ambitious action.

2. High-Energy Efficiency Scenario

- This scenario prioritizes significant improvements in energy efficiency across all sectors, including buildings, transport, and industry.
- Key measures include stringent energy efficiency standards, widespread retrofitting of buildings, and promoting energy-saving technologies and practices.

3. High-Renewables Scenario

- This pathway focuses on maximizing the deployment of renewable energy sources such as wind, solar, and biomass.
- It envisions a rapid expansion of renewable energy capacity, supported by enhanced grid infrastructure and storage solutions to manage intermittent supply.

4. Electrification Scenario

- This scenario emphasizes the electrification of sectors traditionally reliant on fossil fuels, such as transport, heating, and industry.

- It includes measures to promote electric vehicles, heat pumps, and electrified industrial processes, coupled with a decarbonized power sector.

5. Hydrogen Scenario

- This pathway explores the potential of hydrogen as a key energy carrier, particularly in sectors where electrification is challenging, such as heavy industry and long-haul transport.
- It involves scaling up green hydrogen production using renewable electricity and developing infrastructure for hydrogen distribution and storage.

6. Circular Economy Scenario

- This scenario focuses on reducing resource use and waste through circular economy principles, such as recycling, reuse, and sustainable product design.
- It aims to minimize the carbon footprint of materials and products, contributing to overall emissions reductions.

Implementation Mechanisms

To achieve the goals outlined in the decarbonization scenarios, the European Commission proposes a range of policy measures and instruments, including:

1. Regulatory Measures

- Setting stricter emissions standards for vehicles, buildings, and industries.
- Mandating higher energy efficiency standards and renewable energy targets.

2. Market-Based Instruments

- Expanding the EU Emissions Trading System (ETS) to cover more sectors and increase the carbon price.
- Introducing carbon pricing mechanisms for sectors not covered by the ETS.

3. Financial Support

- Providing funding and incentives for research, development, and deployment of low-carbon technologies.
- Supporting regions and communities most affected by the transition through mechanisms like the Just Transition Fund.

4. Infrastructure Development

- Investing in smart grids, energy storage, and renewable energy infrastructure.
- Developing hydrogen and electric vehicle charging networks.

5. Behavioral and Societal Changes

- Promoting sustainable consumption patterns and lifestyles.
- Engaging citizens and stakeholders in the transition process through education and awareness campaigns.

The current status in particular Scenarios

ChatGPT

As of the latest reports, the European Union has been making significant progress towards its decarbonization goals. Each of the scenarios outlined by the European Commission is at different stages of implementation and development. Here is an overview of the current status of the key decarbonization scenarios:

1. Baseline Scenario (Reference Scenario)

Current Status:

- The Baseline Scenario projects the outcomes based on existing policies and measures without additional interventions. As of now, this scenario indicates that while some progress has been made, the EU will not meet its 2050 climate neutrality goals under current policies alone.

- Existing measures have helped reduce emissions, but further action is needed to close the gap to achieve full decarbonization by 2050.

2. High-Energy Efficiency Scenario

Current Status:

- Significant efforts have been directed towards improving energy efficiency, with new regulations and standards being implemented across the EU.
- The Energy Efficiency Directive and the Energy Performance of Buildings Directive have been updated to set more ambitious targets.
- Programs such as the Renovation Wave aim to double the annual rate of energy-related renovations by 2030, targeting improvements in building energy performance.
- Despite progress, challenges remain in achieving the necessary scale of renovations and ensuring financing for all sectors, particularly in residential buildings.

3. High-Renewables Scenario

Current Status:

- The deployment of renewable energy sources has accelerated, with substantial investments in wind, solar, and biomass energy.
- The Renewable Energy Directive sets an increased target for renewables to account for at least 32% of the EU's energy consumption by 2030, and this target is expected to be raised further.
- Member States are on track to collectively exceed the 2020 renewable energy targets, but further efforts are needed to meet the 2030 and 2050 goals.
- Challenges include integrating intermittent renewable energy into the grid and developing adequate storage solutions.

4. Electrification Scenario

Current Status:

- Electrification is progressing in sectors such as transport and heating, supported by initiatives like the European Green Deal and the Sustainable and Smart Mobility Strategy.
- Electric vehicle (EV) adoption is increasing, with targets to have at least 30 million EVs on the road by 2030.
- Heat pumps and electrified industrial processes are being promoted to replace fossil fuel-based systems.
- Investments in grid infrastructure and smart grids are essential to support the growing demand for electricity and ensure reliable supply.

5. Hydrogen Scenario

Current Status:

- The EU Hydrogen Strategy aims to install at least 6 GW of renewable hydrogen electrolyzers and produce up to 1 million tonnes of renewable hydrogen by 2024, scaling up to 40 GW and 10 million tonnes by 2030.
- Several Member States have developed national hydrogen strategies and are investing in pilot projects and infrastructure.
- Progress includes the establishment of hydrogen valleys and partnerships to foster the hydrogen economy.
- Challenges remain in scaling up production, reducing costs, and developing comprehensive infrastructure for hydrogen distribution and storage.

6. Circular Economy Scenario

Current Status:

- The Circular Economy Action Plan, part of the European Green Deal, is driving initiatives to reduce resource use and waste.

- Measures include regulations on product design, waste management, and recycling to promote a circular economy.
- The EU is making strides in sectors like plastics, textiles, and electronics to enhance sustainability and reduce carbon footprints.
- Implementation varies across Member States, and more efforts are needed to achieve full circularity in the economy.

Conclusion

The European Commission Decarbonization Scenarios are essential tools for guiding the EU towards a sustainable, climate-neutral future. They highlight the need for ambitious action across all sectors and provide a comprehensive framework for achieving deep decarbonization while ensuring economic growth and social equity. Through these scenarios, the EU can lead by example in the global effort to address the urgent challenge of climate change.

The European Commission's decarbonization scenarios provide a comprehensive framework for the EU's transition to a climate-neutral economy. While each scenario shows varying levels of progress, collectively they highlight the need for continued ambition and action across all sectors. Through sustained efforts and strategic adjustments, the EU aims to achieve its 2050 climate goals, demonstrating global leadership in the fight against climate change.

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Hafner Manfred, Luciani Giacomo. The Palgrave Handbook of International Energy Economics, 2022, ISBN 978-3-030-86883-3, ISBN 978-3-030-86884-0 (eBook), <https://doi.org/10.1007/978-3-030-86884-0>

Hainsch Karlo, Löffler Konstantin, Burandt Thorsten, Auer Hans, Crespo del Granado Pedro, Pisciella Paolo, Zwickl-Bernhard Sebastian: Energy transition scenarios: What policies, societal attitudes, and technology developments will realize the EU Green Deal?, Energy, Volume 239, Part C, 2022, 122067, ISSN 0360-5442, <https://doi.org/10.1016/j.energy.2021.122067>

Renovate Europe. (April, 2023). 2021-2027 Cohesion policy support for energy efficiency and building renovation

Siddi, Marco. (2020). The European Green Deal: Assessing its current state and future implementation.

Vezzoni Rubén, Green growth for whom, how and why? The REPowerEU Plan and the inconsistencies of European Union energy policy, Energy Research & Social Science, Volume 101, 2023, 103134, ISSN 2214-6296, <https://doi.org/10.1016/j.erss.2023.103134> . with the project work plan must be properly monitored and kept under control.

2 Renewable Energies for Sustainable Development

2.1 Energy

Energy is one of the basic components of our universe, necessary for various processes and activities. We use it to perform work, illuminate cities, drive vehicles, trains, planes and rockets. Energy is needed to heat homes, cook food, play music and transmit images on television. It drives machines in factories and tractors on farms.

The sun is the primary source of energy that provides light during the day, dries our clothes on the line, and supports plant growth through photosynthesis. The energy stored in plants is transferred to the animals that consume them and then to the predators that hunt these animals, thereby obtaining the energy needed for survival.

Energy is also defined as the ability of a system to perform work. This definition includes various forms of energy such as kinetic, potential, thermal, electrical, chemical, and nuclear energy, which can be transformed from one form to another, but can never be destroyed or created, only transformed, which is in accordance with the law of conservation energy.

In all aspects of life and nature, energy is the key factor that enables movement, heat, light and biological processes. Without energy, it would be impossible to do any work or ensure the basic functions of living organisms and technology.

According to Einstein's relation $E = m \cdot c^2$ energy is equivalent to matter. Direct conversion of one form of energy into another is possible, but not in all cases.

When we consume food, our bodies convert stored chemical energy into energy needed for various physiological functions such as movement and intellectual activities. This process, known as metabolism, involves the conversion of biochemical substrates into ATP (adenosine triphosphate), which is the main carrier of energy in cells.

Similarly, mechanical devices such as automobiles, airplanes, light bulbs, ships, and machines convert energy into work through various physical principles. Work in this context is defined as the transfer of energy that causes movement, lifting, heating or other forms of change of state.

Energy can come from a variety of sources, including fossil fuels, renewable sources (such as solar, wind and hydro) and nuclear reactions.

The concept of energy is fundamental to the study of transformational phenomena such as chemical reactions and metallurgy, as well as to the mechanical processes that were crucial during the Industrial Revolution. In the 19th century, the basic principles of energy physics were introduced. Gottfried Wilhelm In 1686, Leibniz showed that the product of the mass and the square of the velocity ($m \cdot v^2$) is conserved, which he called the "living force". In 1788, Joseph -Louis Lagrange proved the invariance of the sum of kinetic and potential energy.

A series of experiments in the 19th century demonstrated key laws of physics:

- A drop of a given weight from the same height always produces the same amount of heat.
- If the terminal velocity is not zero, the temperature rise is smaller because some of the energy is converted into kinetic energy and the rest into heat.
- Heating can cause expansion and an increase in pressure, which can "create work" by moving mass.

- The sum of energies is always conserved, which gave rise to the concept of the law of conservation of energy.

Energy enables the connection of various forms of movement, rotation, temperature, body colour or light, consumption of sugar, coal, wear, etc. If energy is conserved and transformed, some changes are reversible and others are not. For example, the conversion of energy from heat to mechanical work is often irreversible and some energy is lost, which is the basis of the concept of entropy.

The law of conservation of energy is a fundamental principle in physics that enables the study of complex systems and confirms that energy can neither be created nor destroyed, only transformed from one form to another. This principle is crucial for understanding and analysing physical, chemical and biological systems.

2.1.1 Forms of energy

Energy can manifest itself in five basic forms (Figure 1). This classification is not the only one, and it is possible that you will find another classification in the literature.

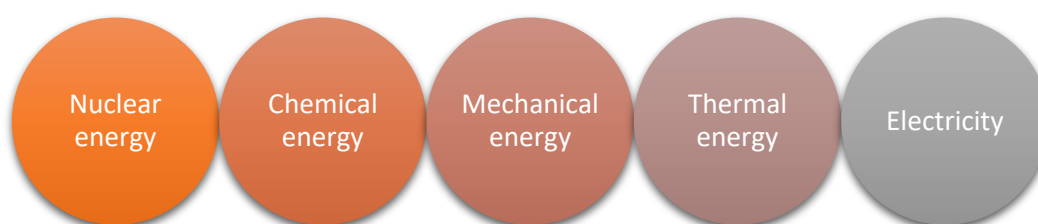


Figure 1: Five forms of energy

Spontaneous or not, energy can generally pass from one form to another or to several others, respecting the principle of conservation of energy

2.1.1.1 Energy sources

An energy source is the form of energy that is found in nature, on Earth, and whose availability is the most obvious. It is a form of energy that is likely to be used, either directly or through several processes. According to the place in the transformation process, we divide energy sources into:

- *Primary sources of energy* are found directly in nature. These include fossil and nuclear fuels, solar energy, wind energy, hydropower and geothermal energy.
- *Secondary energy sources* are energy sources obtained by converting primary sources. For example, heat is obtained from coal (primary source of energy) by burning it, which is a further usable secondary source of energy.

These energy sources can be divided according to their origin into two main categories (Figure 2):

1. Resources created in Earth's past:

- Mineral and rock (nuclear energy): These materials can provide thermal energy through nuclear fission or fusion.
- Organic matter (chemical energy): Geological deposits of organic materials, such as fossil fuels, produce heat when burned.
- Magma: Heat accumulated in the Earth's core that can be used for heating or electricity production.

2. Sources arising from the existence of the Earth in the solar system:

- Solar radiation: Electromagnetic radiation from the Sun that provides heat and light and its consequences in natural cycles such as:
- Hydrologic Cycle: Provides mechanical energy through hydroelectric systems.
- Air currents: Provides mechanical energy through wind turbines.
- Photosynthesis: The process by which plants produce biochemical energy (biomass) that can be used as food or burned for heat.
- Gravitational phenomena: Provide mechanical energy, for example through tidal power plants.

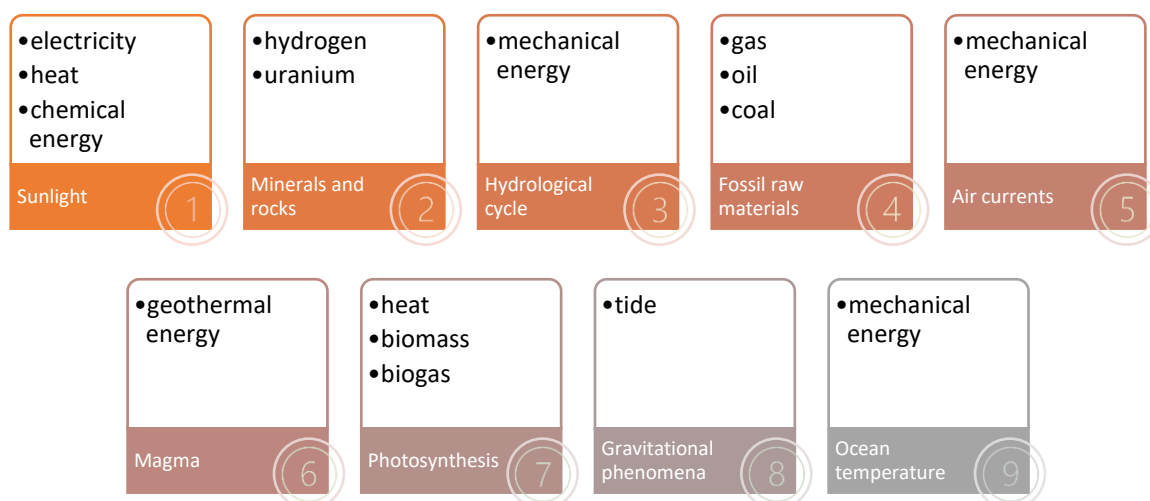


Figure 2: Energy sources

According to renewable energy sources, we can divide them into two main categories:

Renewable energy sources

These resources have the ability to be permanently renewed through natural processes or human activities. Renewable energy sources include:

- Solar energy: includes photovoltaic solar panels and thermosolar collectors.
- Hydropower: includes energy from water currents, waves, water currents and tides.
- Wind energy: includes conventional wind turbines and electricity generation turbines.
- Geothermal energy: used for heating and electricity generation.
- Biomass: includes biomass for heating and biogas for electricity production.

Non-renewable energy sources

These resources have limited reserves, which are gradually depleted by use. Belongs here:

- Fossil fuels: coal, oil, natural gas.
- Nuclear fuels: uranium and plutonium, used in nuclear reactors.

Advantages of using renewable energy sources:

- Safety and availability: Renewable energy sources are generally available and safe to use.
- Reducing dependence on non-renewable resources: Helps reduce dependence on traditional fossil fuels and nuclear energy.
- Ecological benefits: Less environmental pollution and reduction in the production of greenhouse gases such as CO₂.
- Technological progress and employment: The development of new technologies brings new jobs in progressive industries.

2.1.1.2 Energy selection

When choosing suitable energy sources, we have to consider different options, each source having its advantages and disadvantages depending on its characteristics and the form of energy produced, for example:

- Heat: Heat is difficult to transport and store.
- Fuels (fossil or biomass): Can be stored and transported.
- Mechanical energy: It is difficult to transport it.
- Nuclear Power: Can be unleashed but is difficult to control.
- Water: Can be stored.
- Wind: Cannot be stored.

Based on these characteristics, we have to establish criteria for choosing a suitable energy source, which is relatively simple. Hierarchizing the values of these criteria is, however, more complex. Selection criteria include:

- Physical criteria: availability, storage, transformation, transport and utilization.
- Ecological criteria: resource management, immediate external consequences, long-term consequences in time and space, safety, impact on the environment.
- Economic and legal criteria: costs of use, investments, maintenance, financial management.
- Social criteria: safety of use, inclusion and acceptance in the given socio-economic and socio-cultural environment, comfort and ease of use.

These criteria allow us to assess different energy sources according to their ability to fulfil the requirements. To fulfil all criteria, the concept of energy carrier or energy vector is often chosen.

2.1.1.3 Energy carrier

An energy carrier is a material or system that enables the transmission, storage and use of energy. In order for an energy carrier to be efficient and sustainable, it must meet several basic conditions:

- **Sufficient amount of energy to meet the needs of the given community:** The energy carrier must contain a sufficient amount of energy to be able to effectively meet the energy demands of the community. This aspect is crucial for ensuring the continuity of energy supplies and the stability of the energy system.
- **Transformation of a stored amount of energy into its carrier form:** The process of converting energy from a raw or primary form into a form that can be efficiently transmitted and used is essential. For example, the conversion of chemical energy from

fossil fuels to electricity or the conversion of solar energy to electricity using photovoltaic cells.

- **Transfer of energy to the place of final use:** The energy carrier must enable the efficient transfer of energy from the place of its production to the place of consumption. This includes infrastructure for the transmission of electricity, such as power grids, as well as technologies for transporting fuels.
- **The possibility to transform this vector into the desired usable form of energy:** The energy carrier must be able to be converted into a form of energy that is directly usable for the end user. For example, electricity can be used to power machines, heat homes or power electronic devices.
- **Energy carrier storage to respond to changes in use:** The ability to store energy is critical to balancing the gap between energy production and consumption. Energy storage makes it possible to ensure energy supplies at times of increased consumption or in the event of blackouts. Examples include batteries, pumped hydro and thermal storage.

Effective energy carriers enable better use of available energy sources, reduce the burden on the environment and increase energy security. At the same time, they support the development and implementation of advanced technologies that increase the efficiency of energy systems and contribute to sustainable development. This approach ensures efficient and sustainable utilization of energy resources, taking into account various aspects of their processing and application. When planning and implementing energy systems, it is important to take into account not only technical and economic factors, but also ecological and social aspects, which are crucial for long-term sustainability.

2.2 Energy chain and energy production

Energy chain (Figure 3) represents a complex system including various stages, from energy production to its final use. This process includes generation, transmission, distribution and storage of energy. A detailed understanding of each of these stages is essential for efficient and sustainable operation of energy systems.

The production of electrical energy belongs to the field of energy transformations. Energy conversion is necessary because practically directly usable electrical energy cannot be found in nature.

Energy conversion can be:

- single stage
- multi-stage.

Electricity is produced in power plants. A power plant is an electrical energy production facility. From the point of view of the electricity system, which includes equipment for the production, distribution and consumption of electrical energy, each power plant is an active unit where electrical energy is generated by conversion from another type of energy.

Electricity is extremely interesting because of its properties. It is characterized by the fact that it can be transferred over long distances in a relatively simple way, it can be used by converting it into other desired forms of energy (light, heat, electromagnetic waves, etc.). It is considered the most important and noblest form of energy.



Figure 3: Energy chain

2.2.1 Conversion and transformation of energy

Energy can be transformed from one form to another (Table 1) through natural processes (e.g. combustion, radioactivity, photosynthesis, solar thermal energy) or by human activity (e.g. photoelectricity, electric and thermal engines, batteries). The basic principle of energy transformation is that energy can neither be created nor destroyed, only transformed from one form to another, in accordance with the law of conservation of energy.

Table 1 Conversion of different forms of energy

Forms of chemical energy	thermal	electric	Electro-magnetic	mechanical	
chemical	plants, food	combustion, anaerobic combustion	battery, fuel cell	candle, phosphorescence	human and animal muscles
thermal	pyrolytic gasification	heat pump, heat exchanger	thermocouple	fire	gas turbine, steam turbine, memory materials
electric	battery electrifier	hob, toaster, iron	frequency converter	fluorescent lamp, light-emitting diode	electric motor, electromagnet
Electro-magnetic	photosynthesis	solar collector	photovoltaic cell	laser	solar radiation pressure
mechanical	liquid crystallization	friction brake	generator	firestone	water wheel, windmill, pendulum, flywheel

2.2.2 Energy conservation

The most remarkable property of energy is its conservation. When transferring or changing the form of energy, the total amount of energy does not change; energy is neither created nor destroyed. If an object loses energy, another object with which it interacts will gain the same amount of energy.

For example, in a thermal power plant, energy is not "produced", but converted from chemical or nuclear energy into electrical and thermal energy. The overall balance of this transformation is determined by the efficiency of the power plant. For example, a power plant with an efficiency of 33% converts 33 units of nuclear energy into electricity and 67 units of heat, which is removed to the surroundings.

2.2.3 Energy degradation

In energy transformation, the amount of energy is preserved, but its quality changes. Some forms of energy are more "noble" and ordered at the microscopic level (e.g., mechanical, electrical energy), while heat is a disordered form of energy caused by the random motions of molecules.

When changing from one form of energy to another (e.g. mechanical energy to heat), some energy is always lost in the form of heat, a process known as energy dissipation. This phenomenon is a consequence of the second law of thermodynamics, which states that energy transformations tend to proceed unidirectionally to increase entropy.

Examples of energy degradation:

- Bicycle on a hill: The mechanical potential energy of a bicycle at the top of a hill is converted into kinetic energy as it descends. When braking, this kinetic energy is converted into heat, causing the brakes to rise in temperature.
- Automobile: In an automobile, the chemical energy of gasoline is converted into kinetic energy of motion, and some of this energy is lost as frictional heat in the engines and brakes.

2.2.4 Efficiency and limitations of energy transformation

The conversion of energy from one form to another is never 100% efficient. For example, steam turbines in power plants, engines in cars and airplanes have limited efficiency due to energy losses in the form of heat. The laws of thermodynamics therefore set us limits on how much energy can be efficiently converted and how much energy is lost as heat.

Understanding these fundamental principles of energy transformation and degradation is key to designing efficient energy systems and technologies that minimize losses and maximize usable energy.

2.3 The sun and solar energy

In any solar energy conversion system, knowledge of global solar radiation is extremely important for optimal design and prediction of system performance.

When using solar energy, important information regarding:

- **Positions of the Sun:** What is the best inclination of solar collectors according to use? How to calculate the solar screen so that the solar system is not overshadowed?
- **The energy aspect of solar radiation and its spectral composition :** Composition and physical characteristics of the earth's atmosphere, its influence on passing solar radiation and the resulting spectral composition, various components of solar radiation and calculation of solar energy.

2.3.1 Geometric aspect of the Earth's orbit around the Sun

We will be interested in the geometrical aspects of the solar radiation received by the Earth in order to calculate the solar radiation on an inclined plane on the Earth's surface.

2.3.1.1 The movement of the Earth around the Sun

The Earth revolves around the Sun in an elliptical orbit with the Sun at one of the foci. The plane of rotation of the Earth around the Sun is called the plane of the ecliptic (Figure 4).

The amount of solar radiation falling on the Earth is inversely proportional to the square of its distance from the Sun. The mean Sun-Earth distance is called one **astronomical unit**:

$$r_0 = 1AU = 1.496 \cdot 10^8 \text{ km}$$

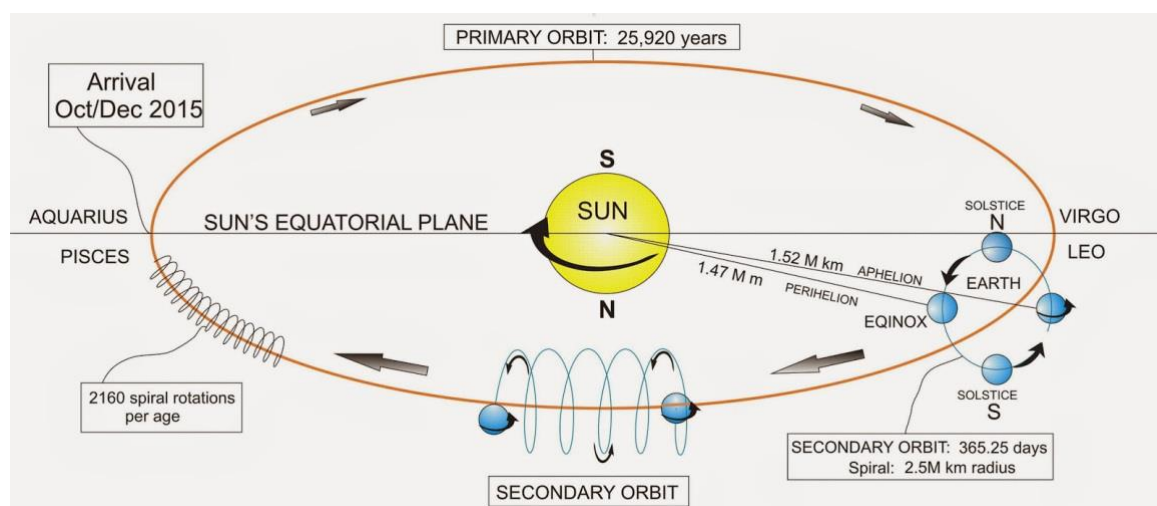


Figure 4: Movement of the Earth around the Sun (Source: www.ssjh.sk/ssjh-modal.php?IDmodal=190)

The Earth is at its closest point to the sun (perihelion) around January 3rd and at its furthest point (aphelion) around July 4th. The correction factor for the eccentricity of the Earth's orbit can be calculated as follows:

$$E_0 = \frac{r}{r_0} = 1 + 0,033 \cos\left(\frac{2\pi d_n}{365}\right)$$

where d_n is the number of the day of the year in the range from 1 (January 1) to 365 (December 31) (Figure 5).

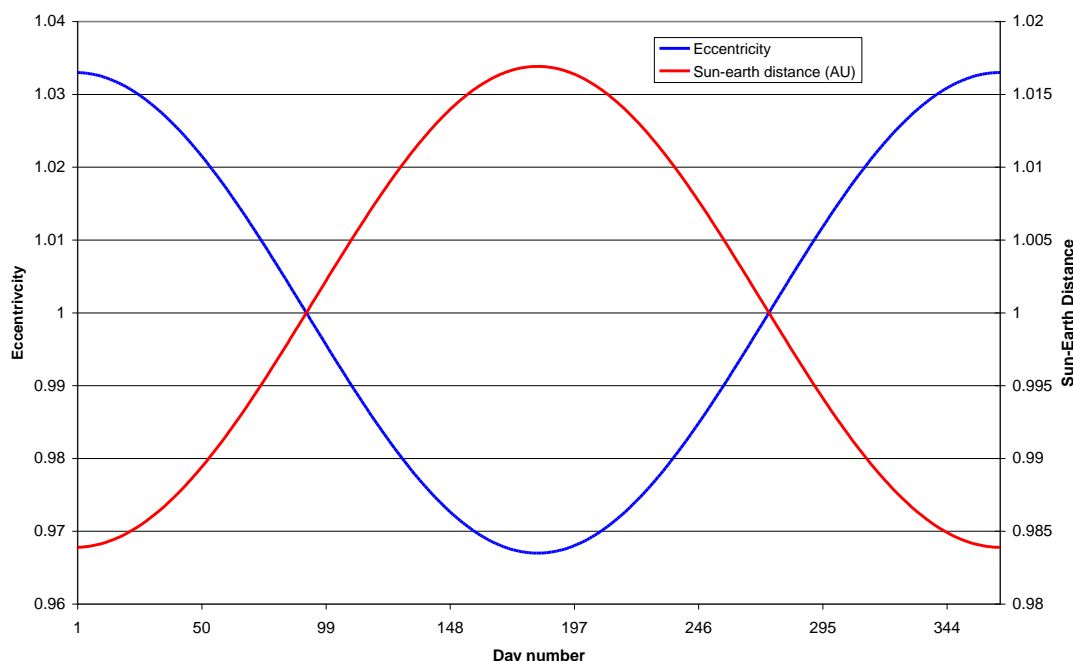


Figure 5: Eccentricity correction factor and Sun-Earth distance versus number of days

The Earth itself rotates around an axis called the polar axis, which is tilted about 23.5° from the normal to the plane of the ecliptic. The rotation of the Earth around this axis causes a daily change in radiation intake, and the position of this axis relative to the sun causes seasonal changes. If the angle between the polar axis and the normal to the plane of the ecliptic remains

constant, the angle between the line connecting the centres of the Sun and the Earth with the equatorial plane changes every moment and is called the solar declination δ (Figure 6).

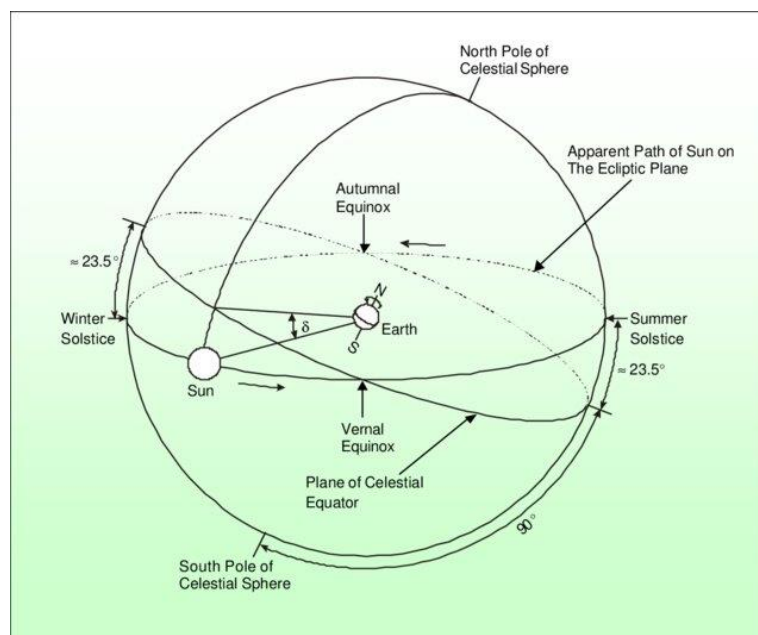


Figure 6: Celestial globe showing the angle of inclination of the sun

Its value is zero at the spring and autumn equinoxes (as well as long nights and days). In 24 hours, the maximum change in declination is less than 0.5° and the declination can be considered constant during the day. δ in $^\circ$ can be calculated using this simplified equation:

$$\delta = \sin^{-1} \left\{ 0,4 \sin \left[\frac{360}{365} (d_n - 82) \right] \right\}$$

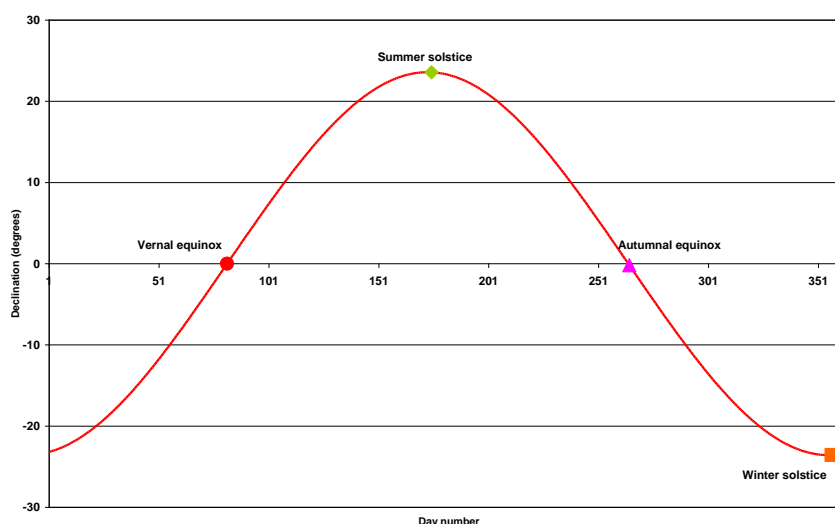


Figure 7: Variation the sun's declination versus the day number

2.3.1.2 The spectrum of solar radiation

Solar radiation, or sunlight, is a form of **electromagnetic radiation emitted by the Sun**. This radiation covers a wide spectrum of wavelengths, from **ultraviolet (UV)** to **visible light** to **the infrared (IR)** spectrum (Figure 8).

- **Ultraviolet (UV) radiation** has wavelengths less than 400 nm. It is further divided into three types: UVA, UVB and UVC, with UVC being the most harmful, but mostly absorbed by the atmosphere, specifically the ozone layer.
- **Visible light** is the part of the spectrum that the human eye perceives and has wavelengths from about 400 nm to 700 nm. Visible light is responsible for color perception and makes up about half of the total solar radiation energy that reaches the Earth's surface.
- **Infrared (IR) radiation** has wavelengths greater than 700 nm and is responsible for the warmth we feel from sunlight. IR radiation is strongly absorbed by water vapor and CO₂ in the atmosphere.

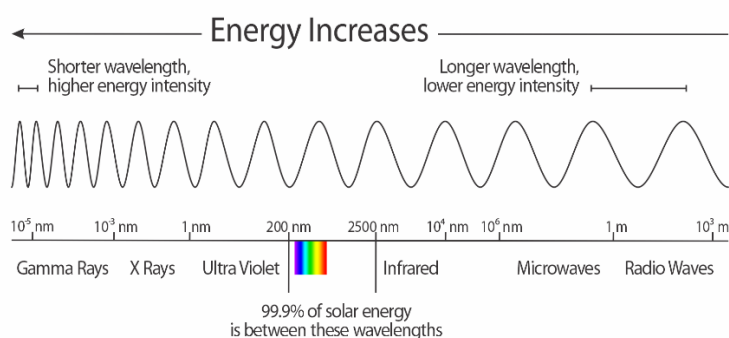


Figure 8: Solar radiation spectrum (www.sunwindsolar.com/blog/solar-radiation-spectrum/)

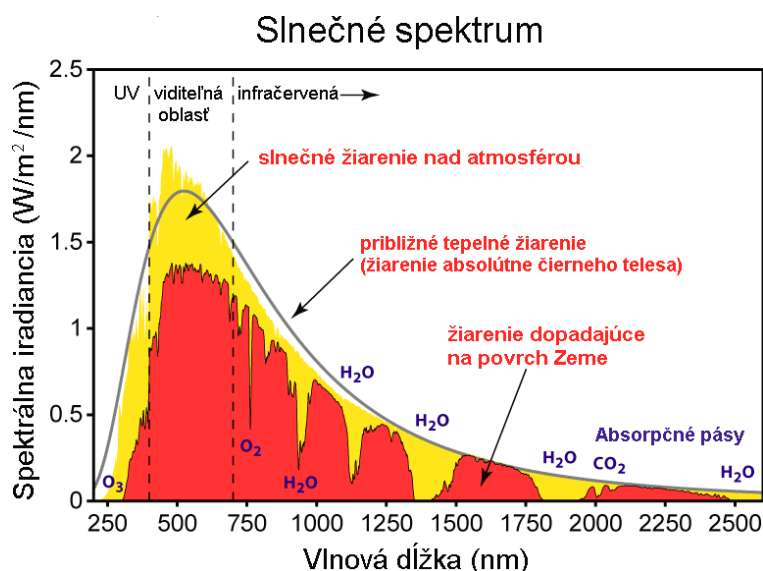


Figure 9: Solar spectrum - Dependence of spectral irradiance on wavelength (<http://www.slpk.sk/misc/2020/solar-systems/docs/kapitola1-3.pdf>)

Place from where to where most of the Sun's radiation comes to us is called **the photosphere**. In the visible region of the spectrum, the photosphere is actually the "surface" of the Sun. Its thickness is only about 700 km, which is caused by the degree of opacity of the plasma for

radiation. This thickness is only about 1/1000 of the Sun's radius, making the edge of the Sun appear sharp.

The shape of the curve of the solar spectrum can be approximated by the radiation curve of an absolute black body. An absolute black body is a hypothetical physical body that produces only thermal radiation. The temperature of an absolute black body with the same radiant power as the Sun, it then indicates the effective temperature T_{eff} of the solar photosphere, which is 5778 K.

From the solar radiation falling on the outer layers of the Earth's atmosphere, only part v reaches the Earth's surface due to the reflectivity of the Earth's atmosphere (albedo) and absorption by molecules in atmosphere. IN the ultraviolet region of the spectrum is dominated by absorption by molecules ozone O_3 in the ozone layer, in the infrared region part of the radiation is absorbed mainly by water vapour molecules H_2O and also by CO_2 molecules.

2.3.1.3 Solar constant

Solar constant I_o (Figure 10) is the energy from the Sun per unit of time, falling on a unit of area perpendicular to the direction of radiation propagation, at the average distance of the Sun from the Earth, outside the Earth's atmosphere. At development cosmic programs she was this one Value constantly refined and in 1981 it was adopted by the WMO (World Meteorological Organization - World Meteorological Organization) value $I_o = 1367 \text{ W} \cdot \text{m}^{-2} \cdot \text{s}$ with an inaccuracy of the order of 1%. FROM it follows that it is not possible to obtain more solar energy per square meter than 1367 W. From an energy point of view it goes about extraordinary interesting the possibility of obtaining energy. Its limited utilization is caused by technological and economic problems.

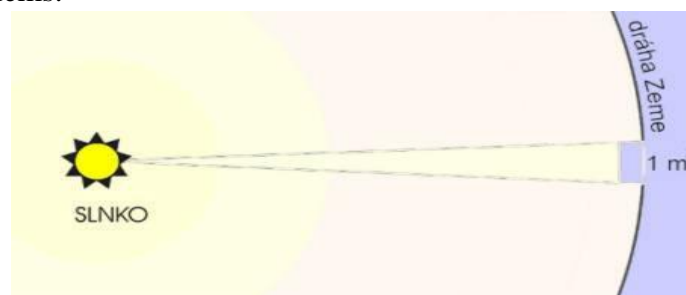


Figure 10: Solar constant (<http://www.slpk.sk/misc/2020/solar-systems/docs/kapitola1-3.pdf>)

2.3.1.4 Types sunny radiation falling on the dazzled surface

Sunny radiation falling on the a certain area we can split on the three components (Figure 11):

- **direct sunny radiation** - sunny radiation falling on the area without of any dispersion in the atmosphere
- **diffusely sunny radiation** - sunny radiation falling on the area after change direction of radiation due to scattering in the atmosphere.
- **reflected sunny radiation** - sunny radiation reflected from surrounding objects.

Direct solar radiation has many times higher intensity in one direction than in others, while diffuse solar radiation has the same intensity in all directions. In practice, this means that direct solar radiation is significantly dependent on the angle of incidence compared to diffuse radiation rays.

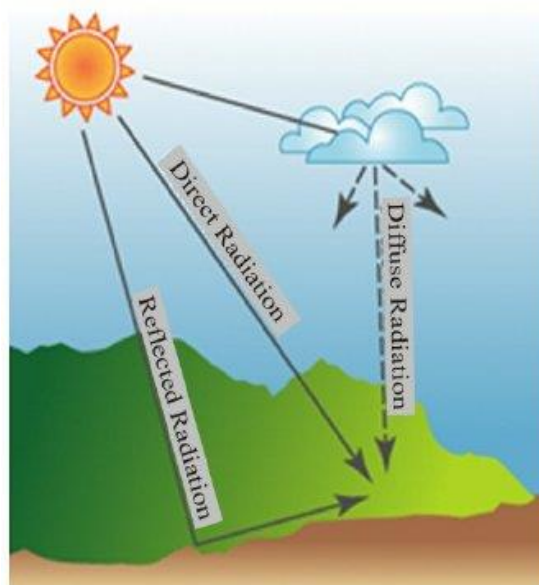


Figure 11: Components of solar radiation near the Earth's surface¹

2.3.2 History of using solar energy

Native Americans and the Ancient Greeks built houses on hillsides, taking advantage of the accumulation of heat from the sun during the day, which was then released during the night. The Romans were the first people to use windows to capture heat from the sun in their homes. Solar energy as we understand it today began to be used since 1860, when Auguste Mouchout built the first active solar engine. Since that time, people have been fascinated by the idea of using solar energy in everyday life (Szabo, 2017)².

2.3.2.1 The beginnings of commercial use of solar energy

In 1897, Frank Shuman, an American inventor, engineer and pioneer in the use of solar energy, built a small demonstration solar module that worked on the principle of reflecting the sun's energy from a square box inside which were placed black tubes filled with ether, which has a lower temperature boil like water. The heated ether produced steam that powered a steam engine. In 1908, Shuman founded Sun Power Company with the intention of building larger solar power plants. Together with his technical advisor ASE Ackermann and the British physicist Sir Charles Vernon Boysom improved the system by using a mirror to reflect solar energy over the collector arrays, which increased the thermal output to the point that water could be used instead of ether. Shuman built a full-fledged steam engine using low water pressure, which allowed him to patent the entire solar engine system in 1912. In 1912 and 1913, in Maadi, Egypt, Shuman built the world's first solar thermal power plant. The power station used parabolic troughs to power a 45 to 52 kW (60-70 horsepower) motor that pumped more

¹, Christos; FAKA, Antigoni and KALOGEROPOULOS, Kleomenis. Assessment of the Direct Sun-Light on Rural Road Network through Solar Radiation Analysis Using GIS. Online. *Open Journal of Applied Sciences*. 2013, year 03, no. 02, p. 224-231. ISSN 2165-3917. Available from: <https://doi.org/10.4236/ojapps.2013.32030>.

² SZABO, Lorand. The history of using solar energy. Online. In: *2017 International Conference on Modern Power Systems (MPS)*. IEEE, 2017, p. 1-8. ISBN 978-1-5090-6565-3. Available from: <https://doi.org/10.1109/MPS.2017.7974451>.

than 22,000 litres of water per minute from the Nile to neighbouring cotton plantations. Although the outbreak of World War I and the discovery of cheap oil in the 1930s halted the development of solar energy, Shuman's vision and basic idea were resurrected in the 1970s, when interest in solar thermal energy increased ³.

2.3.3 Use of solar radiation

Solar radiation from the point of view of technology, we can use it actively, through solar systems that serve to convert the energy of solar radiation into heat or electricity, or passively through solar architecture, which appropriate application in the affected area or we can ensure a certain energy saving for the building. Division of solar systems from the point of view of active and passive use of solar energy is shown in Figure 12.

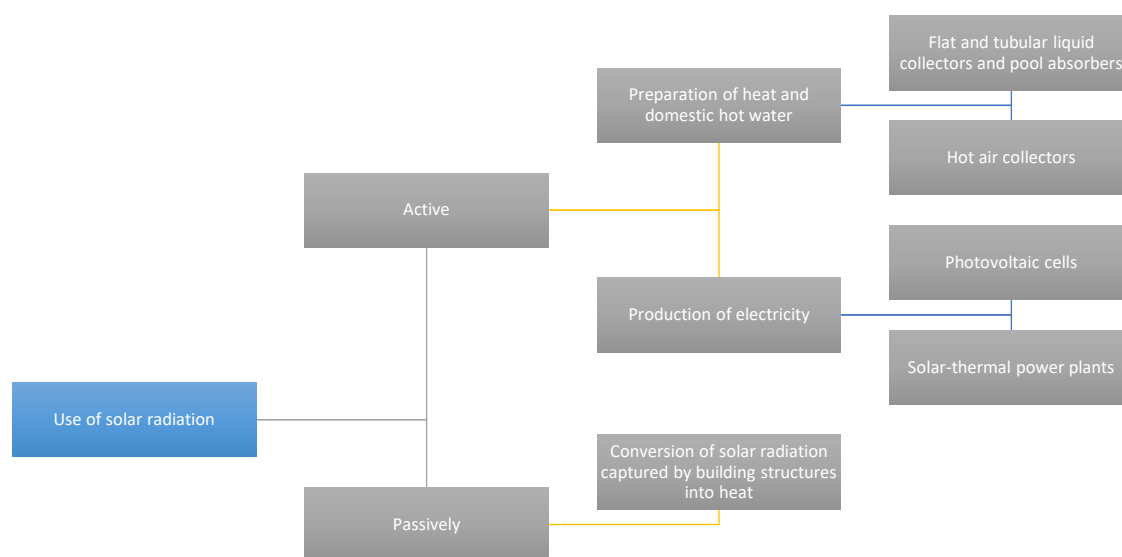


Figure 12: Use of solar radiation

2.4 Basic characteristic of solar collector

The solar system actively uses solar energy and transforms it into thermal energy. Collector, connecting pipeline and appliance they form basis solar device (Figure 13). Come by appliance we mean a storage tank (boiler) for hot water, a swimming pool, a heating system or another way of using thermal energy. Complete solar heating also includes a storage tank, electronic regulation, balancing expansion container circulatory pump, stack (boiler) is a heat exchanger, a control unit and a whole range of other fittings that are necessary for the perfect functioning of solar collectors.

³Smith, Zachary Alden; Taylor, Katrina D. (2008), Renewable and Alternative Energy Resources: A Reference Handbook, ABC-CLIO, p.174, ISBN 978-1-59884-089-6



Figure 13: Solar system for hot water heating in a family house

2.4.1 Solar collector

The basic device of solar systems for converting solar energy into heat is the solar collector. It is a receiving surface capable of falling globally (direct and absorb diffuse) solar radiation and convert it into thermal energy.

Solar radiation passes through the collector cover with certain losses and falls on absorption plate (copper, aluminium, etc.), which is called an absorber. This is usually covered with a black or selective material to increase the absorption of radiation. Absorber se warms and transfers heat through a heat carrier (water, air, brine) to the distribution pipe network. The differently shaped absorber is in contact with pipes, which must have high thermal conductivity (to ensure the transfer of heat to the heat-carrying substance).

So that it doesn't happen to losses heat to the surroundings, is an absorber with tubes placed in a well thermally insulated frame, which is covered with single or double or triple glazing. Light radiation passes through the glass cover, which increases the temperature of the heat-carrying substance. Heat losses of the collector can be reduced by creating a vacuum inside the collector and by special chemical treatment of the absorber surface (reflective coatings).

Solar collectors are placed on the roof structure of buildings as part of them, or outside buildings as a separate technical device, but such an installation requires the use of a special supporting structure.

2.4.1.1 Typology of sunny collectors

Sunny collectors perhaps split according to several criteria for example according to:

- **degree of concentration** into flat and concentration
- **heat transfer media** to liquid and air
- **method of fixing** to stable (fixed) and movable
- **location appearance to the building** on separate technical device (out buildings) and equipment forming part of the building.

According to temperature mode, on which collectors are constructed, we divide them into:

- **Low-temperature collectors** heat water to less than 50 °C and are mainly used for heating water in swimming pools.
- **Medium-temperature collectors** reach temperatures of approximately (60 to 80) °C and are most often used to prepare hot water in buildings. This includes the most common flat glazed collectors in our country.
- **High-temperature collectors** are mainly parabolic mirrors or other structures that heat up to more than 100°C. These solar devices are mainly used for the production of electricity.
- **Blind collector:** hot air sunny collector, with moving slats (blinds) inserted in it, absorbing or reflecting radiant energy.

2.4.2 Solar collector systems

Active systems based on liquid collectors are most often used for the preparation of domestic hot water, heating of pool water, occasionally for additional heating in the heating system in connection with short-term or long-term heat accumulation. All of these systems have a generally similar primary circuit design.

2.4.2.1 Elements of solar collector system

Solar collectors are only one part of solar systems. Solar system (e.g. for water heating) with composed of the following components: collectors, fittings, stack (boiler) with heat exchanger, pump, control unit, equalizing expansion tank (Figure 14).

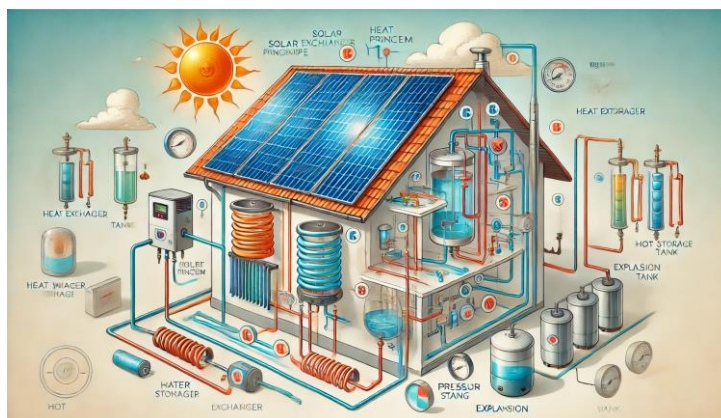


Figure 14: Principle of operation of the solar system

- a) **The circulation pump** is dimensioned according to the same procedures as for heating systems. However, it is necessary to take into account some different circumstances - different viscosity of heat-carrying substances other than water, which changes with temperature. For larger solar systems with larger collector arrays can then cause problems during the start-up in winter the time when the entire volume of the heat-carrying substance is cooled to a low temperature and the viscosity is very high.
- b) **Expansion tank** in the event of a failure of the circulation pump in period with with long sunshine it will grow in collector temperature up to 180 °C (so-called room temperature, varies by type collector a is a listed by the manufacturer). It's running out in addition to evaporation volume liquids in collectors. The expansion tank must



therefore be sized for the temperature difference given by the minimum temperature in the winter season (up to -20°C) and the maximum temperature in the summer season (up to 180°C) and for the evaporation of the volume of the heat-carrying substance from the collectors.

- c) **Flow gas separator** - most often of the spirovent type. The location of the spirovent is determined by its function. The solubility of gases in water decreases with increasing temperature and by decreasing pressure. Therefore, for a good degassing function, the Spirovent must be installed in the place with the highest temperature (just behind the collectors) and with the lowest pressure (circulation pump suction). It is not recommended to install the spirovent behind the collectors on the roof. In the event of a circulation pump failure, the collectors are prevented from overheating by leaking the heat-carrying liquid in the form of steam onto the roof.
- d) **Non-return valve** - prevents reverse circulation in primary circuit during the period when the circulation pump is not running (e.g. in at night, the heat-carrying liquid would take the heat from the reservoir, it would rise to the collectors by natural buoyancy, where it would be cooled).
- e) **Manual venting valve** – used for the first venting of the system after filling with heat transfer fluid. When the solar system is running without problems, it should not be aerated.
- f) **Accumulation container** - due to the fact that the supply of energy from solar radiation is not continuous, is a irregular how during day, so in of course of the year They are storage tanks are part of the solar system. They are produced in a special version for solar systems. The built-in tube exchanger has an enlarged area for better functioning of this system direct heat exchange. For optimal operation of the solar system, systems with upstream storage tank are more advantageous.
- g) **Differential regulator** – after exceeding the set temperature difference (usually 7°C) between the temperature in the collectors and the temperature in the storage tank, the circulation pump turns on. When the temperature difference drops to a certain set value, the circulation pump is switched off.
- h) **Exchanger** - varies according to the purpose of using the solar system (spiral in the DHW tank, plate, tube)

Piping and insulation – piping of the primary (solar) circuit from the collectors to the heat storage (exchanger) must be dimensioned to a temperature of around 150°C (in collectors with a selective layer, the room temperature during empty operation is up to 250°C) and corresponding pressures. It is therefore recommended to convert the entire pipe system from hard copper pipe. An important part is the thermal insulation of the pipeline, because thermal losses from the pipe to the surroundings would significantly reduce the overall efficiency of the solar system. It is recommended to use thermal insulation based on mineral substances, not based on plastics, for this pipe. For distribution systems in outdoor areas, it is necessary to use insulation resistant to moisture and pipes resistant to UV radiation.

2.5 Solar photovoltaic systems

Photovoltaic (PV) system converts solar energy into electricity. The term comes from the Greek word "phos" which means "light", so we can say that it is electrical energy from light. It was discovered in 1839 by Edmund Becquerel, who noticed that it is possible to produce electricity under the influence of sunlight in certain electrochemical configurations. However, **the photovoltaic phenomenon** began to be used for the direct conversion of sunlight energy into electrical energy only in 1954.

A brief history of the photovoltaic cell:

- 1839 – discovery of the photovoltaic effect in liquids by Edmund Bequerel ,
- 1870 – discovered photovoltaic effect in a solid body,
- 1880 – construction of PV device based on selenium with 1-2% efficiency,
- 1940 – 1950 – Czochralský method – “growing” a synthetic single crystal ,
- 1954 – produced photovoltaic cell with 14% efficiency,
- 1958 – use of a PV cell to supply space satellites with electrical energy,
- 1970 – the energy crisis causes an increase in interest in the use of photovoltaic cells,
- 1980 – 1990 – rapid development of PV cell production technologies.

No moving parts are needed for PV operation and the Sun is used as an energy source. As a direct result of the reduction in the price of photovoltaic cells, there is an expansion of their use - from portable personal electronic devices, through the production of electricity for family homes to space missions.

2.5.1 The principle activities photovoltaic article

The majority solar articles is made of silicon, 14. element in the periodic table of elements is a semiconductor, which means it has properties both of them materials - the driver also insulator. Atoms in metals they have free electrons that can easily move when it is brought to the conductor tension. Atoms in insulators they have firmly bound electrons whichwith he can't move. If we consider pure silicon, then under normal circumstances it behaves as an insulator. Molecules form a regular crystal lattice in which atoms are bound by the so-called: **covalent bond**. As soon as we supply a quantum of energy to the silicon structure from the outside, the electrons accept it and become free, and the silicon acquires the properties of a conductor.

We know two types semiconductor materials:

- semiconductor type P (admixtures boron in silicon plate),
- semiconductor type N (admixtures phosphorus in silicon plate).

A great advantage of semiconductors is the fact that their properties can be easily modified by introducing impurities into their crystal lattice. We divide these admixtures into:

- donors,
- acceptors.

Donors admixtures

They are such, in which after creation chemical ties with the mother a semiconductor is a part valence electrons very weakly bound. These electrons they can run over on the levels conductivity belt semiconductor and conduct electric current. Semiconductors subsidized donors with they call semiconductors type N. **Acceptor impurities** vice versa they create with a semiconductor ties that not They are completely saturated and can a flat supplemented you gave me electrons from the valence bands maternal semiconductor . In the valence bands semiconductor is like that less electrons and on relevant energy levels after them they will stay empty places, so called holes. Since valence belt will be like this only partially filled, they can electrons in it lead electric current. Semiconductors subsidized acceptors with them call semiconductors type P.

Basically photovoltaic of the cell is a PN junction, i.e. an interface between conductivities of type P and type N. Diffusion occurs here electrons from the region of type N to the area type P and diffusion holes opposite towards.

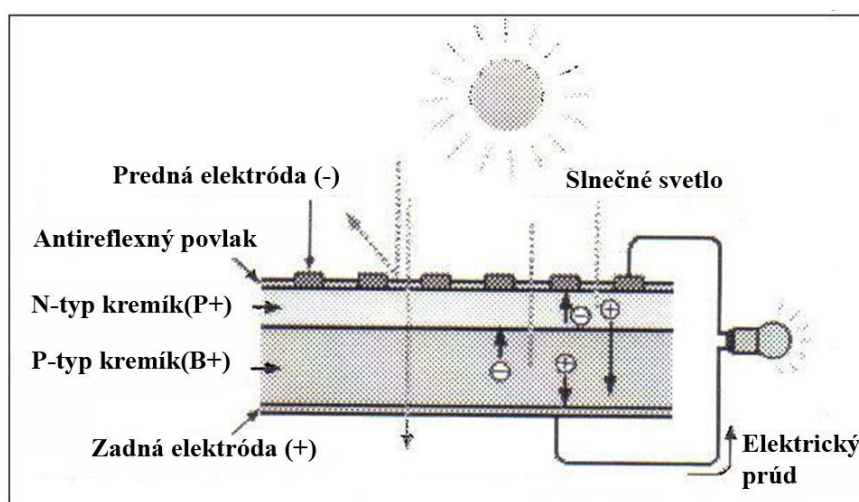


Figure 15: Working principle of a solar cell

2.5.1.1 Conversion sunny lights

On the level light is made of atoms flow of pure particles energy, the so-called **photons**. Flow clean energy comes from the sun and falls on solar panels Articles. Photons they penetrate the crystal lattice and randomly they collide on the atoms silicon. When photon collides with atom silicon, will transfer its energy to the electrons on the valence layers, which will cause them to be released. An atom that has lost an electron becomes a positive ion and tries to fill the valence sphere with the full number of electrons, thus "tearing" an electron from a neighbouring atom. A gradual "relocation of the hole", that is, an electric current, occurs.

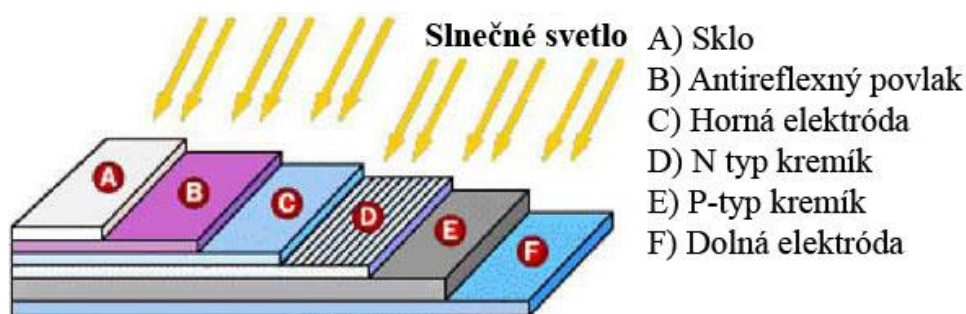


Figure 16: Parts of a photovoltaic cell

A typical solar cell consists of a glass cover that covers the cell, then an anti -reflective layer that maximizes the incoming light, front and back contact respectively. Electrodes and semiconductor layers where electrons start their journey (Figure 16). The electric current stimulated by sunlight is collected at the front electrode and passes through the circuit back to the solar cells through the back electrodes.

Photovoltaic devices

They are reliable and their maintenance is simple. Production electrical energy from the sun does not produce none harmful substances or noise, which is one of the reasons Why with like

this devices placed in urban planning centres. There are also solar systems with accumulators available, which is possible to use to use also when it's cloudy or at night. In case of necessity continuous operation is possible take advantage of photovoltaic generator systems. When photovoltaic an article does not give current turns on with generator which uses energy stored in accumulators.

2.5.2 Photovoltaic articles and modules

Solar modules (or photovoltaic components system) are basis system. Exactly they transform sunny rays on the usable electric energy.

Solar module (or panel) consists of several photovoltaic articles which are serially or parallel connected by using the driver. Quantity energy produced through solar modules depends on number of articles in the module and the way in which these Articles are connected. When the articles are connected serially resulting tension with equal amount tension all articles. In case parallel involvement with intensity electrical current equal amount intensity all articles and results tension with equal voltage manufactured on the once of the article. Every article in the module usually produces 2 to 5 amps about 0.5 V (amount which ones produces ordinary battery for flash). Articles are organized into modules with a purpose to reach necessary voltage and current. By multiplication output voltage with output current is possible to calculate overall obtained energy (in watts). Most often with on the market occur Articles combined into modules provide 12 V, 24 V or 36 V.

In the same way how photovoltaic Articles also solar modules is possible connect so that they generate required voltage and current. Connecting solar panels into different configurations (fig. 13) is possible to regulate what kind tension or intensity current will be in the circuit, which is given system which made electric energy will be consume.

2.5.3 Photovoltaic system

Alone photovoltaic an article it does not produce usable power and its combination with other system components is necessary. Photovoltaic systems can work alone or within a network. The main one difference between by these two types system is that photovoltaic system generates energy in parallel with electricity network and if it is not used, it can be returned to the distribution network.

When lights up sun, unidirectional current from photovoltaics modules with transforms on the alternating by using electronic converter and goes to the distribution one system buildings. Possible excess energy with sends to the network and in the event that supplied energy not enough, he will use with energy from the grid, which supplies the building especially during frowning days. Depending on the use photovoltaic modules with they can to install on the roofs, in parking lots structures, roofs tanks or open fields (Figure 17).

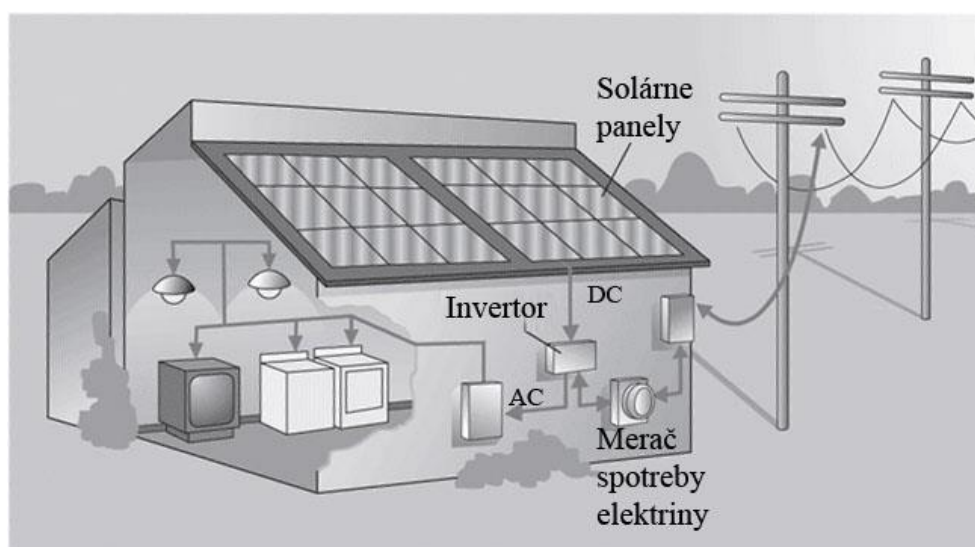


Figure 17: Basic parts of a system for supplying energy using a photovoltaic system connected to the distribution network

2.5.3.1 Efficiency photovoltaic panels

Efficiency transformations of light, incident on the photovoltaic article, on electric energy is the most important parameter of the PV cell. On the total efficiency has influence for example:

- cleanliness surface
- reflections on the surface
 - angle impact
 - reflectivity surface
- serial resistance (so - called ohmic losses):
 - semiconductor
 - contacts

Losses in the connections between cells, the efficiency of power electronics, or the efficiency of energy storage and recovery in accumulators also add to the overall efficiency of the entire photovoltaic system. Since the illuminated part of the cell also fulfils the function of a contact and diverts the produced current, it is important that it offers the smallest possible resistance and therefore that it dissipates the obtained energy with the smallest possible losses.

Table 2 shows the efficiency of photovoltaic cells depending on the type of substrate.

Table 2 Energy efficiency of different types of modules

Type photovoltaic article	efficiency
amorphous silicon	4-8%
polycrystalline silicon	10-18.5%
polycrystalline silicon	13 - 17%
high performance monocrystalline cells	34%

2.6 Wind Energy

Wind energy is energy from renewable sources contained in the force of the wind that blows on the earth's surface. Wind is caused by the movement of air masses with different temperatures. Different temperatures cause different properties of water and soil to absorb solar heat. Wind is created when the Earth is unevenly heated by the Sun, which creates air movement. The kinetic energy of the wind can be used to turn a turbine, which then generates electricity. On a global scale, massive air movements are caused by the temperature difference between the equator and the poles.

This form of energy is practically inexhaustible and has been known since ancient times, when it was used to move sailboats and windmills. Currently, wind energy is converted into electricity using wind turbines. A more precise description can be found on Wikipedia (http://sk.wikipedia.org/wiki/Veterná_energia). Wind energy is the energy obtained from the wind through wind turbines to produce electricity, windmills convert wind energy into mechanical energy, wind pumps are used to pump water or sails to power ships.

2.6.1 History of wind energy use

Persian windmills had windmill arms made of bundles of reeds that rotated around a vertical axis and were used to grind grain. They were used by the Persians in the seventh century BC. Later, the mills were oriented in the direction of the wind and the sails were designed to capture more wind energy.



Figure 18: A windmill with a vertical axis and a windmill with a rose made of sails

2.6.1.1 Windmills in Europe

The first windmills were built in Europe in the 12th century in northern France and southern England, and subsequently spread to Belgium, Germany and Denmark. European windmills were used to grind grain, cut logs, crush tobacco, make paper, press linseed for oil, and grind stone to obtain paint for paintings.

The Europeans developed windmills with rotors that spin around a horizontal axis, unlike the Persians who used the principle of a vertical axis. A typical European windmill had four rosette leaves, occasionally windmills had five or six leaves. Many of these European windmills had two or three floors where they stored goods (grain, paint, tobacco).

The first European windmills were capable of producing 25-30 kW of mechanical power, but at the peak of their development, at the end of the 19th century, they could produce approximately 1500 MW. This value was not exceeded until 1998. American farm windmills were mainly used to pump water from wells for agricultural needs in the western states of the USA. American windmills were a safe and efficient way to draw water from great depths.

However, they only produced about one-tenth the power of a correspondingly sized wind turbine. Therefore, they are not suitable for the production of electricity.

Windmills were popular on farms in the early 20th century. More than one million of these mills are still in operation worldwide. In the years 1850-1970, more than six million of them were built in the USA.

The electrification of homes in the 1930s spurred the development of wind turbines that charged batteries. The so-called wind chargers were the forerunners of today's wind turbines with two or three leaves of a wind rose, which are used to generate electricity for remote dwellings and buildings, and also supply energy to villages in developing countries. Modern wind turbines generate approximately 250-300 kW of energy, almost 10 times more than traditional European turbines of the same size.

2.6.2 Wind turbines: components and distribution

A wind turbine works in the opposite way to a fan. Instead of using electricity to "produce" wind, a wind turbine uses the wind to produce electricity. Wind turbines are devices that convert the kinetic energy of the propeller into mechanical energy. If the mechanical energy is then converted into electrical energy, we get wind-driven green wind energy. Wind turbines are connected to a medium-high voltage, which is converted into a high-voltage electric current by a transformer, which is supplied to the distribution network. A properly designed turbine, located in an unobstructed area and with the right wind, can meet the demand for electricity.

2.6.2.1 Wind turbine components

- **Anemometer:** device on the measurement speed wind, speed information transfers to the control room units.
- **Propeller:** leaves propellers with they rotate when wind it blows above by them and so on they spin the rotor. The majority turbine they have either two or three leaves propellers.
- **Brakes:** in case needs or danger they stop the rotor mechanically, electrically or hydraulically.
- **Controlling unit :** starts the rotor at speed wind about 8 to 16 miles per hour (mph) and shuts off device probably at 55 mph. Turbines do not work at speed wind above 55 mph, how much strong wind can turbine to damage
- **Gearbox:** connects low speed shaft with high speed shaft and increases revolutions from about 30 to 60 revolutions per minute (RPM) at about 1,000-1,800 rpm. This one speed turning requires the majority generators on the production electrical energy. The gearbox is an expensive (and heavy) part windy turbines a engineers they are investigating option of use so called "Direct Drive " generators that they work at lower ones revolutions and do not need gearbox .
- **Generator:** generates alternating stream; it is usually inductive generator.
- **High speed shaft:** drives generator.
- **Low speed shaft:** his the speed is about 30-60 revolutions per minute.
- **Gondola:** it is located on towers and contains gearbox, low and high speed shaft, generator, control unit and brake. Some gondolas They are enough big to on them he could to land helicopter.
- **Letters propeller:** blades (blades) of a propeller affect revolutions rotor and maintain them so that they are not too much high or low on the production electricity.
- **Rotor:** leaves a axis, on which They are caught form a rotor.

- **Tower:** it is made of steel pipes, concrete a steel grids. Given that speed wind with increases with height, higher towers they allow turbines to capture more windy energy and so on to produce more electrical energy.
- **Wind direction:** determines construction turbines.
- **Pinwheel :** measures direction wind a sends information to the management unit , which correctly will set turbine relative to the direction wind ;
- **Rotation engine turbines:** turns turbine against the wind after the wind filmed turbines do not require bottling leaves becausewind it blows so that turns the rotor away. (according to <http://energy.gov/eere/wind/inside-wind-turbine-0>).

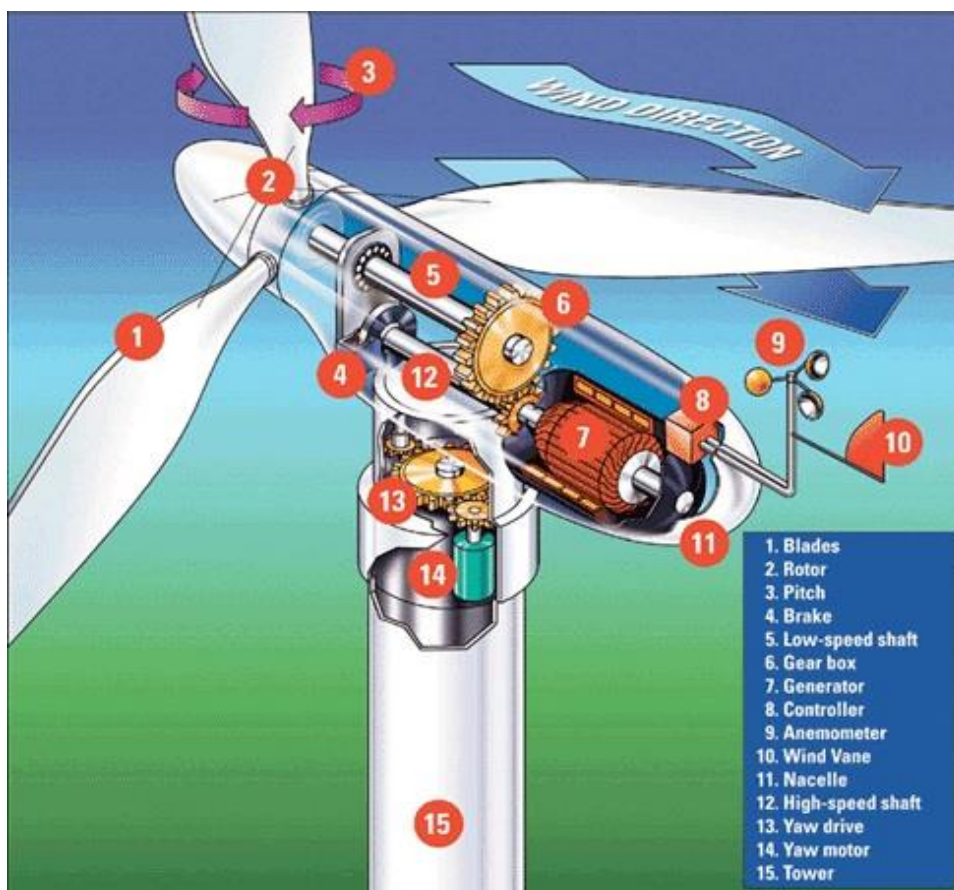


Figure 19: Wind turbine components

Wind turbines can be divided according to several criteria:

Depending on the axis of rotation

Wind turbines with along the horizontal axis (HAWT, Figure 20) have a rotor and an electric voltage generator in the upper part of the tower. Small turbines are directly driven by low wind speeds, while larger turbines usually use a servo motor. This requires a gearbox that changes the slow rotation of the blades into a faster rotation of the generator so that the speed is suitable for the production of electricity. Due to the fact that the tower is exposed to turbulence, the turbine is usually placed against the direction of wind action on the tower. The blades of the turbine are of a solid construction, which will prevent them from being deformed by strong winds.



Figure 20: Turbine with horizontal axis (source: https://en.wikipedia.org/wiki/Wind_turbine)

The advantages of using HAWT are:

- propeller with located nearby centre of gravity turbines , what increases stability towers
- filming propeller in direction wind represents the most suitable angle leaves propellers and teams allows to maximize energetic efficiency
- edges propeller is possible fold down so that prevented destruction turbines when the wind is too much strong.

The disadvantages of using HAWT are:

- because of windy turbulences HAWT turbine efficiency decreases with height towers
- transport tower and propeller with long the blade is problematic, costs on the transportation they can to reach up to 20% of the price devices
- the installation of a HAWT turbine is complex and requires cranes and qualified workers
- high turbines they can to create obstacles for radars aviation basic
- due to their height , tower turbines has unfavourable impact on the scenery countries
- turbines with rear propeller they have low visibility because of air turbulences.

Vertical axis wind turbines (VAWT, Figure 21) have the main axis of the rotor arranged vertically. In this type of turbine, the axis is vertical, the generator and all sophisticated components are located at the base of the turbine, which makes installation and maintenance easier. Instead of a tower, this type of turbine uses support wires and the rotor is placed close to the ground. These turbines are always oriented in accordance with the wind direction, so no

adjustment is necessary if the wind direction changes. However, they are located close to the ground where the wind speed is low, so they have relatively little efficiency.

The advantages of using VAWT are:

- easier with they maintain , because movable parts They are placed closer to the ground
- leaves propellers They are vertically, so for setting the right one orientation propellers not a " rudder " is needed
- thanks to his own shape they have vertically turbines high aerodynamic efficiency at high also low pressure
- at the same average propellers they have shoulder blades turbines with vertical axis bigger average how turbines with horizontal axis
- VAWT turbines They are more effective in turbulent areas by the wind , because leaves propellers They are placed closer to the ground
- their smaller height allows installation even in places where legal adjustment does not allow to build too much high buildings
- They don't need VAWT tower , on top which they have a flat installed , so They are Cheaper a more durable towards strong by the wind
- tips leaves propellers they have smaller angular speed , so VAWT better they resist strong the wind how turbines with horizontal axis
- VAWTs don't have to a flat oriented downwind, so with effectively they give to use even in areas with turbulent by the wind
- VAWTs can a flat constructed also in bigger ones dimensions, mechanisms, which completely they turn, however, already they require expensive and special bearings.



Figure 21: Turbine with vertical axis

The disadvantages of using VAWT are:

- VAWT efficiency represents on average only 50% efficiency of HAWT
- must a flat installed on the straight away surface

- most VAWTs need have got electric motor, which is switched on at unsuitable weather conditions – weak wind
- VAWT, which They are anchored by using supportive ropes, cause mechanical stress clamping mechanism driving shaft
- the majority part of the VAWT turbine is located in the lower parts, so is required when replacing them disassembly whole construction (<http://www.energie-eoliana.com/avantaje-dezavantaje-turbine-eoliene/>).

Depending on the location of the propeller blades

Depending on the location of the propeller blades, we distinguish two types of turbines:

- against wind (wind reaches at the earliest leaves propellers and then gondola) - known Too how windward turbine
- in the direction wind (wind at the earliest reaches gondola and then blades) – leeward turbine.



Figure 22: Wind turbine



Figure 23: Wind turbine

Wind turbine

The rotor of the wind turbine is located at the front of the device, similar to a propeller plane. This is the most common type of small turbine. If you want to maintain the orientation of the propeller towards the wind, it is necessary to have a wind vane available.

Advantages: less influence of tower shielding. The wind first hits the blades of the propeller and then passes around the tower. Any power loss from shielding is significantly smaller than in the case of a leeward turbine.

Disadvantages: the extended nacelle requires the rotor to be located far enough from the tower to avoid problems with propeller blades. Propeller blades must be made of solid material to prevent them from bending towards the tower. This means that the place where the blades are attached to the rotor will be very stressed at high impact speeds.

Wind turbine

The rotor is located on the back side of the turbine. The nacelle is usually designed to find the wind on its own, so there is no need for a separate turning mechanism.

Advantages: the rotor blades can be flexible because there is no danger of them hitting the tower. Flexible rotor blades have two advantages:

- They are less costly ;
- mitigate tension on the towers at high speeds wind or impactful weather conditions , because flexible material allows to some pressure wind convert directly on the shoulder blades the place on the the tower

Disadvantages: the advantage of flexible propeller blades also represents a certain disadvantage, as springing causes blade fatigue. The wind shadow of the tower presents a problem for the leeward turbine as the rotor blades actually move behind the tower. This fact can cause turbulence and thus increased fatigue of the material from which the wind turbine is constructed. (<http://www.power-talk.net/upwind-turbine.html>)

Depending on the number of rotor blades

Depending on the number of rotor blades, there are two types of turbines:

- turbines with two leaves ;
- turbines with three leaves (most often).

Depending on the location

Depending on the location, the turbine can be placed in water or on land.

2.6.3 Wind farms: location types; how to build a wind farm

The global potential of wind energy is five times greater than its current use. However, such a rate of use would require covering 12.7% of the earth's surface (excluding oceans) with wind farms, assuming that 6 large wind turbines were placed for every square kilometre. These figures do not take into account improvements in turbine efficiency and technologies used. Wind energy is now widely used and new wind turbines are being built all over the world. Wind energy is the energy source with the fastest growth in recent years. In the period 1995 - 2005, the annual growth rate was about 30%, resulting in a total installed capacity of 32,000 MW, double that of nuclear power over the same period. Current areas that use wind energy:

- production electrical energy
- pumping water from wells and wells
- transformation mechanical energy on the thermal
- deliveries electrical energy for households.

Wind systems provide energy for

- separately networks
- centrally energetic networks
- remote power supply
- supportive network for the time energy spikes
- reduction risks fluctuations prices energy
- reducing transmission and distribution loss.

2.6.4 Wind farms

Wind farms represent groups of wind turbines located close to each other, for the purpose of producing electricity from the wind. The wind turbines are connected to medium high voltage, which the transformer subsequently converts to high voltage, which is supplied to the distribution system. Whether an area is suitable for the use of wind energy depends on **the year-round wind speed** (at least 15 km/h), **altitude** (higher altitude means higher wind speed, due to low wind viscosity), **terrain conditions** and year-round **temperature** (low temperatures require lubricating fluids with low freezing point, more durable materials and even installation of heating systems for wind turbines).

Depending on the location where the wind park is installed, we distinguish three types of locations:

- **Inland** - windy turbines They are placed 3 or more kilometers from coasts . The place must take into account effects acceleration flow air through obstacle (in this case shore). From that reason wrong location can to mean massive decline quantity produced electrical energy. Exist studies, carried out during at least one year, how to determine correctly place for installation windy parks.
- **On the coast** - there are wind parks placed from coast a maximum of 3 km inland or up to 10 km in the direction of the sea. These windy ones farms they use flow air arising thanks temperature difference between temperature water and soil. Some problems with they concern migration birds, influence on the aqueous habitats, transport and visual effect.
- **In the sea** - windy turbines are located in the sea more as 10 km from the coast. They do not cause negative visual they don't even create an effect none noise. They work at higher average speed wind. Between disadvantages are listed above costs for their construction, establishment and maintenance (in particular those that are placed in salty water which has high corrosive effect). If the distance from coast enough big, these windy farms they can directly to produce high tension.

2.6.4.1 *How to build a wind farm*

Identification of wind potential: the measurement is carried out for at least a year and the results can be extrapolated using specialized software.

Acquiring the necessary land for the construction of a wind park: through acquisition, leasing, property ownership, etc. And designing a wind farm for the optimal potential of the territory. It often happens that the most suitable turbine for the plant is not available at the time of construction because the contractors are not able to supply it in a reasonable time. In many cases, the equipment that can be obtained the fastest is then used, even if the optimal use of the wind potential of the territory is not ensured.

Creating a feasibility study: it must demonstrate the rate of profitability and the return period of the investment in accordance with the expectation of investors in order to convince the investor to finance the project.

Choosing a solution for connecting the wind farm to the electricity network (distribution, transport): most often it is the investment of the company implementing the construction. It then passes into public property or the property of the distributor. The amount of investment has a significant impact on the feasibility of the project, especially if the station connection will be far from the wind farm.

Project approval: the number and types of approvals vary from case to case, but are generally very high. Depending on the location where the wind farm will be located, the building permits issued by the authorities also differ. Obtaining a permit from the environmental authorities is a very complex process, in many cases an environmental impact study is required. Additional permissions must be obtained from the aviation authorities. The basic plan for the construction of the wind park must first be presented to the authorities, and then the authorities must also comment on the detailed plan.

Contracting of equipment: equipment (wind generators) must be contracted as quickly as possible. Due to the global crisis, demands are increasing in markets such as China and India, delivery dates often take years.

General contractor: a general construction contractor is needed to handle the installation of the wind farm. This phase is quite complex. For example, if a wind turbine has rotor blades 45m long, it is installed at a height of 90m. However, mounting at such heights requires special equipment, which is not easy to provide. The most suitable figure for determining the economic

performance of a wind farm is the amount of delivered energy per year. Not all produced energy is supplied to the consumer. Part of it is used to drive own equipment and light the power plant. About 90% of the energy produced in the wind park is delivered to the consumer and the remaining 10% is used for own needs.

2.6.5 Profit and return of wind energy

A small wind turbine with an output of 100 - 2000 W (Watt - unit of measurement of power) can be easily installed and operated by a user with minimal knowledge of mechanics and electrical engineering. A small power wind turbine is usually installed on a pole at a sufficient height. It can also be installed on the roofs of buildings, if they are not an obstacle to the wind. The goal of using small wind turbines is to reduce budget expenses, maximize the use of natural resources and reduce significant energy costs. Regions with high electricity prices could thus save significantly, since the costs of building and operating a small wind turbine are not high.

2.6.5.1 Wind turbine profitability analysis

A wind turbine profitability analysis includes the following:

- option location windy turbines in given place and dependence on the speed wind ;
- initial costs on the installation windy turbines
- overall costs , interest loan rate
- lifespan windy turbines
- costs on the operation and maintenance
- average shop the price energy produced windy turbine.

A detailed analysis of profitability with the above indicators must be prepared before financial investments are made in this area. Investors can perform an initial analysis of profitability based on data obtained from existing tables.

2.6.5.2 Wind farm return

From the point of view of quality, reliability is the ability of the wind turbine to work with the required parameters without damage and in precisely defined operating conditions for a specified period of time. From a quantitative point of view, the reliability of a wind turbine is defined as the probability that it will work without failure with the required parameters and in precisely defined operating conditions for a specified period of time. Device reliability is an attribute that should not be ignored. Maintainability is the ability of the wind power plant/turbine (and its components) to reach such a technical state through repairs that it can meet functional requirements. Maintainability represents the probability that repairs can be carried out on a given system (or element) by a given time. The performance of the system itself is conditioned by how the components perform their own functions, which leads to the conclusion that the reliability of the system depends on the reliability of the individual parts.

Reliability depends on:

- analysis disorders (causes , occurrence and development processes , methods repairs)
- quantitative evaluations performance individual of products in time and in dependence from internal and external influencing factors
- introduction methods and models for calculation and forecasts reliability , based on the specific ones testing and monitoring performance products

- introduction structural , technological and operational methods on the retention and increase reliability systems , devices and components
- creation methods on the selection and processing reliability information products
- determination optimal values indicators reliability.

Small wind power plants (with a maximum output of 100 kW) are often the cheapest way to generate clean electricity, e.g. under suitable conditions, they represent a very cost-effective option for rural electrification. Although small wind systems involve relatively high initial investments, they can be competitive with conventional energy sources in terms of long-term returns, especially when the rising prices of conventional fuels are taken into account.

The cost of wind turbine systems has two components: initial installation costs and operating costs. Installation costs are the purchase price of the entire system (including tower, wiring, technical connection of equipment and batteries, power supply, etc.), energy transmission costs, licenses, royalties and fees.

Criteria for placing wind turbines:

- availability of wind with a constant speed suitable for the required size windy turbines
- hedging even flow air for the most part of the year
- appropriate locations represent hills , rounded hills and coastal areas
- inappropriate They are rocky terrains, sharp and uneven obstacles (forests, walls, structures, etc.)
- on the basis meteorological map suitable distribution frequency speed wind
- directional fluctuation there should be no wind be in short era big.

Small wind turbines start producing electricity at a wind speed of 3.5 - 4 m/s. Up to this speed, even when the rotor is spinning, no electrical voltage is generated. The exception is only very small wind power plants that have very little power, below 100W or even lower, which will allow voltage generation already at a wind speed of about 2-3 m/s. A small wind turbine does not require any special maintenance, it is reliable and its service life can be very long, unless it is damaged by a strong storm. The energy obtained by the wind turbine can be processed and used in several ways. In isolated communities that would otherwise use diesel generators, wind turbines can be used as an alternative. Individuals may purchase these systems to reduce or eliminate their dependence on electricity grids for economic reasons or to reduce their carbon emissions into the air (the so-called carbon footprint). Wind turbines have been used to generate electricity for households in remote areas for decades. (http://en.wikipedia.org/wiki/Wind_power#Small-scale_wind_power)

Users of off-grid systems can either adapt to intermittent power supply or use batteries, photovoltaic or diesel systems as a complement to the wind turbine. Devices such as parking meters, warning traffic signs, public lighting or Wi-Fi access points can also be powered by small wind turbines, or they can be connected to a photovoltaic system that charges small batteries, replacing the need to connect to the electricity grid.

2.7 Biomass

Obtaining energy from biomass is one of the oldest energy technologies used by mankind. Biomass has been used for the production of heat and light since the Early Stone Age and was the main source of energy for more than 400,000 years. It lost this primacy only with the advent of fossil fuels and electrification.

Biomass is biological material suitable for energy use, which is found in nature or is the result of human activity. Basically, it is solar energy stored by plants and transformed into organic

matter through photosynthesis. Whether biomass is in the form of wood, plants or waste from agricultural production, including waste from livestock, they can provide useful forms of energy:

- electric energy
- heat
- liquid motor fuels vehicles.

Biomass is one of the most important renewable energy sources, moreover, it represents a domestic source of energy whose volume of production and the associated price of fuel can be predicted with sufficient accuracy for the future.

Biomass is biological material derived from living or recently living organisms. Most often, these are plants or materials of plant origin, which are specifically called lignocellulosic biomass. As an energy source, biomass can be used either directly through combustion to produce heat or indirectly after conversion in the form of various biofuels. The conversion of biomass into biofuels can be achieved in different ways, which can be divided into: thermal, chemical and biochemical methods. We can obtain other usable forms of energy from biomass, such as methane or fuels such as ethanol and biodiesel. Rotting garbage and waste from agricultural production or municipal waste release methane, also called "landfill gas" or "biogas." Crops such as corn and sugarcane can be fermented to produce the fuel ethanol. Biodiesel and other fuels can be made from leftover food products, such as vegetable oils and animal fats. Research is also ongoing in the field of liquid biomass (BTLS) and ethanol from cellulose.

2.7.1 Types of biomass

According to the EU Directive on renewable energy sources ⁴, the term "biomass" describes the biodegradable parts of products, waste and residues of biological origin from agriculture (including plant and animal matter), forestry and related industries, including fishing and aquaculture, as well as biodegradable parts from industrial and municipal waste. Biomass includes a wide range of raw materials such as wood, agricultural crops, by-products of wood processing, products of the agricultural and forestry industry, manure and the organic fraction of waste (Table 3).

Table 3 Sources for biomass

Rural resources:	City resources:
residues from forestry production and wood waste	wood waste
residues of agricultural crops	gas from liquid fuels
Energy crops	biogas from wastewater treatment plants
Fertilizer from biogas production/animal production	residues from food production

2.7.1.1 Residues from forestry production

Residues from forestry production are defined as biomass that remains in forests where logging took place and its composition is almost identical to forest cover. Because only wood of a certain quality can be used for industrial processing and sawmills, biomass - surplus wood - is

⁴ <https://eur-lex.europa.eu/eli/dir/2018/2001/oj>

left in the forests as waste. This wood waste can be logging residues, trees that are too small, rough or rotten wood. These residues can be collected after logging and used for energy purposes. Usually, this waste is either left in the forest or burned in accordance with forest management programs.



2.7.1.2 Animal production

Manure

Fertilizer biogas is a product of animal production, when manure is decomposed anaerobically (without access to oxygen) in digestion tanks. Livestock production uses anaerobic digestion to reduce odors and pathogens as well as effectively separate the solid and liquid parts of sludge for use as fertilizer or irrigation water. Composting devices are specially designed composters that optimize the production of biogas during the decomposition of manure. Biogas obtained from manure fermentation typically contains 60 to 80 percent methane, depending on the animal species and the manure recovery system, resulting in an energy value of approximately 600 to 800 BTU (British Thermal Unit) per standard cubic foot. The rest of the biogas consists of CO₂ and a trace amount of hydrogen sulfide.

Poultry droppings

Poultry droppings, or manure is organic material, poultry waste, which consists of animal feces and urine. Poultry droppings are a mixture of manure with some bedding or bedding materials (shavings or sawdust) and feathers. It has a calorific value of 9-15 GJ/t, which is a value slightly lower than that of wood. The moisture content is between 20 and 50%, depending on the method of poultry farming.



Cattle breeding

The way cattle are raised can significantly affect the amount and quality of manure that can be supplied to the anaerobic digestion process. The number of cows, the method of housing and transport determine the amount of sludge produced and thus also the amount of energy produced. Cattle breeding can be done using different methods. The most commonly used systems include free runs, pens with paved feeding lanes, and a number of open systems. Commonly used methods of manure removal in livestock farming depend on its consistency. Manure is liquid and pumpable, manure with a higher dry matter content is removed from the barn by mobile mechanisms.

Sheep farming

Sheep manure, like other animal fertilizers, is a slow-release natural fertilizer. The nutrients in sheep manure provide adequate nutrition for the garden. It contains a higher proportion of phosphorus and potassium, elements necessary for optimal plant growth. Sheep manure can

also be used as organic compost. Due to its weak smell, sheep manure can be used to fertilize ornamental gardens.



Pig farming

Pig manure (urea) has a solid consistency and is a significant source of nutrients. It is obtained either directly from grazing animals or is collected in a urine pit from litter placed on a wooden lid so that it is able to absorb urine. Grazing animals naturally spread urea throughout the area where they graze. In stabled pigs, urine is collected in a urine pit, on which a wooden lid is placed, which captures coarse dirt. The urine is taken out of the urine pit every few months.



Urea is usually applied on the surface, in some cases it can be incorporated into the soil. Composting is another option for producing solid manure.

As in the case of cattle manure, urea can also be used as a source substrate for anaerobic digestion.

Waste from slaughterhouses and fishing

Slaughterhouse waste is defined as unconsumed animal body parts in food industry processes. This waste can come from a number of sources, including slaughterhouses, restaurants, shops and farms. Abattoir waste is a potential hazard to the environment and human or animal health. The EU regulation on animal by-products (2003) states that these animal wastes must be safely disposed of, which can be a very expensive process, but this type of waste can also be used as a substrate for anaerobic digestion.

Organic solid municipal waste (PKO)

Organic PKO is any waste collected from commercial or residential buildings, such as food waste, paper, etc.

2.7.1.3 Energy plants

Energy crops are grown specifically for their calorific value. There are several crops that can easily be used as a source of energy. Cutting forest with a short felling period (KRD) or fast-growing grass stand (RRD) are plantations of fast-growing trees - woody plants (such as agave, poplar, or willow) on land for agricultural or cultivation purposes.

Clearcutting forest with a short felling period (KRD)

Some fast-growing trees can be cut down to a low stump (or stem) before winter and produce many new stems the following growing season.



Such a practice has been carried out for many years in Great Britain and in Europe and has been a traditional method of forest management and wood production for various purposes, including charcoal, fencing and shipbuilding, for several hundred years.

Coppice forest from the first harvest are expected to be in the range of 7-12 t of dry material per hectare per year. Breeding new varieties can bring significantly higher yields. A coppice forest with KRD of approximately 3000 ha can generate up to 5 MW of energy through gasification.

Miscanthus

Miscanthus (commonly known as elephant grass) is a high-energy crop that grows over 3 meters tall and resembles bamboo. It yields every year without the need for replanting. Fast growth, low mineral content and high biomass yield make it a popular biofuel, more suitable than corn or other alternatives. Miscanthus is mainly used for both energy and non-energy uses. It is a valuable crop that offers great benefits to many sectors of agriculture and beyond.

2.7.1.4 Pellets

Wood pellets are made from dried and thickened sawdust, shavings or wood powder. The production of pellets is currently the most economical way of storing energy and converting biomass into fuel with high energy efficiency and quality. For this reason, it is one of the fastest developing methods of modern biomass use in Europe and throughout the world. Pellets can be used both for household heating and for commercial heating and electricity production. World annual production exceeded 12 million tons in 2010 and could grow to more than 100,000,000 t in 2020. Europe currently represents the largest market for pellets.



Environmental advantages of wood pellets:

- wooden pellets They are carbon neutral
- transition from coal on the earthy gas will reduce emissions greenhouse gases by 50%
- transition from coal on the wooden pellets will reduce emissions greenhouse gases 100.

2.7.1.5 Wood chips

Chips are 2-4 cm long pieces of wood that are made by chipping wood waste, e.g. from the thinning of stands or branches or from waste products of the wood industry. The advantage of wood chips is that they dry faster and also enable automatic operation of boilers when using a fuel tank and conveyor.



Wood chips can be used as solid fuel and are a raw material for pulp production.

2.7.1.6 Other biogenic fuels

In addition to the above-mentioned fuels such as biomass, the following plant products can also be used ⁵:

- straw
- wheat
- potatoes
- sugar turnip
- processing residues fruit (e.g. stones , chaff , ...)
- wooden waste from woodworking industry (sawdust , dust)
- residues from woodworking industry (e.g. from the paper industry industry)
- biogenic fuels (biodiesel from oily seeds such as canola oily methanol from cereals).

2.7.2 Production of energy from biomass

Biomass currently provides about 10% of the world's primary energy supply, it is most widespread in developing countries and is used as firewood or coal for heating and cooking. Despite the current side contribution of modern bio-energy to global energy, biomass has, in the long term, the potential to contribute much more significantly to the global energy supply. Biomass fuels include agricultural wastes, crop residues, wood, waste materials, etc. During the processing of biomass, there is no increase in the carbon dioxide content in the atmosphere, as it consumes the same amount of carbon dioxide during its growth. It is the cheapest ecological renewable energy source.

Gasification is the process of converting a solid fuel such as wood, agricultural residues or coal into a more suitable combustible gas. It is the cleanest and most efficient burning method. This process is carried out in gasification boilers, where combustible gas is generated and with the help of this gas the production of electricity is possible. Of the various gasification boilers, the bottom draft boiler is the most suitable for the production of electricity, because it produces a reduced tar content in the gas produced.

Converting biomass to energy (also called bioenergy) encompasses a wide range of different biomass types and sources, conversion options, end-user applications, and infrastructure requirements. Biomass can be obtained by cultivating suitable energy crops such as fast-growing woody plants (RRD) and grasses, etc.; by collecting residues from forest and other plant residues; from waste biomass such as organic sludge from industrial waste and organic domestic waste or other wastes. In any case, biomass must be collected before being processed into a form suitable for the chosen energy conversion technology, or obtain, transport and possibly store.

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- ⁵http://www.esru.strath.ac.uk/EandE/Web_sites/03-04/biomass/background%20info4.html

The use of biomass for energy purposes is only one of the forms of renewable energy that can be used to reduce the impacts of energy production and use in the global environment. As with other energy sources, in the case of biomass there are limitations regarding the use and applicability of biomass and they must compete not only with fossil fuels but also with other renewable energy sources such as wind and solar energy or wave energy (Peter McKendry . 2002, Bio-source technology 83 (2002) 47-54).

Restrictions on the use of biomass for energy purposes:

- production biomass on the energetic purposes in competition with others uses biomass (e.g. production food or feed)
- increase production biomass requires expansion productive soil or increase intensity production , what generates demand to increase investments on the production biomass
- acquisition energy from biomass in the present heavy ones economic conditions competes with conventional ones resources energy , in addition legal regulations in the area of life environment can evoke radically changes
- maximum utilization biomass on the energetic purposes from the global point of view is problematic appearance on the division resources biomass and consumers energy and with that related problems with transport and distribution energy.

On the other hand, there are several advantages of using biomass for energy purposes:

- eliminates negative impacts on the life environment (e.g. not increasing share of CO₂ in the atmosphere)
- this one source energy is in nature renewable
- he is a homebody source energy, what reduces the need import
- resources biomass not They are on the local level limited
- managed production biomass contributes to development country and caring for it
- effectively they can a flat utilized flammable and sometimes to the end toxic wastes.

2.7.3 Biofuels

Biofuels are produced from living organisms or by-products of metabolic processes (organic or food waste). For a fuel to be considered a biofuel, it must contain more than 80 percent renewable materials. The raw material for biofuels is created in the process of photosynthesis and is therefore often referred to as a source of solar energy. There are many advantages but also disadvantages of using biofuels as energy sources.

2.7.3.1 Solid biofuels - wood

Wood has been one of the most important fuel sources for man for many millions of years. Wood is one of the most valuable energy biomasses, 1000 kg of dry wood is equivalent to:

- 450 kg of black coal
- 520 kg of coke
- 340 kg of heating oils
- 320 kg of butane.

Wood is considered the very first source of energy for mankind. Even today, it is still the most important source of renewable energy and covers more than 9% of the world's primary energy

sources. Wood for energy purposes is as important as all other renewable energy sources (hydro, geothermal, waste, biogas, solar and liquid biofuels) (<http://www.fao.org/forestry/energy/en>). More than two billion people depend on wood for cooking and/or heating, especially in households in developing countries. This also represents an energy source available on the domestic market. Household cooking and heating with wood fuel accounts for one-third of global renewable energy consumption, making wood the world's most decentralized energy. Wood-based fuels are very important forest products. Global production of firewood exceeds production of industrial logs in terms of volume. Fuelwood and charcoal production are often the predominant use of woody biomass in developing countries and economies in transition. Today, due to climate change and energy security concerns, wood for energy purposes has entered a new phase of importance. Wood for energy purposes is considered a climate-neutral and socially viable source of energy from renewable sources, but only if it meets the following conditions:

- the wood is sourced sustainably managed resources (forests , trees outside forests etc.)
- has corresponding to parameters fuel (content water , calorific value , shape , etc.)
- effective burning or gasification minimizes internal and external emissions
- utilization wooden fibres according to used material and their repetition use and recycling by use on the production energy.

2.7.3.2 *Solid biofuels - straw*

Waste from agricultural production is a very important resource in terms of energy content. This group mainly includes straw or manure. Today, these resources are intensively used in several countries, including developing ones. Straw has a higher specific calorific value than brown coal and is used as heating fuel in many developed countries today. The construction of straw incinerators in developed countries has been supported partly for reasons of environmental protection (burning straw in fields is prohibited) and partly because it is economically advantageous and such incinerators provide an additional source of income for farmers. Looking at the fields, it is evident that millions of tons of straw are left unused. Much of it is often burned, buried, or left to rot. The effort to remove waste from the fields leads to an important question: how much waste should remain in the fields to ensure sustainable production? Based on the experience of developed countries, it is possible to collect up to 35% of waste from the fields without any problems, without having an adverse impact on the quality of the soil and future plant production. The energy content hidden in the straw is considerable - 4.9 kWh.kg⁻¹ of dry matter or 4.0 kWh.kg⁻¹ for straw with a moisture content of about 15%. The energy contained in 1 m³ of compressed straw thus represents about 500 kWh.

Energy utilization of straw has several positive impacts on society. Above all, it brings new job opportunities and at the same time provides farmers with the possibility of financial savings through energy savings. The burning of straw also brings certain limitations, and today its use is concentrated only in large boiler houses, usually connected to a centralized heat supply system or to agricultural enterprises. This is related to the fact that straw is a rather complex fuel, above all it is inhomogeneous and in terms of energy density it occupies a large volume 10 to 20 times larger than coal. In addition, 70% of the combustible parts of the straw are contained in the gases escaping during the heating of the so-called volatile components. Such a high content of volatile components creates problems during combustion, especially when mixing the right amount of air. Straw also contains chlorine compounds that can cause corrosion of materials, especially at higher temperatures. Despite the mentioned difficulties, the burning of straw is technically mastered and also very economical. The number of such devices in the world is therefore growing rapidly.

Straw delivered to incinerators must meet certain requirements. Mainly the moisture content is a critical parameter. The humidity is usually at the level of 10-25%, but it can be higher. The problem is that different types of straw behave differently during combustion. Some burn explosively, while others burn very slowly, with almost all the ash remaining on the grate. Experience shows that the operation of these incinerators is very specific. Smaller incinerators with an output of less than 1 MW are usually used in agricultural enterprises. Most of these incinerators are manually operated and in the past they also had problems with leaking smoke. Currently, automated devices with straw replenishment 1 to 2 times a day and without problems with emissions are being promoted on the market.

2.7.4 Liquid biofuels

Unlike solid and gaseous biofuels, liquid biofuels are mainly used to power motor vehicles. Fuel for motor vehicles that they can produce themselves is a dream of many people, and biomass is practically the only renewable resource that makes this possible. Currently, the most important fuels produced from biomass are ethanol, methanol and biodiesel.

2.7.4.1 Alcohol fuels

From a global point of view, the most widespread liquid biofuels are the so-called alcoholic fuels - **ethanol** and **methanol**, which are mainly produced in the world from:

- grain
- corn
- sugar reeds.

The advantage of alcoholic biofuels, in addition to the fact that they can be grown, is that fewer harmful substances are formed when they are burned. This is due to the fact that these fuels have a simpler structure than gasoline or diesel, they burn better and the whole process leads to less unburned residue. From this point of view, methanol is a better fuel than ethanol. Properties of ethanol and methanol and their comparison with other fuels are in Table 4.

Table 4 Properties of alcohol fuels

	Ethanol	Methanol	Gasoline	Diesel fuel
Energy value (MJ.kg⁻¹)	26.9	21.3	43.7	42.7
Boiling Point (°C)	78.3	64.5	99.2	140 - 360
Octane rating	106	105	79 - 98	-

Biomass is characterized by a relatively good energy density - 1 million tons of oil is energetically equivalent to 2.3 million tons of dry biomass, which leads to the fact that the use of alcoholic biofuels has become part of the national strategy in many countries.

2.7.4.2 Ethanol

Ethanol is a substance that occurs only sporadically in nature and its ingestion (in small quantities), unlike methanol, is not toxic to humans. Ethanol is now commonly used as a substitute for gasoline in internal combustion engines, being one of the oldest fuels. However, ethanol is also used for purposes other than transport. Its application in the food industry is very important, and this universality is one of its main advantages.

The disadvantage of producing ethanol from agricultural products is that if we were to try to replace conventional fuels on a large scale, from a global perspective, biofuels would compete with food production and monocultures could threaten biological diversity. These disadvantages are not associated with ethanol production from wood biomass, which appears to be very promising. Similar examples include the production of ethanol from waste biomass from agricultural production.

More than 95% of gasoline in the US contains ethanol (eg E10 10% ethanol, 90% gasoline), the fuel is oxygenated, which reduces air pollution.

Ethanol is also available as E85 or as an ethanol blend. This fuel can be used in vehicles that can run on a mixture of ethanol, gasoline or any mixture thereof. Another blend, E15, has been approved for use in newer vehicles and is slowly becoming available.

There are several steps involved in the process of making ethanol as a fuel:

- entrance fee raw materials on the biomass They are grown , collected and transported to facilities on the production ethanol
- ethanol with produces from the input raw materials on the production equipment and then it is transported to the storage tank propulsion mass
- ethanol with mixed with gasoline so that achieved concentration of E10, E15 or E85 and then it is distributed to pumping stations.

2.7.4.3 Methanol

The production of methanol (methyl alcohol) from wood has been known in the world for a very long time. However, methanol often appeared here only as a by-product in the production of charcoal. However, such production was characterized by a very small yield. Today the situation is different. Charcoal gradually lost importance and methanol became an important fuel for motor vehicles.

Methanol is a poisonous substance for humans. It is a clean, odorless liquid that occurs only sporadically in nature. The energy value of one liter of methanol is 18 MJ, but the efficiency of the engine for such fuel is higher than in the case of gasoline (about 20%), which essentially increases the energy value of a litre of methanol to 22.5 MJ.

Methanol can be converted to high octane fuel at relatively low cost. The advantage is that such fuel does not contain sulfur and the pollution from its combustion is very low. Two questions are important for the production of methanol: what amount of biomass is needed for production and what is the ratio of energy obtained and input from such production. Experience shows that about 700 litres of methanol can be produced from one ton of dry biomass. The answer to the second question is that the ratio of the obtained energy (methanol) and the energy input for its production depends mainly on the production method. In the production of methanol from renewable sources, this ratio is highly positive.

Use of methanol in combustion engines

Vehicles running on methanol are similar to gasoline or diesel vehicles in terms of performance and other characteristics (range). Methanol can be used as a fuel in its pure form or as a mixture. However, the engine requires some modification. In the case of diesel engines, it is necessary to equip vehicles with an auxiliary ignition system, as the cetane number of methanol is low. These engines can also burn a mixture of methanol and diesel. Even with the content of a few percent of diesel in such a mixture, it is not necessary to use a spark plug.

Methanol has a high ratio of hydrogen atoms and a much higher energy density than liquefied hydrogen. For this reason, its use in fuel cells, which are a very promising source of energy for motor vehicles, is also being investigated.

Methanol vehicles depend on the input material from which they were made. Methanol produced from wood and used as a substitute for gasoline is characterized by lower emissions of all pollutants (on average by 20% to 70%). Substitution of diesel for methanol in diesel engines means a substantial reduction in emissions of solid particles (smoke). The ecological advantages of methanol used in a truck compared to diesel are documented in Table 5.

Table 5 Ecological advantages of methanol

	Emission reduction (%)
NO_x	- 65
WHAT	- 95
Hydrocarbons	- 95
Smoke	- 100

Compared to conventional fuels, methanol has several advantages and disadvantages. The advantage is that production technologies are tested in practice, reliable and widely used (alcohol production). The advantage of methanol compared to ethanol is that there is a wider potential of input raw materials for its production. Methanol also has the advantage over gasoline in that it has a higher octane number of about 105. Methanol also has the advantage of being high in calorific value, allowing for higher combustion efficiency in the engine, having a lower burning temperature, producing fewer pollutants, and generally being less risk. Moreover, compared to ethanol, methanol is cheaper.

The disadvantage of methanol is that it causes faster corrosion of metal materials and has a negative effect on plastic materials. Another disadvantage is the toxicity of methanol both when inhaled and when applied to the skin (risk when pumping fuel). In gasoline engines, methanol causes more problems when starting at temperatures below freezing. Preheating the fuel, as in the case of diesel, helps to solve this problem.

The energy value of methanol is about half that of diesel, so methanol vehicles need roughly twice as much fuel to reach the same range.

2.7.4.4 Biodiesel - vegetable oils

Vegetable oil can be obtained from more than 300 types of different plants, among which is e.g. oilseed rape, sunflower, olive, soy, coconut, etc. Oil is found in them in seeds or fruits. Although there are significant differences in viscosity between such oils, they can all be used in diesel engines as a replacement for diesel. The importance of biodiesel is mainly that almost every diesel engine can, in principle, be modified to burn biodiesel. However, the use of pure vegetable oil in engines brings several difficulties, which is why this oil is modified by esterification to methyl ester, known here as MERO, abroad the term RME (rape seed) is used methyl ester - rapeseed methyl ester). Esterification reduces the viscosity of vegetable oil and brings many benefits. Engine operation, fuel production, transport and storage are not a problem after esterification. Such oil has a positive effect on reducing emissions during combustion. However, unlike vegetable oils, MERO contains some carcinogens and is just as toxic as diesel. Some properties of MERO and pure vegetable oil and their comparison with diesel are shown in Table 6.

Table 6 Properties of MERO and pure vegetable oil

	Diesel sulphur	low	Biodiesel (MERO)	Pure rape seed oil
Cetane number	46		61.2	42.6
Boiling Point	191		347	311
Sulphur content (%) (weighting)	0.036		0.012	0.022
Heat of combustion (kJ /kg)	46,42		40.6	40.4
Density	0.8495		0.8802	0.906

Biodiesel, which is understood as pure vegetable oil or MERO, approaches the quality of diesel in terms of the energy contained in one litre of fuel, while this value is higher than the energy density of other alternative fuels.

The production of biodiesel consists of rapeseed pressing, filtering and subsequent splitting of the oil (esterification) into methyl ester (MERO - biodiesel) and glycerol. Glycerol as a by-product is suitable for the chemical industry and pomace is a valuable feed mixture. MERO is an ecologically clean fuel and, compared to diesel, has a 3 to 40 times lower hydrocarbon content in the exhaust gases when burned. It has reduced smoke, the gases contain less solid particles and other dangerous substances. However, the use of MERO requires a small modification of the engine, reducing its performance and fuel consumption by about 5%. The scheme of the biodiesel production process can be seen in Figure 24.

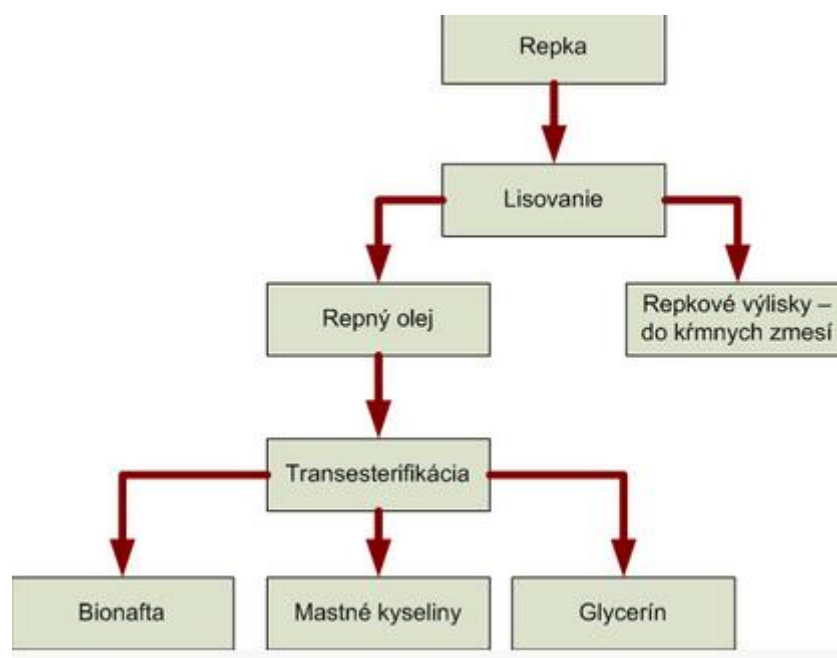


Figure 24: Scheme of biodiesel production

Although the energy balance of MERA is positive, there are many experts who believe that this fuel is suitable as a replacement for diesel only in local conditions for farmers. Its transport over longer distances would cause the energy profit from production to drop to almost zero value. MERO as a fuel (also as a mixed fuel) has good environmental parameters and its combustion produces a lower amount of emissions than in the case of diesel.

The main advantages of using biodiesel can be summarized as follows:

- positive energetic balance

- low emissions pollutants and reduction CO₂ emissions
- economical and ecological utilization of soil taken out of production food crops
- fast degradation in the soil, which does not cause pollution
- security at treatment (that's right safe how food industry oil).

Disadvantages of pure vegetable oils:

- they have high viscosity (up to 40 times higher than diesel)
- during their storage there is a reduction in quality of fuel
- at burning they clog the engine
- They are aggressive towards plastic and varnish and cause higher emissions of rigid particles and N₂O.

2.7.5 Biomass usable for energy purposes

Biomass suitable for the production of electricity can be divided into five basic groups:

- phytomass with high content of lignocellulose
- phytomass of oily crops
- phytomass with high content of starch and sugar
- organic waste and by-products of animal origin
- mixture of various organic wastes.

For energy production, it is possible to use:

- **biomass grown for this purpose:**
 - for production of ethyl alcohol (sugar beets , grain , potatoes , sugar cane)
 - for production of raw vegetable oils and methyl ester (oilseeds - rapeseed oil)
 - on direct combustion (energy fast growing wood - willow, poplar, alder, aspen and other).
- **biomass waste :**
 - vegetable agricultural residues from primary production and maintenance countries
 - animal waste production
 - communal organic waste from rural headquarters
 - organic food and industrial waste productions
 - forest waste – dendromass.

The essence of using biomass for energy purposes is the generation of heat, which is used at or near the place of production. The heat is used either directly for the preparation of hot water or for the production of steam with the subsequent drive of an electric generator and the production of electricity. Other products are e.g. charcoal or liquid biofuels for powering motor vehicles.

2.7.6 Biomass energy production processes

The possibilities of using biomass for energy purposes are mainly determined by its physical and chemical properties. A very important parameter is humidity, or dry matter content in biomass. Division of processes according to dry matter content:

- up to 50% dry matter - **wet** processes
- over 50% dry matter - **dry** processes.

Division according to the principle of energy conversion:

- thermochemical transformation biomass (dry processes):
 - combustion
 - gasification
 - pyrolysis.

Biochemical conversion of biomass (wet processes):

- alcoholic fermentation
- methane fermentation
- physical and chemical transformation biomass:
 - mechanical (splitting, crushing, pressing, briquetting, pelletizing, grinding, etc.)
 - chemical (esterification raw vegetable oils).

Recovery of waste heat during biomass processing:

- composting
- aerobic cleaning water
- anaerobic fermentation.

There are several ways of using biomass for energy purposes (Figure 25), in practice different forms of combustion prevail in dry processes, while in wet processes biogas is produced by anaerobic fermentation. Of the other methods, it is mainly the production of methyl ester from bio-oils.

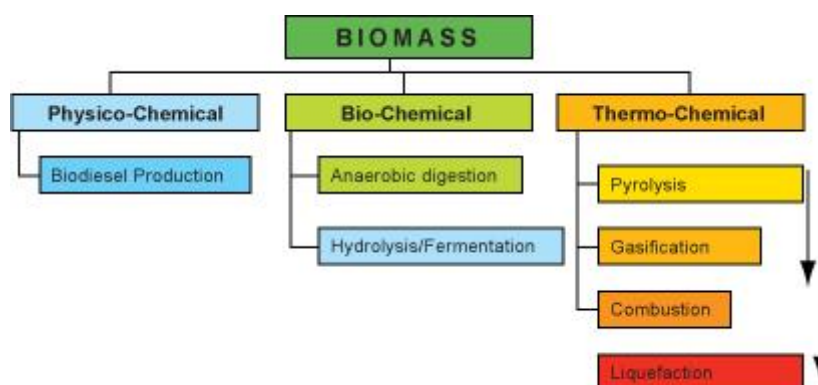


Figure 25: Biomass energy production processes

2.7.6.1 Combustion

Combustion is the process of burning biomass in the presence of a sufficient amount of oxygen so that complete oxidation occurs. It is used in modern biomass boilers to produce hot water or steam for domestic or industrial use. For efficient combustion, it is necessary to ensure:

- enough high temperature
- enough air
- enough time to be able to run across complete burning biomass.

Although direct combustion is the simplest and most common method of using biomass energy, it is not always an efficient process. Designing a combustion boiler that would be characterized by significantly higher efficiency therefore requires an understanding of the entire combustion process. An important step is to understand the evaporation of water from wood, that is, the

process that consumes energy. However, the consumed energy represents only a small percentage of the total usable energy. Modern combustion systems are very similar to those used to burn coal and are characterized by a combustion efficiency of up to 90%.

2.7.6.2 Pyrolysis

Pyrolysis is the process of burning biomass without the presence of oxygen or other oxidizing agents. First, moisture is removed, and then volatile compounds (mainly hydrocarbons) are evaporated from the biomass. Smaller vapor molecules remain in a gaseous state even when cooled (e.g. carbon monoxide, carbon dioxide, light hydrocarbons), while larger ones condense to form a liquid, referred to as tar or bio-oil. The solid substance that remains after the volatile compounds is called coal or bio-char (**Biomass scoping study, Bulletin 4862, 2014**). Pyrolysis is a rapidly developing technology with great potential, but the process is more suitable for the production of heating oil and is more suitable for use in diesel engines and gas turbines. Today's world generates millions of tons of plastic and tire waste every month, which you can turn into billions of dollars worth of energy using pyrolysis. A power plant with pyrolysis technology is a promising alternative that will drive tomorrow's growth and protect the environment by reducing the number of waste plastics and tires.

2.7.6.3 Gasification

The basic principles of biomass gasification have been known since the beginning of the 19th century. This technology was so universal and reliable that during the Second World War, several million vehicles with a gasification unit producing wood gas, which was subsequently burned in the vehicle's engine, were moving on European roads.

Gasification is a process between combustion and pyrolysis, as a limited amount of oxygen enters the process. In practice, gasification usually has a phase of combustion (to produce heat), pyrolysis (evaporation of volatile substances) and reduction (treatment of gas to a higher quality for fuel). If only pyrolysis is used, high-quality coal or oil is obtained, while gasification produces high-quality gas known as synthesis gas or production gas.

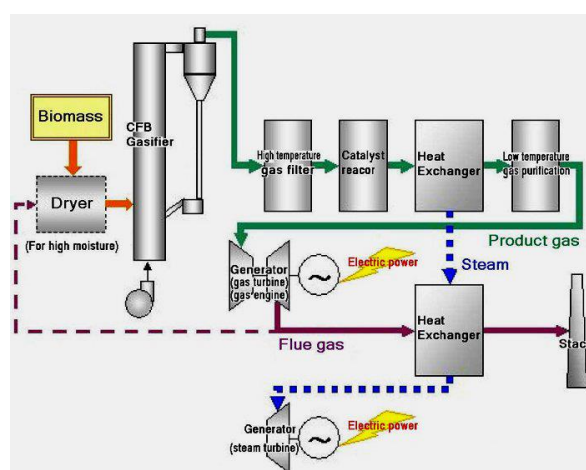


Figure 26: Biomass energy production processes

2.7.7 Fermentation

Yeast is added to the hydrolyzed "mash" and allowed to ferment for several hours to several days until the sugars are consumed and ethanol is produced. Typical fermentation temperatures are in the range of 30°C to 40°C. The process takes place with constant stirring. Sugaring and fermentation can take place either in one mixing tank or in separate vessels. Separate processes allow better control and optimization of individual processes, which can be carried out at different temperatures, different pH values and mixing modes. The simultaneous course of these processes in one vessel requires a compromise in the optimal conditions of sugaring and fermentation, but may have higher efficiency.

The entire fermentation process requires a significant input of heat, which is usually produced by burning plant residues. Although the energy loss in ethanol production is large, it is usually compensated by the quality of the fuel and its easy transportation.

2.7.8 Anaerobic digestion

When moist organic materials such as manure, food or agricultural waste are placed in a warm, closed tank with limited access to air, naturally occurring microorganisms break down and produce a flammable gas called biogas. It usually contains 50 to 70% methane, with the rest being mostly carbon dioxide. Biogas is an important product because it can be burned to produce energy for heating, lighting, cooking and motor vehicles.

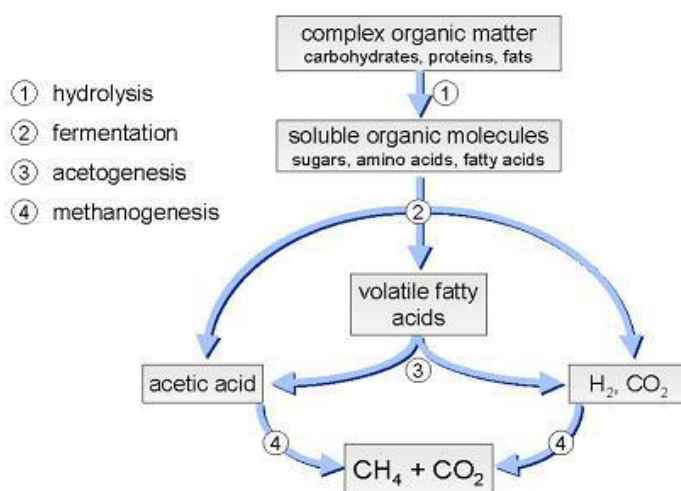


Figure 27: Anaerobic digestion process (Biomass scoping study, Bulletin 4862, 2014)

2.7.9 Production of electricity from biomass

The traditional way of producing electricity from biomass is, in most cases, based on its direct combustion and the production of steam that drives a steam turbine, similar to what happens in coal-fired power plants. Today, this technology is very sophisticated and allows the use of several types of input raw materials. Its disadvantage is that it requires relatively high investment costs per unit of output, the overall efficiency of production is low and, moreover, it does not provide opportunities for further improvement.

The production of electricity by gasification of biomass is a new method. Instead of direct combustion of biomass, the process of its gasification and subsequent combustion of gas in a

gas turbine is used, similar to the production of electricity in gas-fired power plants. The advantage of this technology is much higher efficiency, since during gasification up to 65-70% of the energy contained in biomass is converted into flammable gas. The investment costs for the construction of gas turbines are relatively low, and in addition, there are considerable opportunities for improving the technology. Although the gasification method provides several advantages, it is not yet developed enough to be used routinely.

Biomass gasification power plants consist of the following components:

- device on the preparation and transport fuel
- gasification reactor container
- cleaner gases and mixing system
- turbine or Combustion engine.

Combustion of gases in engines or turbines requires the use of very clean gas. The production of such gas requires not only additional equipment such as coolers and mixing systems, but also a specially adapted reactor vessel, which greatly complicates the entire technology. In addition, the technology is quite sensitive to the type of biomass used (different species behave differently), which requires a higher control of input raw materials than in other types of power plants. The best fuel is charcoal free from moisture and other volatile substances, but this means special equipment for its production.

In the simplest gas turbines, hot waste gases are released directly into the atmosphere. However, in modern technologies, these gases are used to produce steam in special steam generators. This steam can either be used to heat objects (cogeneration unit) or it is injected back into the turbine, increasing the output and efficiency of production (Steam-injected gas turbine - STIG), or it will be used for further electricity production in a steam turbine (Gas turbine / steam turbine combined cycle - GTCC), which also leads to an increase in the overall performance and efficiency of the device.

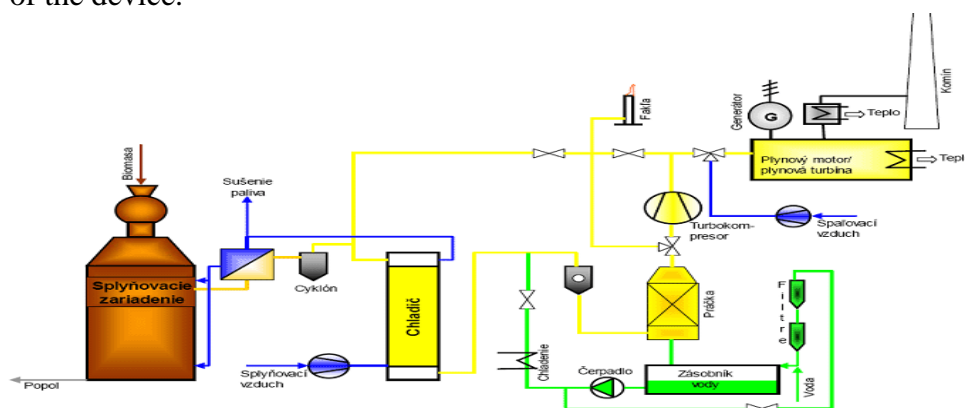


Figure 28: Scheme of combined production of electricity and heat from biomass based on gasification

2.7.9.1 Innovative technologies for biomass processing: the Rankine Cycle

The Rankine cycle is a thermodynamic cycle that converts heat into work. Heat is supplied from the outside into a closed loop, in which water is usually used as the working fluid. The Rankine cycle using water accounts for approximately 85% of global electricity production.

The Rankine cycle is named after William John Macquorn Rankine (July 5, 1820 - December 24, 1872), Scottish engineer and physicist. He was one of the most important scientists working in the field of thermodynamics. Rankine defined the complete theory of the steam engine and thus essentially of all heat engines. His manuals for engineering sciences and the practical use

of knowledge were used for a long time after their publication in the 1850s and 1860s. He is the author of several hundred lectures and notes in the field of natural science and technical disciplines. His interests were very diverse - in his youth he also devoted himself to botany, music theory and number theory, but also to most major fields of science, mathematics and engineering.

The Organic Rankine Cycle (ORC) typically uses water as the working fluid. Applications of the cycle with different working fluids swa began to appear quite early, for example diesel ships. In 1883, Frank Ofeldt developed a unique energy system that could replace steam. His diesel engines were steam engines that burned diesel instead of water and powered pistons with steam. The reason for this was the fact that at that time the government required a license for the use of water in steam engines, but a license was not required if gasoline or diesel was used instead of water.

ORC is currently a well-known and widespread technology for energy production, mostly from biomass and geothermal energy, but it also has its potential in the field of solar and thermal technologies. Environmental protection, climate change and rising oil prices are serious reasons to support the development of this efficient, clean and reliable way of generating electricity.

Efficiency

The ORC cycle has a high overall energy efficiency - up to 98% of the thermal energy contained in the working fluid is converted into electrical energy (around 20%) and heat (78%). Thermal leakage, thanks to thermal insulation, represents an extremely small 2%. Heat radiation and losses in the generator in the case of non-generative technologies are much higher (24% and more).

ORC offers several advantages, such as:

- high efficiency turbine / thermodynamic cycle
- low mechanical stress turbine
- absence humidity (causes erosion shoulder blades turbines) during expansion vapors ;
- simple launching
- automatic and continuous operation
- simple maintenance
- does not require the presence operator
- long lifespan power plants (> 20 years)
- is not necessary demineralization water.

2.7.9.2 Biomass usable for energy purposes

Biomass suitable for the production of electricity can be divided into five basic groups:

- phytomass with high content lignocellulose
- phytomass oily crops
- phytomass with high content starch and sugar
- organic waste and by-products products animal origin
- mixture various organic waste.

For energy production, it is possible to use:

- **biomass intentionally grown for this purpose:**
 - for production ethyl alcohol (sugar beets , grain , potatoes , sugar cane)
 - for production raw vegetable oils and methyl ester (oilseeds - rape oil)

- on the direct combustion (energy fast growing wood - willow, poplar, alder, agate and other).
- **waste biomass:**
 - vegetable agricultural residues primary production and maintenance countries
 - animal waste production
 - communal organic waste from rural headquarters
 - organic food and industrial waste productions
 - forest waste – dendromass.

2.7.9.3 Ways of using biomass for energy purposes

The possibilities of using biomass for energy purposes are mainly determined by their physical and chemical properties. A very important parameter is humidity, or dry matter content in biomass. The value of 50% dry matter can be considered as borderline between wet (dry matter content is less than 50%) and dry (dry matter content is higher than 50%) processes. According to the principle of energy conversion itself, it is possible to define several ways of obtaining energy from biomass (Table 7).

Table 7 Methods of obtaining energy from biomass

Type of biomass conversion	Biomass conversion method	Energy output	Waste material or secondary raw material
thermochemical conversion (dry processes)	combustion	heat bound to the carrier	ash
	gasification	generator gas	tar oil, carbonized fuel
	pyrolysis	generator gas	tar oil, solid combustible residues
biochemical conversion (wet processes)	anaerobic fermentation	biogas	fermented substrate
	aerobic fermentation	heat bound to the carrier	fermented substrate
physical-chemical conversion	esterification bio-oils	methyl ester , bio-oils	glycerin

In practice, different forms of combustion prevail in dry processes, while in wet processes biogas is produced by anaerobic fermentation. Of the other methods, especially the production of methyl ester from bio-oils.

2.7.9.4 Energy value of individual types of biomass

Due to the different forms of biomass, the energy contained in it is also different (Table 8).

Table 8 Energy value of biomass

BIOMASS	Water content %	Calorific value MJ/kg	Calorific value kW/kg
Wood - oak	20	14.1	3.9
Wood - spruce	20	13.8	3.8
Straw	15	14.3	4.0

Grain	15	14.2	3.9
Rapeseed oil	-	37.1	10.3
Coal	4	30.0 - 35.0	8.3
Brown coal	20	10.0 - 20.0	5.5
Heating oil	-	42.7	11.9
Bio- methanol	-	19.5	5.4
Landfill gas	-	16.0	4.4
Wood gas	-	5.0	1.4
Biogas from manure	-	22.0	6.1
Natural gas	-	31.7	8.8
Hydrogen	-	10.8	3.0

2.8 Farmer as a grower of energy biomass and producer of fuels and electricity

As already mentioned at the beginning, biomass is defined as a substance of biological origin (or waste that comes from plant production, animal production, ecological and organic waste). The form of biomass is given by the focus of production activities or the use of agricultural waste, food production and forestry, communal sphere, care and maintenance of the landscape. In this regard, the activity of farmers can be defined as firmly linked to the production of waste or intentionally produced biomass.

For simplicity, we divided farmers into three groups: producers of biomass, biomass and consumers of biomass products.

In any case, it is possible to cite a number of positive examples that show the economic and ecological benefits of using biomass.

The best example of biomass production by farmers is the cultivation of energy crops.

Energy crops are grown for special use - as fuel and offer high yield per hectare with low inputs. In general, the principle is that the purpose is to maximize the performance of the desired crop. Energy crops are classified as fast-growing energy crops - the primary purpose is not to produce wood for sawmills, but for energy, so there is a requirement that they grow in a short period of time. Furthermore, the annual growth rate of biomass per hectare tends to be greater when plants are only a few years old, although this depends on the plant species. As a result, there is considerable interest in growing fast -growing plants that allow the harvesting of fast-growing wood for biomass after only a few years. Since the stems are harvested young, the biomass has a relatively high proportion of bark. Among the grasses and non-woody energy crops we can include Miscanthus, which reaches a height of up to 3.5 m and is a woody perennial. Miscanthus through C4 photosynthesis, it binds carbon and water very efficiently. Other grasses: millet (*Panicum virgatum*), scab reedy (*Phalaris arundinacea*), sown rye (*Secale cereale*), common reed (*Arundo Donax*), hemp seeds (*Cannabis sativa*). They are grown all over the world, primarily as fibre crops.

Agricultural energy crops are crops grown for sugar, starch and oil.

For energy "plantations", various fast-growing crops (e.g. willow, poplar, alder, agave) are suitable, which can be burned directly, ethanol can be produced from them through the fermentation process, or plants rich in oil can be used for the production of biodiesel, such as oilseed rape, which is already used for these purposes in Slovakia.

Growing biomass for energy purposes is very promising for many countries. A large surplus of production of agricultural products in Europe and the USA and subsidies for farmers, cause a desire to use unused land for these purposes. The European Union expects that up to 20 to 40,000,000 ha of land will be used in the near future for growing energy crops. A similar

situation can be expected in other countries, including Slovakia. For the cultivation of energy plants, not only soils for growing agricultural crops can be used, but also soils of lower quality, e.g. around roads or contaminated soil.

The disadvantage of fast growing trees is that it is necessary to use fertilizers as in the case of other crops. However, the ash from burning these crops can be used as fertilizer. When it comes to energy production, it is important that the energy input is such that the overall energy balance is positive. The ratio of energy obtained and invested is usually 5:1.

Plants, for example some types of willow or grass, are suitable for direct combustion in boilers. The advantage of these devices is that, unlike wood, the "production" time (the time between harvesting and sowing) is short - typically 3-8 years. For some types of grass, it is even less - only 6-12 months. Currently, the world uses about 100 million hectares of land for growing fast-growing trees. Most of these trees are used in the wood processing industry. The parameters that are decisive when choosing fast-growing trees are: availability and suitability for a given type of soil and climate, potential yield per hectare and year (t/ha/year). The extract is the most important indicator, and willows grown in our conditions can reach 15 tons of dry matter per hectare per year. The profit from some willows ranges from 2 to 3 meters per year (2-3 cm per day during the summer). Normal planting density is 5,000-20,000 trees per hectare (distance between trees about 1 m) and harvesting is done in two to five year cycles, while trees can remain productive for up to 30 years.

From the point of view of environmental protection, willow is very suitable. It can be used for water purification in biological wastewater treatment plants. Every year, each hectare can ecologically clean 10-20 tons of waste water and sludge. The combination of biological functions of plants and energy crops makes willow a unique biological species. Another promising plant is hemp, which is characterized by a high production of living matter of up to 24 t/ha in approximately 4 months. However, growing hemp is illegal.

2.9 Water energy

Water energy has its origin in solar energy. Water in nature is a carrier of:

- mechanical energy of atmospheric precipitation
- mechanical energy of glaciers
- mechanical energy of water flows
- mechanical energy of the seas.

In the conditions of Europe, only the use of the energy potential of water streams is important.

2.9.1 Water cycle in nature

The water cycle is the continuous circulation of water in the Earth's hydrosphere. It is controlled by sunlight. How water moves in a cycle and changes its state. Water that evaporates is carried by the atmosphere and falls in the form of precipitation. The greater part evaporates from the seas and the greater part of the water also falls here again. A smaller part is transferred to the land, and this atmospheric transport is balanced by the flow of water in rivers from the land to the seas and oceans. From a geographical point of view, we distinguish between two circulations:

- large water circulation - exchange occurs between the ocean and the land
- small water circulation - the exchange takes place over the ocean, or only over the land.

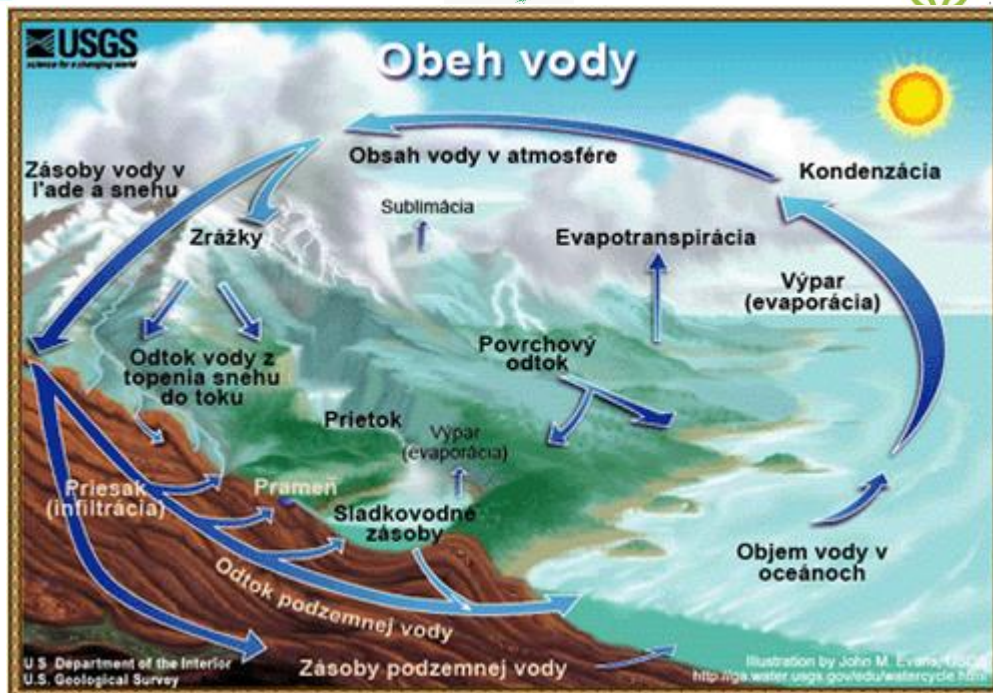


Figure 29: Water circulation in nature

The main physical processes involved in the water cycle are:

- evaporation - a phase change in which a liquid turns into a gas
- liquefaction or condensation - a thermodynamic process in which a substance passes from a gas to a liquid phase. If a sufficient amount of water molecules binds in the gas phase, a raindrop is formed, which falls to the earth's surface in the form of rain.

2.9.2 Hydropower potential

In order to be able to determine how much electricity can be produced on a given stream, it is necessary to know its hydropower potential. The hydroenergetic potential (HEP) of a watercourse is the total energy of the flowing water. As a rule, its average value for 1 year is given. This value is only theoretical for the production of electricity, because when determining it, e.g. with changing flow in a given section of the river due to evaporation or seepage into the subsoil. Therefore, the total HEP is calculated as the product of the HEP of individual sections. Hydropower potential:

- gross hydropower potential - it is determined from the altitudes of the studied stream and its average flow. However, this HEP has no informative value for planning its use for electricity production.
- technically usable hydropower potential - is defined as the total potential that can be used for the production of electricity. Its value is about 0.4 times the gross HEP. Worldwide technically usable hydropower the potential is approximately 20,000 TWh per year.

2.9.3 Distribution of hydropower plants

There can be many criteria according to which hydropower plants can be divided. The size of the installed power is fundamental:

- small hydropower plants with an installed capacity of up to 10 MW

- medium hydropower plants with an installed capacity of 10 MW to 200 MW
- large hydropower plants with an installed capacity of over 200 MW.

Small hydropower plants themselves are divided into:

- domestic hydropower plants with an installed capacity of up to 35 kW
- aqueous micro power plants with installed power from 35 kW to 100 kW
- hydro mini power plants with an installed capacity from 100 kW to 1 MW
- industrial hydropower plants with installed capacity from 1 MW to 10 MW.

Hydroelectric power plants are divided into:

- low-pressure, using a drop of up to 20 m
- medium pressure, using a drop from 20 m to 100 m
- high-pressure, using a slope of more than 100 m.

According to the working mode, hydropower plants are divided into:

- flowing, which they do not accumulate water and use only natural flow rates
- storage, which use the controlled withdrawal of water from the storage tank above this VE
- pumping stations, which use the water accumulated in the upper tank and pump it there from the lower tank.

2.9.4 Electric machines for hydropower plants

Large hydropower plants use synchronous electric rotating machines for production, the so-called hydroalternators. These are 3-phase, low-speed, multi-pole AC generators with a large diameter and short length. Unlike turbo-alternators in thermal power plants, which are high-speed bipolar, with a small diameter and a long length. They generate a 3-phase electric current of a harmonic course with a frequency of 50 Hz. They require precise speed control.

Small hydropower plants often use an asynchronous (induction) machine. An asynchronous electric machine consists of:

- engine,
- generator,
- brake.

In a small hydroelectric power station, the asynchronous machine works in three modes - at start-up it first works as a motor and the turbine as a pump. After the nozzle is watered, the flowing water starts to drive the turbine and the asynchronous machine to supersynchronous speeds, when the machine goes into the generator mode. Such use of an asynchronous machine presupposes its connection to the electrical network.

2.9.5 Water wheels

The water wheel is the oldest and at the same time the simplest water machine, which uses the positional or kinetic energy of the water flow to convert it into mechanical energy ⁶. Water wheels have several great advantages: they enable efficient use of water energy even in locations with very low gradients, even less than 0.5 m, they can also be designed for very low

⁶DUŠIČKA, P., GABRIEL, P., HODÁK, T., CIHÁK, F., ŠULEK, .: Small hydropower plants, Jaga group, vos, Bratislava 2003

flows, even below $0.1 \text{ m}^3 \cdot \text{s}^{-1}$ and they can process even very polluted water without problems. They are almost irreplaceable for slopes of up to 1.5 m.

Water wheels have gradually improved in their development, so that they reach an efficiency of $\eta = 0.6-0.7$, which is a value comparable to the efficiency of some small turbines operating in comparable conditions.

According to the design of water wheels, in which the mechanical energy of water is changed into the energy of a rotating shaft, water wheels are divided into:

- bowls that use the potential energy of water;
- bladed, using the kinetic energy of water.

According to the location of the water drive, water wheels are divided into upper, middle and lower water wheels, more correctly with upper, middle and lower drive (Figure 30).

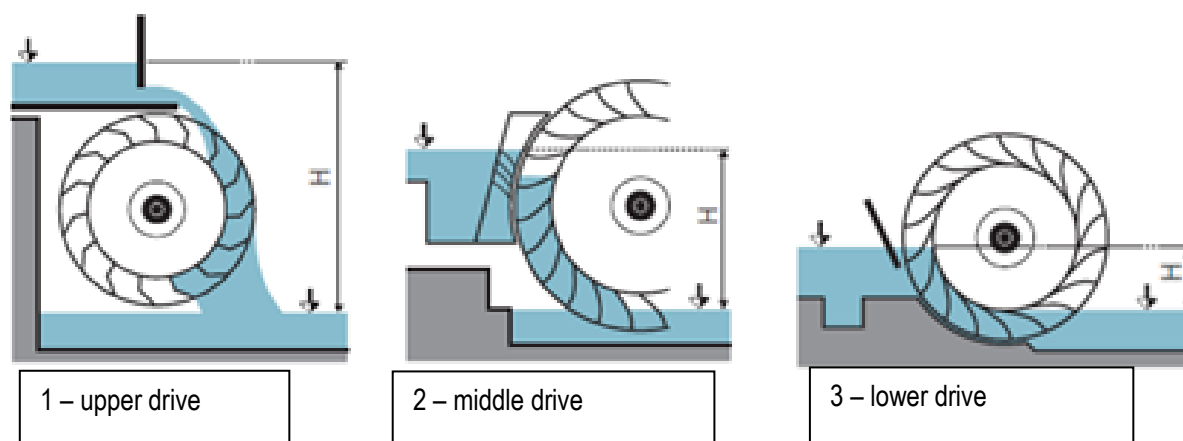


Figure 30: Types of water wheels⁷

Bottom water wheels are the only suitable device that can use very low gradients, even around 0.1 m, even though the efficiency is relatively low at such gradients - around 20%. However, with larger gradients and a suitable construction, the efficiency of the water wheel can approach up to 70%.

In localities where it was possible to reach falls of more than 3 m, water wheels for upper water were the most widespread. The diameter of the wheel is only slightly smaller than the gradient and the wheel moves just above the lower level. The side rims of the wheel form buckets together with the blades, and the efficiency of the wheel can be close to 70%. At these falls, however, water wheels are already displaced by modern water turbines, mainly because of their problematic operation at temperatures below 0°C .

Water wheels have low revolutions and therefore a gearbox is needed when using them. However, their entire construction is very simple, generally cheaper than a water turbine, and their operation is trouble-free. Even the construction part of the work, which uses a water wheel, is simpler with comparable performance to water turbines, and therefore cheaper to invest.

2.9.6 Water turbines

There are a large number of water turbines in various variants and design solutions. Water turbines have gone through a long historical development and currently represent a proven and significantly improved version of water machines (compared to a water wheel).

⁷DUŠIČKA, P., GABRIEL, P., HODÁK, T., CIHÁK, F., ŠULEK, .: Small hydropower plants, Jaga group, vos, Bratislava 2003

The following water turbines are mostly used in modern hydropower plants:

- **Francis turbine** - is an overpressure turbine, which means the water pressure at the turbine inlet is higher than the pressure at the turbine outlet. Typical solution Francis turbines consists of a switchboard wheel (turbine control element) and impeller. It is suitable for large and small falls and for large and small flows.

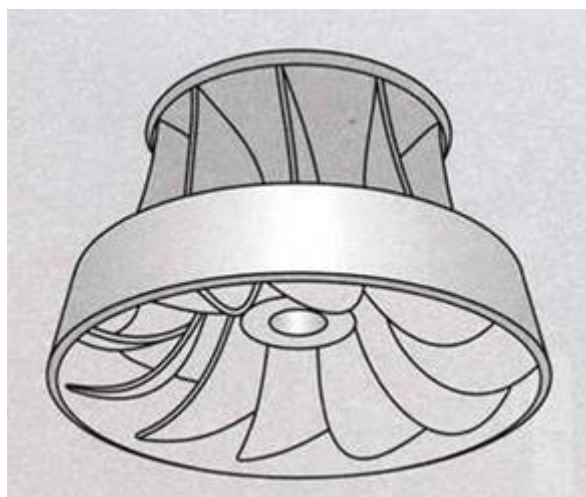


Figure 31: Types of water wheels

- **Kaplan's turbine** - is an overpressure turbine that is characterized by double regulation, namely the application of an adjustable distributor and the rotation of the impeller blades. It is universally applicable and widely used.

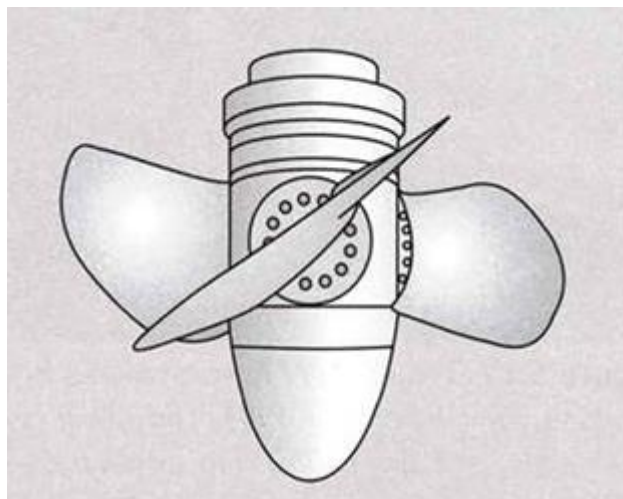


Figure 32: Types of water wheels

- **Pelton turbine** – is an impulse turbine in which water is supplied by means of a nozzle and directed onto typical spoon-shaped blades, located on the circumference of the impeller. It is very suitable where there are higher gradients and is often used in hydropower plants in mountainous terrain.

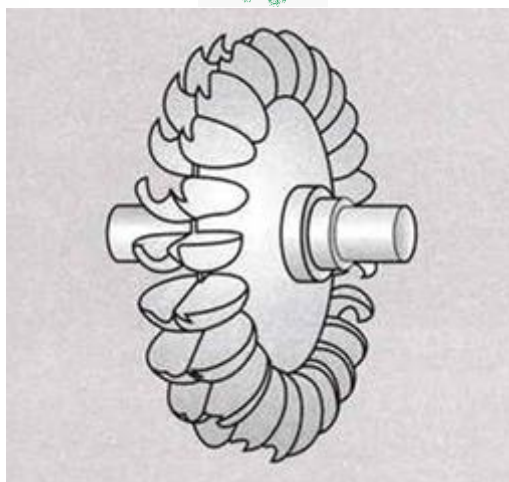


Figure 33: Types of water wheels

- **Bánki turbine** – is a constant pressure turbine characterized by the fact that water flows through the impeller twice. It is used with success in small hydropower plants with small heads and small flows.

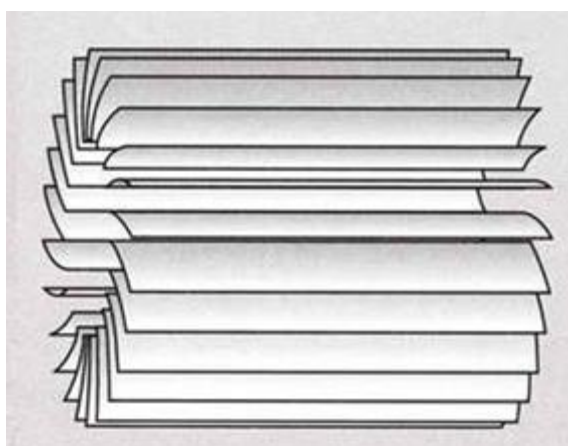


Figure 34: Types of water wheels

The suitability of using individual types of turbines for different gradients and water absorption rates is shown in the following figure.

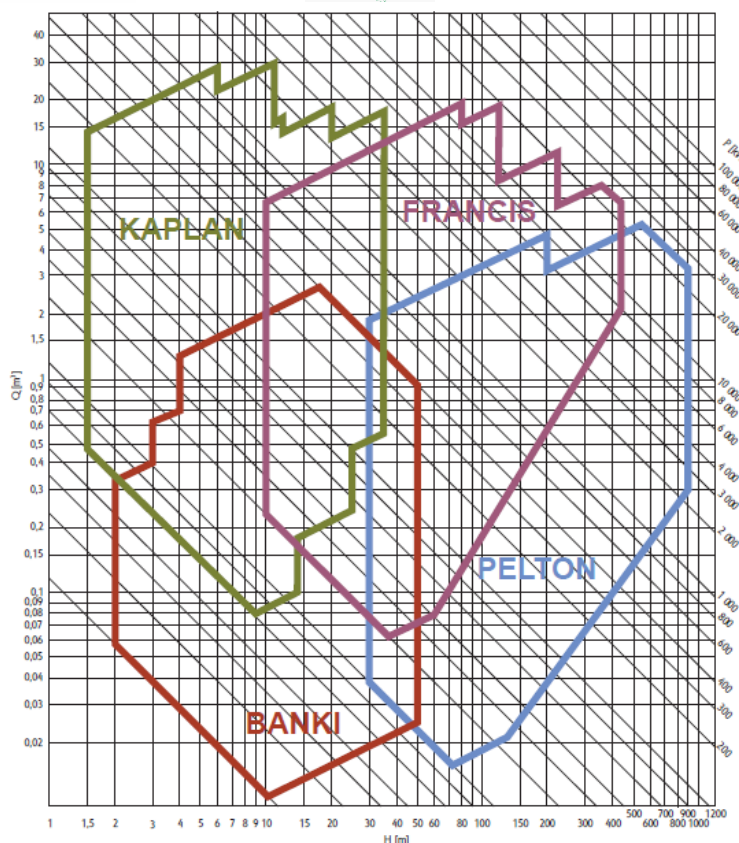


Figure 35: Suitability of use of individual turbines

2.9.7 The impact of hydropower plants on the environment

Advantages:

- hydropower is a renewable source of electricity
- its distribution does not pollute the environment
- domestic energy source
- decentralization of production
- indirect reduction of air emissions during electricity production
- require minimal service and maintenance
- the possibility of using it to cover peak consumption
- reliability and high efficiency of water energy use
- long service life of equipment (often over 70 years)
- low operating costs.

Disadvantages:

- high investment costs
- availability of technologies
- negative impact on the environment in case of incorrect implementation
- dependence on a stable water flow
- dependence on the season and weather
- the technical difficulty of installing equipment
- long payback period.

2.9.8 Small hydropower plants and their construction possibilities

Watercourses are usually scattered over a large area with a relatively small flow rate. Their centralized use by large water works is considerably limited. It is small hydropower plants that eliminate this deficiency.

Small hydropower plants can effectively use the scattered hydropower potential in small streams with high efficiency and a gentle approach to the environment.

The use of small hydropower plants does not have a negative effect on the surrounding flora and fauna, but in many cases they modify the water regime of the area.

Small hydropower plants represent a decentralized source of electricity and thus enable their installation even in remote areas. And the electrical energy obtained from small hydropower plants is among the cheapest!

2.9.8.1 *Structural parts of a small hydropower plant*

The water work intended for hydropower purposes consists of two parts:

- from hydraulic and construction equipment
- from mechanical and electrical equipment.

Hydraulic and construction equipment serves to supply water to the turbine, store the turbine and remove used water from the turbine. We can divide these into:

- inlet objects
- rake
- feeders and wastes.

A task **inlet objects** is to ensure a sufficient inflow of water from the stream to the small hydropower plant. Distribution:

- **pressure** - they are used to take water to feeders or directly to the impeller of the turbine. They can be directly part of the hut, possibly the dam, or independently on the banks with a free surface.
- **non-pressurized** - they are used to supply water from the tank tanks to non-pressurized feeders with a free level. They are also equipped threshold and gross rakes .
- **specially** - formed They are self-service tidal inlets with fine also gross rakes , self-service suction baskets and sieves suitable for micro resources .

Rake they are an essential part of all collection objects. Their main task is to prevent the ingress of such impurities that could impair the flow of the distributor or impeller channels and to protect all flowed parts of the system from damage. Distribution:

- **coarse** - capture heavier floating objects such as ice floes, trunks, branches, etc.
- **delicate** - capture delicate objects, leaves, prevent small fish from swimming in, etc.

Feeders and wastes they often form a significant financial part in the construction of hydroelectric power plants. Distribution:

- **non-pressurized** - they are cheaper and are constructed as a channel, either covered or open, and are most often designed with a trapezoidal or rectangular profile.
- **pressure** - they are used to overcome large falls and are constructed as pipes and tunnels, when appropriate natural conditions are used and they are dug directly into the rocks.

2.9.8.2 *The principle of operation of small hydropower plants*

Small hydropower plants use the hydropower potential of small streams. For this reason, their power maximum reaches 10MW. They are most often designed as a compact turbine with a so-called generator. hydro aggregate. They deliver the produced electricity to the distribution system to which they are connected. To a lesser extent, they supply the selected location in island operation. Accordingly, they work with an asynchronous or synchronous generator.

2.9.8.3 *Turbines for small hydropower plants*

We use different types and species in small hydropower plants turbine. For small flow and small drop we vote Bánki turbine. Vice versa high flow and gradient can make the best use of Francis turbine. Pelton turbine was designed for smaller flow but high drop, on the order of tens of meters. Kaplan makes better use of it a larger amount of water even with a smaller drop.

2.9.8.4 *When will it pay off?*

The costs for the construction of a small hydropower plant range from 2 to 4.3 mil. €/MW. If there is already a water management part, the costs are 1 to 2 mil. €/MW. Once a site is selected, more detailed on-site measurements must be taken. It is necessary to decide on a structural and technical solution. It is very important to do a preliminary economic analysis. This should tell about the power the power plant will deliver, that is, what the profit will be from the energy produced and also what the return on the investment will be. This is especially important when considering a loan, but also when planning investments for any business plans...

All hydropower plants are characterized by high investment and low operating costs. MVEs built for low heads and outputs are usually more expensive per unit of power than MVEs using high water heads. Entry prices are the biggest barrier to their development. Despite the fact that the payback period for investments is long (often 7-10 years), MVEs have a great advantage compared to other technologies using renewable energy sources - a long service life. These facilities are capable of producing electricity for more than 70 years, making them very profitable for potential investors. In addition, the price of electricity (income from the operation of MVE) will only be higher in the future, which means that the investments made will be returned many times over.

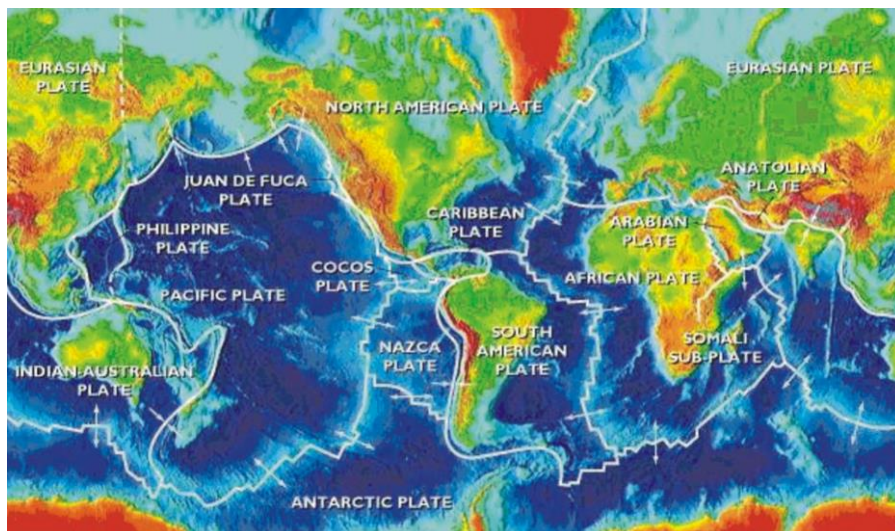
2.10 Geothermal energy

Geothermal energy can be considered **the oldest energy**. In the true sense of the word, it cannot be considered as renewable energy. Geothermal energy comes from the hot core of the Earth, which has a temperature of more than 4000°C. However, due to the inexhaustibility of these reserves, it is classified as a renewable resource. It reaches the surface through volcanic fissures in the rocks.

If we talk about the use of geothermal energy for energy purposes, hot water or steam is of practical importance. According to the method of extraction of hot water, we can define **technologies of use**. The ideal conditions are areas where there is hot water kept under pressure in hot rocks. There are two possibilities here:

- water is in sufficient quantity and it is enough to drill holes for its extraction
- although water is found in the given place, but in small quantities.

In this case, we use technology based on pumping hot water. We have to realize that not every place currently suitable for energy use will remain a suitable place. Water does not need to be renewed and can be exhausted. Many large companies spend huge investments just to explore the subsoil and thus the return on investment. If the applied technology runs out of water, it is no longer possible to



use the energy potential. Some resources are exhaustible within a few decades. Another problem is the depletion of the high content of mineral salts together with the water. They have a negative effect on the environment and, in addition, cause severe corrosion of work equipment and corrosion of hot water pipes. Therefore, direct use is not possible, but we have to use exchangers. This problem is solved by re-injection of the deep well.

Hot steam is created by the fact that in the Earth's lithosphere at a depth of 30-60 km below the oceans, there can be water lakes, which, if they come into contact with the molten mantle, create deposits of dry or moist steam, which also reaches the surface. However, this steam is in many cases highly harmful to health. When using hot steam to generate electricity, we must first filter it due to the content of corrosive acid gases and sand, which would aggressively damage the turbine. Only afterwards can we use it if it maintains the necessary parameters, especially pressure and temperature. Otherwise, we are forced to use the exchanger again.

With high efficiency and a minimum of financial costs, geothermal energy can be used in places of geological faults in the earth's plates, where tectonic activity rises to the surface or near the surface. These are shown in the picture ⁸. It is no coincidence that the most developed network for the use of geothermal energy is located in Iceland. Almost 100% covers the energy requirements of the population. It is through this island that the mentioned curve passes. However, the largest number of power plants is located in California, Canada.

In other areas outside the curve, it is necessary to implement deep wells, which are accompanied by a high demand for drilling technology. On average, one drill is destroyed at a depth of 100-300m. After reaching the required depth, the quality of the subsoil must be measured and the possibility of water injection must be carried out. Through deep drilling and injection, geothermal energy can be used practically with logical exceptions all over the world.

2.10.1 Geothermal bearings

We divide the places where there are the best conditions for the use of geothermal energy as follows:

1. Places with a high groundwater level are characterized by a normal gradient. They are characterized by the fact that there is no heat source. It is a suitable subsoil with several fractures:

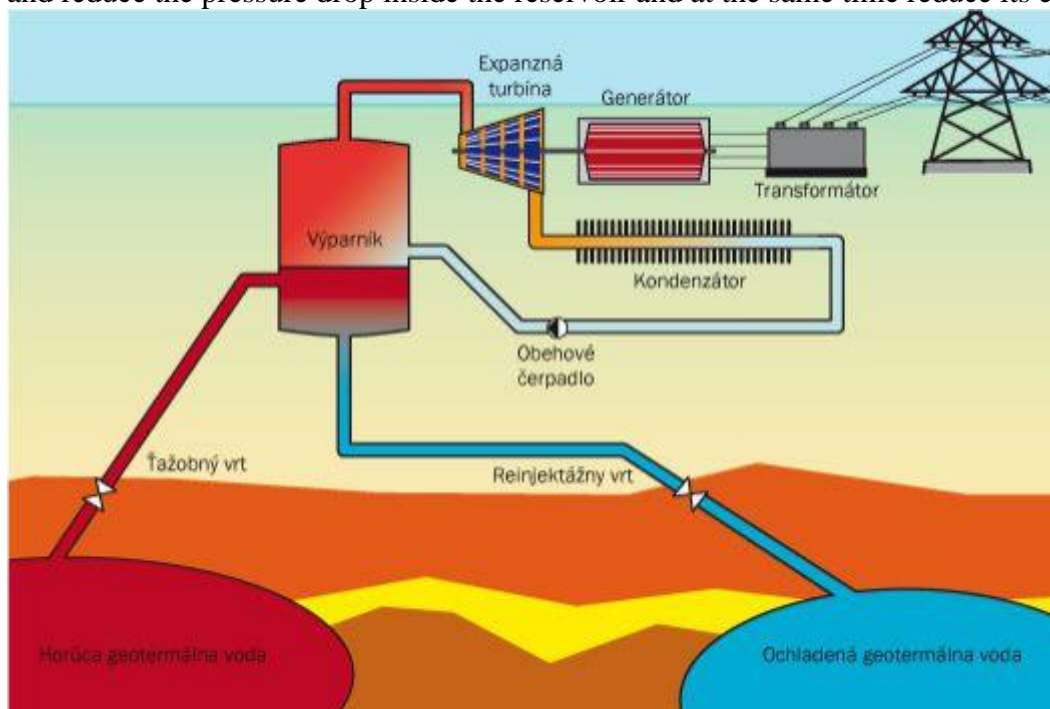
⁸www.kozmo.cz



- hot springs, water temperature reaches over 200°C, with impurities of Na, K, Ca, Au
 - fumarols, gas springs created by the degassing of hot magma or the radiation of surface water, reach a temperature of over 1000°C
 - mud volcanoes are hot springs with a high content of solid particles
 - geysers, regularly supplied hot springs with a temperature of up to 140°C.
2. Hyperthermic fields, places saturated with water or steam:
- dry, in the form of steam, water superheated in hot rocks and concentrated in a reservoir
 - wet, the water reaches the surface in a liquid state and partially evaporates due to a change in pressure.

2.11 Production of electricity from geothermal sources

One of the most important types of use of geothermal energy is the production of electricity. In this method of electricity production, hot water and steam from the Earth are used to drive the generator, while no harmful emissions of gases into the atmosphere occur, but only water vapor is released. Another advantage is that such power plants can be used in different environments such as farms, sensitive desert or forested areas, or recreational areas. The operating principle of a geothermal power plant is simple. Cold water is pumped into the hot granite rocks (reservoir) located near the surface and hot steam comes out, which has a temperature higher than 200 °C. Under high pressure, it then enters the turbine to which the generator is connected, which will transform the turbine's mechanical energy into electrical energy. The system is similar to conventional thermal power plants that use fossil fuels as a heat source. The water coming out of the turbine is diverted to rivers, or much more often and more efficiently returned to the reservoir. By recycling the water into the reservoir, we simultaneously avoid pollution and reduce the pressure drop inside the reservoir and at the same time reduce its emptying ⁹.



⁹<http://www.priateliazeme.sk/>

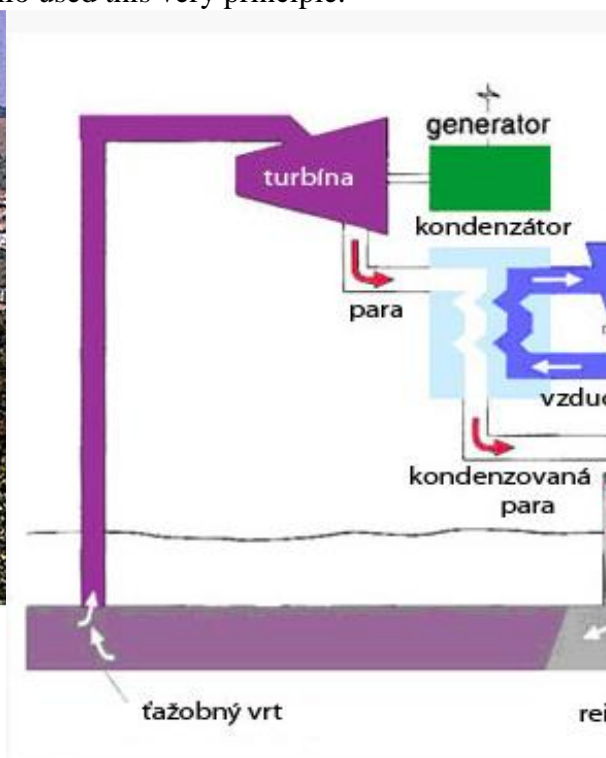
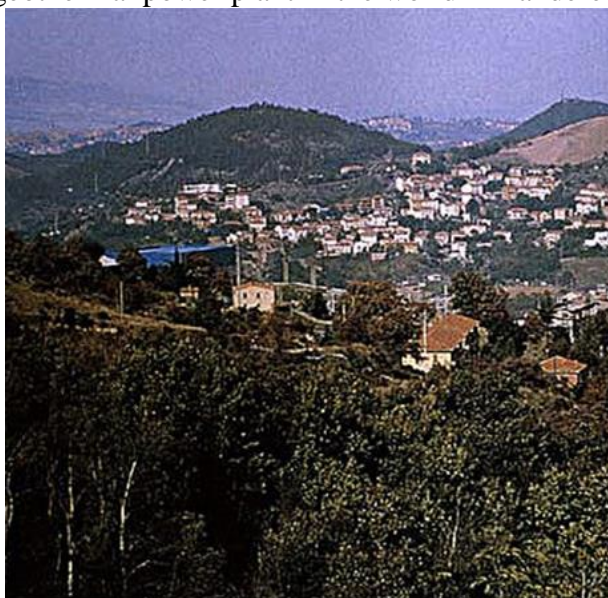
Three basic principles of geothermal power plants are currently used:

- principle of dry steam
- flash principle
- binary principle.

The price of electricity production depends on the temperature of the liquid in the geothermal reservoir. From an economic point of view, the production of electricity is most advantageous at a temperature of the geothermal source higher than 180 °C. It is also possible to produce electricity at a lower temperature of the geothermal source, but in this case, in order to achieve higher efficiency, water cannot be used, but another organic liquid that will pass through the turbine. The organic fluid obtains heat from the geothermal fluid in a heat exchanger.

2.11.1 The principle dry vapours

Only hot steam is used, usually above 235 °C (445 °F). This steam is used to directly spin turbines and generators. It is one of the simplest and oldest principles and is still used because it is the cheapest way to generate electricity from geothermal sources. The mentioned first geothermal power plant in the world in Landerello used this very principle.



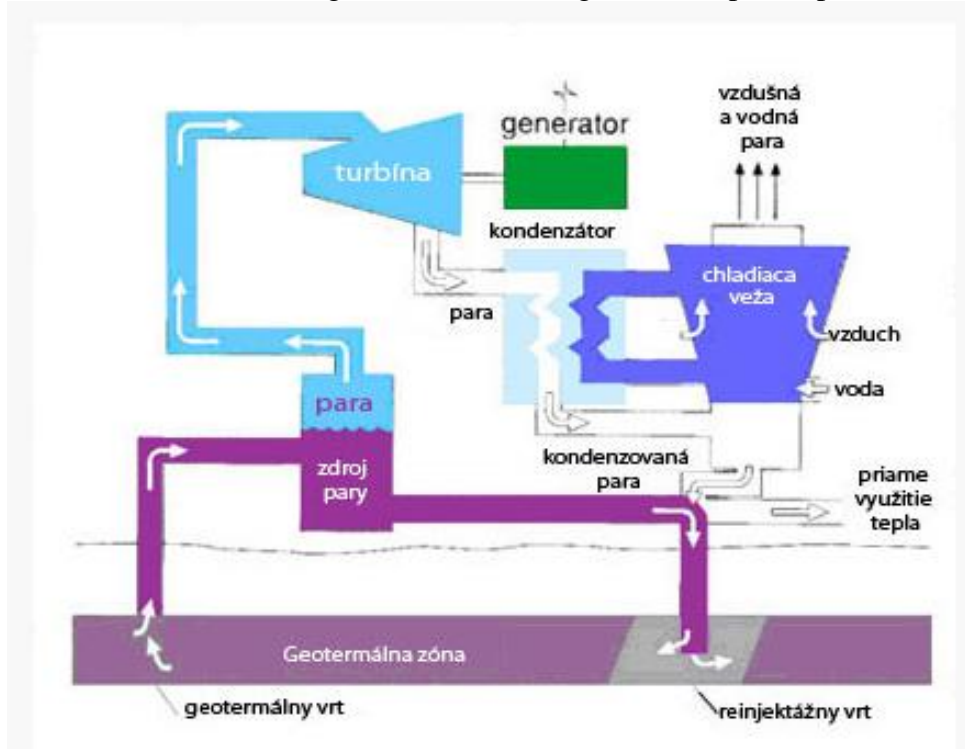
Geothermal power plant in Landerello (Italy)

Principle diagram of the operation of a geothermal power plant using the principle of dry steam

2.11.2 Flash principle

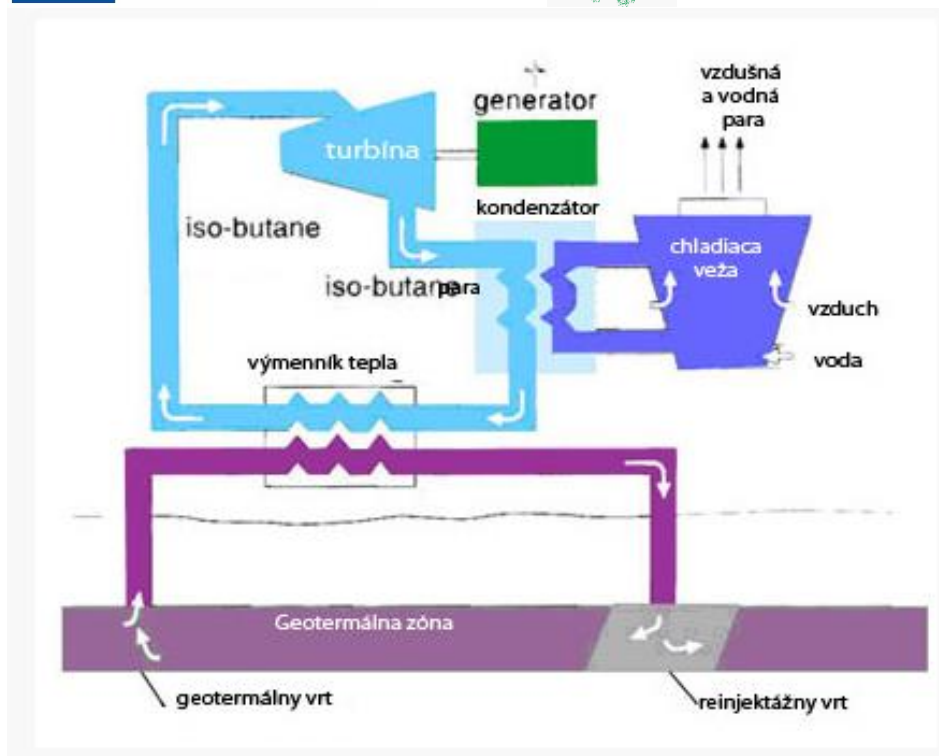
This geothermal power generation system uses hot water from a geothermal reservoir that is under high pressure and at a temperature greater than 182°C (360 °F). By pumping water from this reservoir to a power plant on the surface, the pressure is reduced and the hot water is turned

into steam, which then spins the turbine. The water that has not turned into steam is returned to the reservoir to be used again. Most modern geothermal power plants use this way of working.



2.11.3 Binary principle

The water used in the binary principle is colder than the water used in other methods of generating electricity from geothermal sources. In the binary principle, hot water is used to heat a liquid that has a significantly lower boiling point than water from a geothermal spring. This liquid turns into steam at a temperature close to the boiling point and spins the turbine and generator. The advantage of this method is greater efficiency of the given procedure. The availability of the necessary geothermal reservoirs is much greater than with other procedures. Another advantage is the complete closure of the entire system due to the fact that the used water is returned to the reservoir and thus the loss of heat and water is reduced to a minimum. Most of the planned new geothermal power plants will use this principle.



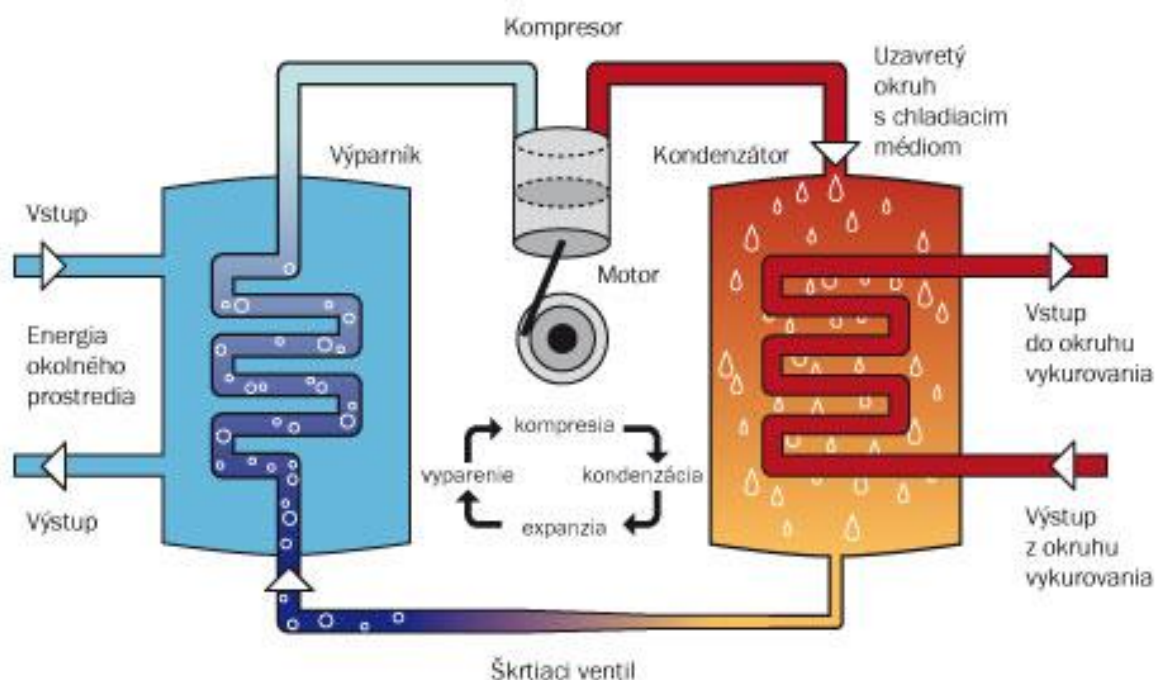
2.12 Heating using geothermal energy

The second interesting way of using geothermal energy is heating. Space heating is one of the most interesting ways of directly using the low temperature of geothermal fluid (up to 100 °C). The principle is based on the simple use of geothermal fluid, which transfers the temperature to the water in the exchanger, and this is transported through pipes to radiators in homes, or elsewhere. Such a heating system requires very thick insulation in order for the hot water to reach the users (large heat losses). The largest geothermal system used for heating is located in Iceland, respectively in the capital Reykjavik, where almost all buildings use geothermal energy for heating. Despite the fact that Iceland is clearly the largest consumer of geothermal energy per person, it is not the only one in the use of geothermal energy. Geothermal energy is also widely used in the territory of New Zealand, Japan, Italy, the Philippines and in some parts of the United States of America, such as San Bernardino in California and the Idaho capital Boise. Other ways of using geothermal energy for heating are e.g. fish breeding, heating of roads and sidewalks, balneology - use for recreational and spa facilities, etc.

2.13 Heat Pump

A heat pump uses thermal energy contained in the ground, water or air. The heat pump can heat e.g. house with water that is only a few degrees above zero. Due to the fact that the thermal energy is very dispersed in the given substance, it cannot be used directly for heating the house

under any circumstances. The principle of the heat pump is best understood from the following diagram¹⁰:



First phase - Evaporation: The refrigerant circulating in the heat pump takes heat from the air, water or earth, changing its state from liquid to gas and subsequently evaporates.

Second phase - Compression: The compressor of the heat pump sharply compresses the gaseous refrigerant, heated by several degrees, and thanks to the physical principle of compression (at higher pressure, the temperature rises), as a temperature lift, it multiplies a small increase in heat to a higher temperature level, which is around 80°C.

Third phase - Condensation: The heated coolant transfers heat to the water in the radiators with the help of the second exchanger, then cools down and condenses. The radiators radiate the obtained heat into the room, and the cooled water in the heating circuit travels back to the second exchanger for reheating.

Fourth phase - Expansion: The refrigerant travels through the expansion valve back to the first exchanger, where it is heated again.

However, the heat pump is not a perpetual motion machine either - it is driven by another, mostly electrical energy, while the input energy makes up about 20 to 40 percent of the pump's resulting energy.

Currently, heat pumps with a compressor driven by an electric motor are used almost exclusively for heating family houses. In terms of the compressor used, heat pumps are divided into:

- Heat pumps with a spiral compressor - they are more expensive, but they achieve the best heating factor. It is currently the most used type. The service life of the compressor is at least 20 years.
- Heat pumps with a rotary compressor - you can meet them in air conditioning equipment. They have a slightly lower heating factor than heat pumps with a compressor.

¹⁰<http://www.priateliazeme.sk>

- Absorption heat pumps - they work without a compressor and are therefore completely silent. The disadvantage is a worse heating factor. Currently, they are used only exceptionally for heating, but they are found in air conditioning equipment.

According to the type of cooled and heated medium, the following types of heat pumps are distinguished:

- air/water - universal type, for central heating
- air/air - additional heat source, hot air heating, air conditioning
- water/water - use of waste heat, geothermal energy, central heating
- antifreeze liquid/water - universal type for central heating, the heat source is most often a well or a soil collector
- water/air - hot air heating systems.

2.14 Natural sources for thermal pumps

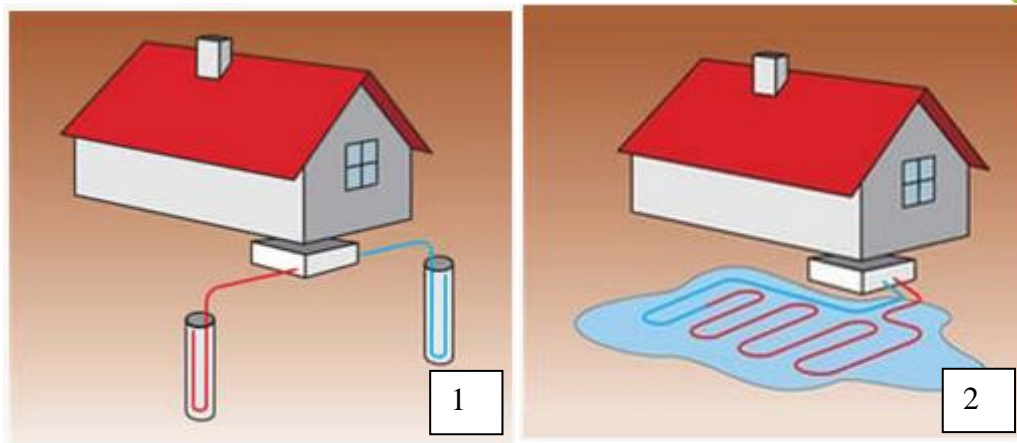
When choosing a natural source for a heat pump, it is necessary to consider mainly its availability, quality, abundance and temperature. In the event that pollution exceeds the permissible values for a specific heat pump, it is possible to use a separate heat transfer circuit, but it is necessary to take into account that the temperature of the auxiliary working medium (water, brine) will be approx. 5°C lower than a natural polluted source.

The individual natural sources for the heat pump and their temperature ranges are as follows:

Natural sources of heat	Temperature range, °C
Outside air	-10 to -15
Waste air	15 to 25
Underground water	4 to 10
Surface water (lake, river...)	0 to 10
Geothermal water	15 to 90
the rock	0 to 5
Earth, soil	0 to 10
Waste water	more than 10

2.14.1 Water

The advantage of using groundwater is that it has a constant and relatively high temperature (approx. 10 °C) and is therefore a very suitable heat source for a heat pump. The main prerequisites for construction are favourable hydrogeological conditions and sufficient abundance of underground water. With this principle, it is necessary to have two wells, from one of which the water is pumped out by a submersible pump and returned to the other after being cooled.



1 – Using the groundwater
for the thermal pump

2 – Using the surface water
for the thermal pump

The mutual distance of the wells should be from 10 to 25 m. In addition to underground water, surface water is also used, e.g. from stream, river, lake and waste water from industry or household.

2.14.2 Soil

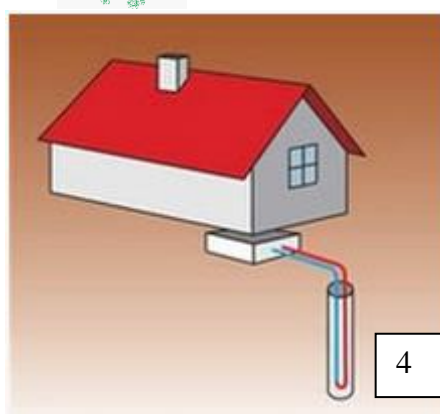
Due to the fact that in our climatic conditions the ground at a depth greater than 80 cm does not freeze, this source can also be considered temperature stable. In this design, the heat transfer between the ground and the heat pump is realized through a plastic pipe laid in the ground either horizontally or vertically. Horizontal installation is much less demanding from a financial point of view, but to heat a family house, two to three times the area of the collectors is needed, as is the area of the heated space. The pipe is laid at a depth of 1.5 to 2 m while the distance between the pipes is 1 m. The length of one pipe should not exceed 350 m. If this length is not enough, it is necessary to store more pipes, which must be the same length and must not be shaded. If the land or other conditions do not allow using horizontal collectors, deep wells are used.

The advantage of deep wells, similar to groundwater, is a relatively high temperature even on cold days, that is, when we need the most heat to heat our homes. Wells are usually 50 to 120 m deep. Their biggest problem is the high financial cost involved in the implementation of the well itself. The exact depth of the well depends on the geological conditions and the power of the pump. If a greater depth is required than the geological conditions or technical possibilities allow, the total length can be divided into several identical wells, at least 5 m apart. If the individual boreholes are shorter than 50 m, it is recommended to increase the total length of the pipeline (and therefore also the boreholes) by 10 percent.

The heat from the soil is transferred using an antifreeze mixture, which is filled with polyethylene pipes. Circulating water takes heat from the ground, which is processed and transferred in the pump. This process causes the earth to cool down, which is manifested, for example, by its later thawing. This fact must be taken into account when designing the heat pump and the pipes must be placed so that the hypothermia of the ground does not endanger the house or plants. The most suitable soil for heat pumps is moist clay soil that conducts heat well.



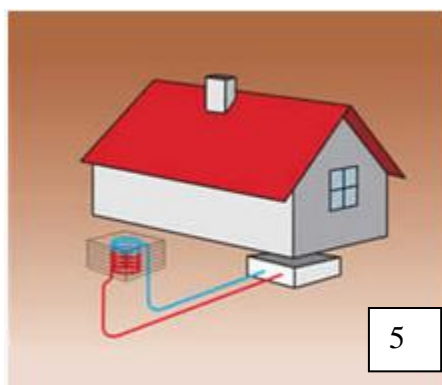
3 – Using the soil on the surface for the thermal pump



4 – Using the soil in-depth for the thermal pump

2.14.3 The air

The use of heat, which contains air, is the easiest, because this system can be implemented without technical limitations. The heat pump works up to air temperatures of -15°C , while the efficiency of the pump is relatively low at such temperatures. Therefore, in the event that the outside air temperature drops below -5°C , it is more advantageous to heat with a backup heat source. On the contrary, the pump achieves excellent efficiency in spring and autumn, when the air temperature is higher than, for example, the temperature of the ground or water. The big fluctuation in air temperature is the main disadvantage of this energy source. In addition to fresh air, waste air produced by the household (for example during controlled ventilation), industry or agriculture, where pigs and cattle are a large source of heat, can be effectively used.



5 – Using the air for the thermal pump

2.14.4 Purpose of use thermal pumps

- Heating - in general, heat pumps are suitable for low-energy heating systems (e.g. floor / wall heating), but current developments offer heat pumps with higher outputs that are suitable for all types of family houses (not only low-energy) and for all types of heating

systems . The efficiency and savings obtained by the heat pump will be more pronounced the more energy we need to supply to our house.

- Water heating - heat pumps are used not only for heating but also for heating water, many heat pumps have a built-in hot water tank. As a rule , water heating is preferred over heating, i.e. first, the heat pump heats the hot water and then releases the heat into the heating system
- Cooling - the cooling function is being integrated more and more often. In this case, the heat pump can work "in reverse" - it takes heat from the rooms and cools it through the working substance, which transfers the heat back to nature.

2.14.5 Operational modes thermal pumps

When familiarizing ourselves with the internal arrangement of the heat pump, we must not forget what affects the method of operation and with it the economic effect.

- Monovalent operation – in this case, the heat pump is the only source of heat for the entire building. It works throughout the heating season. It is suitable for low-temperature systems with a water temperature of up to 60°C.
- Alternatively - bivalent operation - the heat pump works only for part of the heating season and is shut down during the worst frosts. The heat is then supplied by another source (e.g. boiler). Suitable for systems requiring a water temperature of up to 90 °C.
- In parallel - bivalent operation - the heat pump works throughout the heating season even at low temperatures, where its performance is insufficient. This deficiency is compensated by connecting another heat source, while both sources work simultaneously.
- Partially parallel - bivalent operation - the heat pump only works for a certain part of the heating season. It is shut down during the worst frosts. Before shutting down, the heat pump and another heat source (boiler) work simultaneously for a certain period of time. This system is suitable for systems requiring a heating water temperature of up to 60 °C.

2.14.6 Thermal factor thermal pumps

A very important parameter of a heat pump is the heating factor. It expresses the ratio of supplied heat to the amount of energy consumed.

$$\varepsilon = \frac{Q}{E}$$

Q - heat supplied for heating, kWh

E - energy for driving the heat pump, kWh

The thermal factor of a heat pump is usually between 2 and 5. It depends on the inlet and outlet temperature, the type of compressor and other factors. Suppliers usually state the heat factor at different inlet and outlet medium temperatures. In practice, this means that 2-5 kWh of heat is produced from 1 kWh of electricity that the heat pump needs for its operation.

When calculating the heat factor, the consumption of circulation pumps (or fans), which are necessary for the operation of the hot water tank, is sometimes not taken into account. The actual heat factor can then differ significantly from the data in the prospectus.

The heat factor for compressor heat pumps can also be determined from the difference between the condensation temperature and the evaporation temperature. The approximate relationship for calculating the heat factor of a compressor heat pump is as follows:

$$\varepsilon = k \cdot \frac{T_k}{T_0}$$

T_k - is the condensation temperature (of the heated system), K

T_0 - is the evaporation temperature (temperature of the source), K

k - correction factor taking into account the actual circulation; $k = (0.4 \text{ to } 0.6)$

In order to achieve minimal energy consumption and achieve a high value of the heating factor, it is necessary:

- **The temperature of the source** should be **as high as possible**, while it must not exceed the maximum temperature allowed by the manufacturer. Its abundance must be sufficient.
- **The temperature difference** at the inlet and outlet should be **as low as possible**. The maximum working temperature of the hot water heater at the outlet is approx. 55 °C. The use of a heat pump is advantageous in combination with a **low-temperature heating system** (floor heating). The smaller the temperature difference the heat pump has to overcome, the less energy it consumes and the higher the heat factor.

The heat factor fluctuates throughout the year depending on the inlet and outlet temperature of the heat pump. **The average annual heat factor** is the ratio of **annual energy consumption** and **annual heat production** and is used to evaluate the operation. Normally, heat pumps deliver three to four times more heat under ideal conditions than they consume electricity for their operation.

2.14.7 Factors affecting on the economic efficiency thermal pumps

Before starting a heat pump project, there are several important factors to consider:

- purpose of use - related to it, the necessary power of the heat pump, type, functions, need for an auxiliary heat source, etc.
- heating system - low-temperature heating systems are most suitable for heat pumps - e.g. in-floor heating. The more we reduce the necessary output usable thermal energy from the heat pump system, the more efficiently this system works.
- source of low-potential heat - in addition to the yield, purity and temperature of the source (this applies especially to groundwater), its distance from the place of need must also be considered. This is related to the necessary initial investment - laying pipes, number of pipes, depth of the well, costs of filtering, water purification, etc.
- operating overhead - this includes the costs of operating the compressor and pumps (usually electricity), determining the performance number - the smaller the difference between the evaporation temperature and the condensation temperature, the higher the efficiency of the heat pump. The winter months are decisive, when the temperature of the surrounding environment is the lowest and the need for heat is the highest.

2.15 Advantages and disadvantages of using geothermal energy

Before we describe the disadvantages and advantages, we must also be clear about the ecological point of view. During production, there is a leakage of emissions of smelly chemicals, mainly ammonia and sulphur. The loading of the surroundings with steam is applied to a lesser extent, as a large part of the energy is lost during the transformation. This also follows from the very principle of production.

Advantages

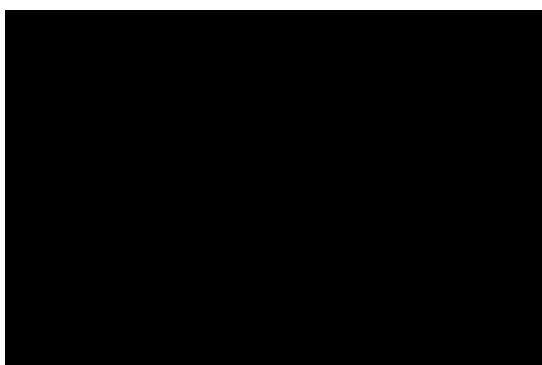
- renewable energy source with minimal exhalations,
- has a sufficiently well-known and developed technology,
- comparable price of produced electricity with other energies.

Disadvantages

- limited potential, depends on geological conditions,
- low conversion efficiency, depends on the achievable temperature of the working substance,
- high initial investment,
- high water consumption.

2.16 Greenhouse heated by geothermal energy in Horná Potôň

In the village of Horná Potôň in the Dunajská Streda district, they have completed the project of a special greenhouse with a cultivation area of six hectares, which will ensure the annual production of tomatoes of up to 3.25 million kilograms. We will use geothermal energy for heating. Geothermal water in the well has a temperature of 18°C.



6 – Greenhouse in Horná Potôň

7 – Galanta – geothermal well FGG-3

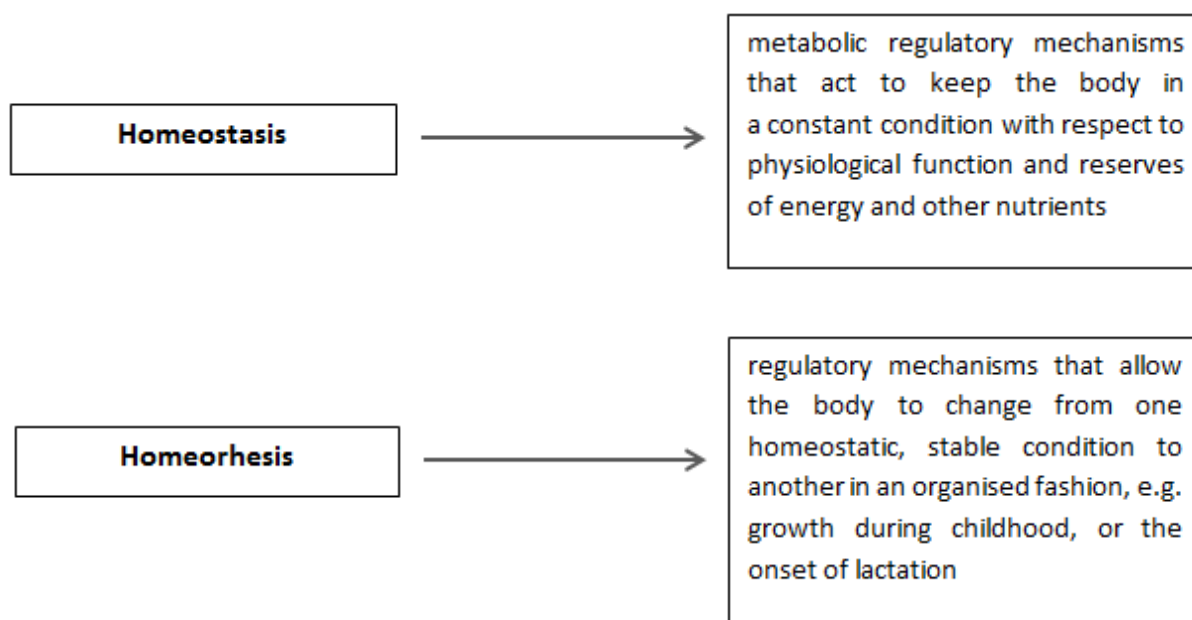
8 – Greenhouse in Horná Potôň – geothermal waste water release

3 Environmental Nutrition and Health

Environmental Nutrition and Health responds to the need of illuminating the connection between food value chain, agriculture, environment, climate, nutrition and human and animal health in order to improve public health through efforts related to environmentally sustainable food production by research activities. Knowledge in terms of innovative research on the food system, control tools to protect human and animal health in Slovakia and the EU, and risk factors in the food chain related to food and feed for maintaining health is an important point of research and focus in the field.

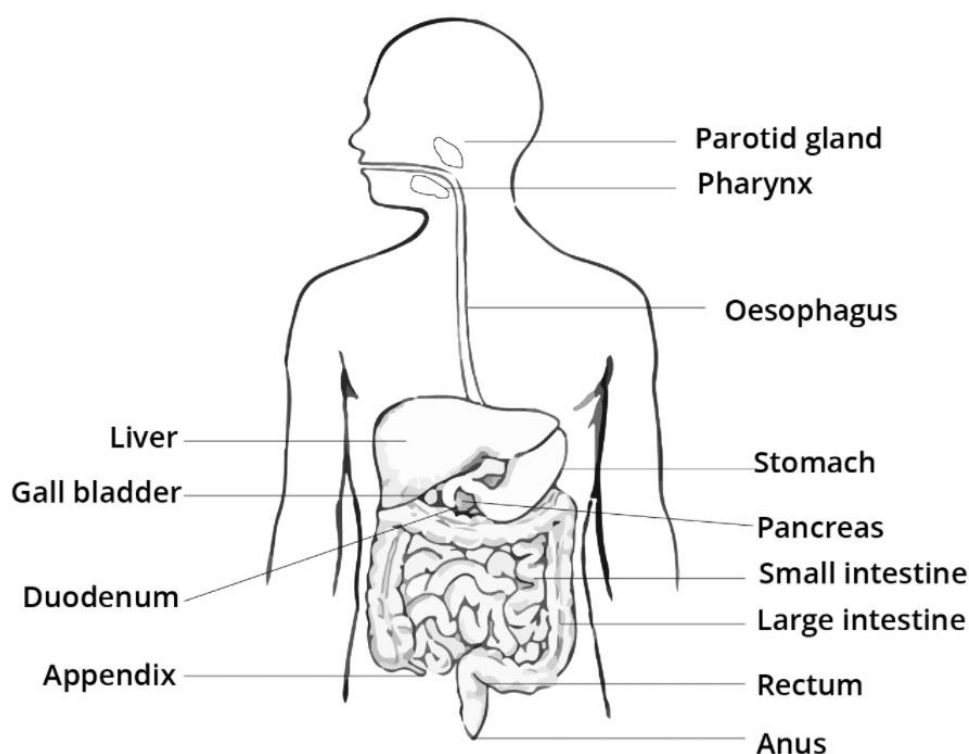
3.1 Nutrition

Energy intake presents a basis need for humans and all living organism. It is essential to preserve energy **homeostasis**, body weight, and ultimately health.



Eating behaviour is one of the most precisely controlled behaviours and involves environmental, peripheral, and central stimuli. Redundant neuronal and hormonal mechanisms cooperate to match energy expenditure and anabolic needs.

The role of digestive system is to digest food and absorb nutrients and water. Ingested material (mainly food) is subject to an orderly and controlled process of modification. During the passage, fluids containing enzymes that break down complex molecules are secreted into the lumen of the gut. The secretory processes are synchronized and coordinated by the enteric nervous system and intestinal hormones. Products of the digestion are absorbed across the epithelial cells, mainly in the small intestine. For gastric and intestinal motility the smooth muscles are decisive. It is also coordinated and regulated by the enteric nervous system and by intestinal hormones.



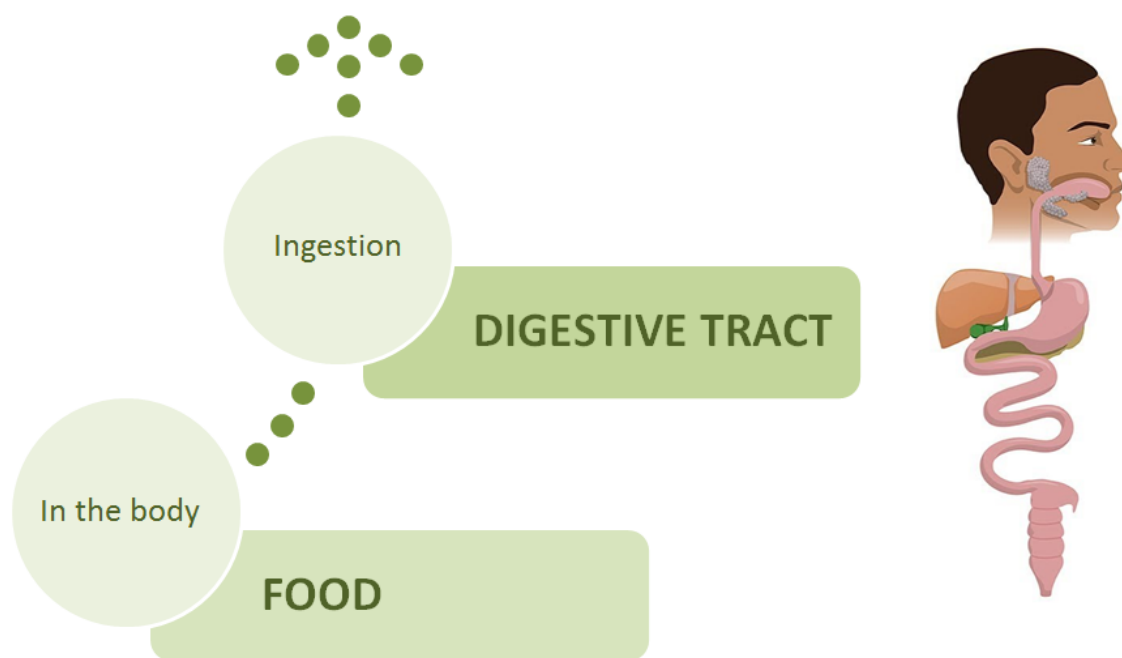
The principal parts of the digestive tract are mouth, teeth, tongue, pharynx, oesophagus, stomach, small intestine and large intestine. Salivary glands, liver and pancreas serve as accessory organs.

Nutrition serves to meet the material needs of the body - supplying energy and substances necessary for body construction.

Proper nutrition is one of the key factors for ensuring the basic physiological processes taking place in the human body and for maintaining health.

Food represents all materials that serve to nourish living organisms. **Foodstuffs** – are consumables, whose main function is to supply nutrients and energy to the body. The nutritional or nutritional value of a food is determined by the nutrient content present and its energy value.

- division food into smaller parts ↑ digestion
- the structural units or other simple chemical compounds finally enter the body by crossing the intestinal barrier ↑ absorption



The main tasks of digestive system (gastrointestinal tract) are: digestion, absorption, motility, excretion, storage, protection.

Digestion can be characterized as mechanical and chemical processing of food and the associated secretion of digestive juices.

The main digestive juices are:

- saliva
- gastric juice
- pancreatic juice
- bile
- intestinal juice

They are formed by glandular cells in the mucosa or in special glands of the digestive system. Their composition corresponds to the process of digestion in the different parts of the GIT. About 5-7 litres of digestive juices are produced per day, which contain 35 g of protein in the form of digestive enzymes and mucus. A chemical cleavage process (hydrolysis) that is dependent on the presence of specific enzymes of a protein nature.

Absorption It means that the basic building units formed after the digestion process (e.g. simple carbohydrates, fatty acids, etc.) can pass through the mucosa of the small intestine into the fluids of the internal environment - blood and lymph. Individual nutrients used by the body as building materials are taken up as complex organic substances which could not be absorbed in the small intestine without prior digestion.

Motility (the movements) of the initial section (oral cavity) and the final section (anus) are facilitated by the skeletal musculature and are under the control of the organism, voluntary. Other sections of the GIT move by contraction of smooth muscle and they are not controllable, involuntary.

3.1.1 Types of movements

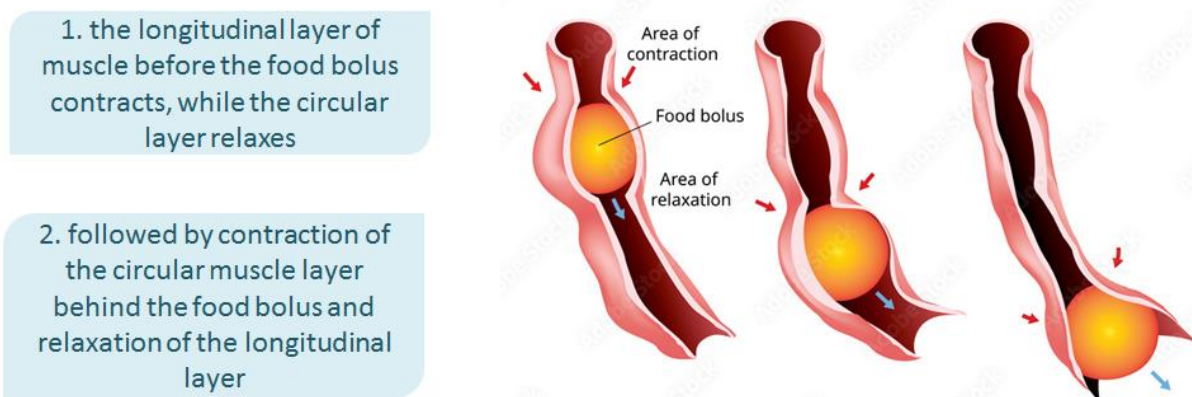
Propulsive movement is controlled forward movement. It moves the contents from the stomach into the small intestine and then into the large intestine. Undigested food parts and waste products are subsequently eliminated from the body by defecation.

Trituration movement means that its task is to grind the ingested food into small particles. There is an increase in their surface area.

Mixing movements - their task is to mix the ingested food with the secreted juices. They bring nutrients into contact with the absorbent surface.

Relaxation-adaptive movements respond to a change in the remitt of a particular body.

Peristaltic wave is controlled movement of chymus in the GIT lumen over different distances. It is typical smooth muscle cell contraction.



Excretion - the digestive system contributes to the elimination of metabolic wastes and some harmful substances. The liver excretes bilirubin, cholesterol and its derivatives, some harmful substances ingested from food, administered drugs and their metabolites in bile and subsequently in faeces. The mucosa of the small intestine is similarly involved in excretion, e.g. some substances present in enterocytes are released into the intestinal contents after their death and subsequently excreted (Fe, cholesterol).

Storage - food intake at longer or shorter intervals. The activity of the cells of individual tissues requires a constant supply of nutrients and building blocks in the blood. This "problem" is balanced by the digestive system by gradual release of food from the stomach, the slow process of digestion and absorption and other mechanisms. In this way the body prevents a rapid rise in blood levels after a meal and a significant drop in the interval between meals.

Protection in digestive tract means action of antigens and allergens. Important is intact mucosa of the digestive tract. The mechanical, humoral, cellular, immune and non-immune protective factors of the intestinal mucosa are called the mucosal barrier, part of which is the immune system.

3.1.2 Summary – digestive system

The process of digestion begins in the oral cavity, or mouth. The three pairs of salivary glands produce fluid called saliva. Saliva is released from the parotid, submaxillary and sublingual glands and is poured into the mouth.

From the mouth, food passes to the pharynx. The pharynx opens into the oesophagus, a muscular tube extending to the stomach.

The stomach is composed of a fundus, a body with its greater and lesser curvatures, and an antrum. The openings allowing food in and out of the stomach are controlled by rings of muscles called sphincters. Its upper cardiac sphincter opens into the oesophagus while the pyloric sphincter allows food to leave the stomach when it has been sufficiently digested. The lining mucous membrane secretes a large amount of mucus apart from hydrochloric acid and enzymes. The stomach secretes gastric juices containing an enzyme (pepsin) needed to convert proteins to smaller substances called peptones. Hydrochloric acid is necessary for the proper action of pepsin. The role of the stomach is to prepare food chemically and mechanically so that it can be received in the small intestine for further digestion and absorption into the blood. The small intestine is composed of the duodenum from the food passes in peristaltic waves into the jejunum and ultimately into the ileum. In the wall of the entire small intestine are minute finger-like villi. It is through the capillary network of the villi that digested foods pass to enter the bloodstream.

The colon or large intestine extends from the ileum to the anus. It is made up of the caecum with the vermiform appendix, ascending, transverse and descending colon, the pelvic (sigmoid) colon, and the rectum. The rectum terminates into the lower opening of the gastrointestinal tract – the anus. The large intestine receives the fluid by-products of digestion from the small intestine. Water is reabsorbed into the bloodstream while the unabsorbed material is eliminated from the body as faeces.

Three important accessory organs of the digestive system are the liver, gallbladder and pancreas. Although food does not pass through these organs, they play a crucial role in the proper digestion and absorption of nutrients. The liver is the most important digestive gland. Above all, the liver produces a thick fluid called bile which is stored in the gallbladder. Without bile, most of the food taken into the body would remain undigested. Besides producing bile, the liver has many other important functions, e.g. keeping the amount of glucose in the blood at a normal level, manufacturing protein substances, destruction of worn-out red blood cells, removal of poisons or toxins from the blood, formation of antibodies to fight diseases, and production of urea – a waste product of protein breakdown.

The pancreas functions as both an exocrine and endocrine organ. It secretes pancreatic juice which helps to break down all types of food. As an endocrine organ, it produces a hormone called insulin which enters the bloodstream directly and plays an important role in the utilization of sugar in the body.

Breakdown of complex substances -digestion

Passage of simple nutrients into the bloodstream – absorption

Formation of wastes and removal from the body – excretion

Chewing – mastication

Contraction and relaxation of muscle to propel food along the gastrointestinal tract – peristalsis

3.2 Food

Food is made up of a large number of chemicals, some of which are referred to as nutrients. They are divided to the macronutrients and micronutrients. **Macronutrients** are needed in relatively large quantities (grams per day). These include: carbohydrates, fats and proteins.

Micronutrients are needed in small quantities (milligrams per day, or micrograms per day). These include: vitamins and minerals.

3.2.1 Nutrients

Classification of nutrients according to function:

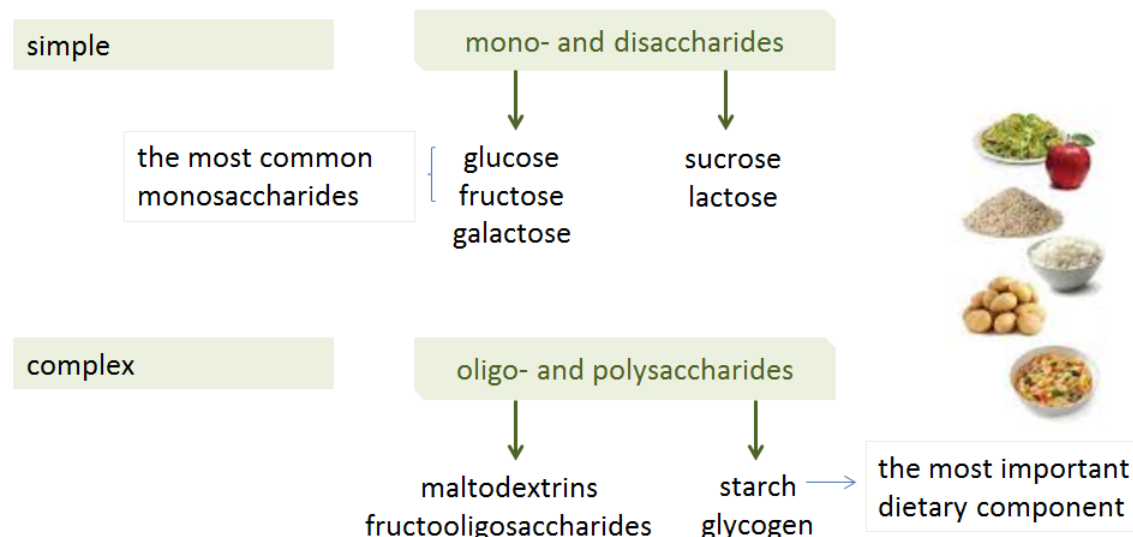
- **at the genetic level**, nutrients are involved in the regulation of gene transcription, thereby influencing protein synthesis, including enzymes
- **at the cellular level**, nutrients participate as cofactors in the control and regulation of metabolic reactions and energy release
- **immune and defence mechanisms**, work by releasing highly reactive molecules (free radicals), which must then be destroyed by antioxidants

Interactions:

- **interactions between nutrients and other substances** during food consumption (processing and metabolism)
- there is no point in studying the nutrient itself without considering other factors

3.2.2 Carbohydrates

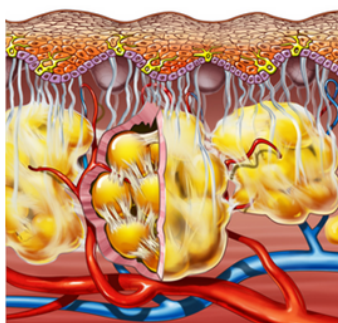
- the most important source of energy
- being converted to glycogen or fat as energy stores
- include:



3.2.3 Fats

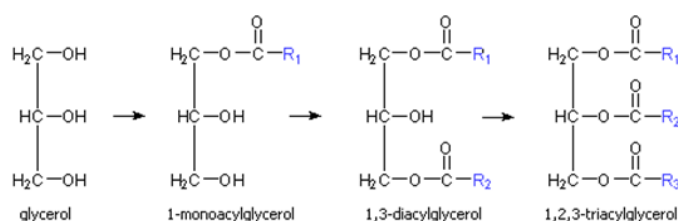
- a diverse group of substances, insoluble in water

triacylglycerols



TAG

- they "decay" and create energy
- an important source of energy in the body
- 2x more calories than carbohydrates and protein
- the main energy store in adipose tissue
- certain fatty acids in TAG (essential) are important for cell membrane formation and function



3.2.4 Proteins

- chains of amino acids, contain 20 different amino acids
- nitrogen-containing macromolecules that occur in major amounts in foods

diversity among dietary proteins in the amino acids sequence

THE 11 NON-ESSENTIAL AMINO ACIDS

Alanine
Arginine
Asparagine
Aspartic acid
Cysteine
Glutamic acid
Glutamine
Glycine
Proline
Serine
Tyrosine

THE 9 ESSENTIAL AMINO ACIDS

Histidine
Isoleucine
Leucine
Lysine
Methionine
Phenylalanine
Threonine
Tryptophan
Valine

3.2.5 Vitamins

fat soluble

A, D, E, K

structural tasks
cell integrity
homeostasis
antioxidants
nerve impulses

water soluble

B, C

metabolism
cell division
antioxidants
cofactors for enzymes
synthesis of
neurotransmitters

3.2.6 Mineral substances

calcium, phosphorus, sodium, chloride, potassium, magnesium, iron, copper, manganese, iodine, selenium

-structural tasks
-cofactors for enzymes
-acid-base balance

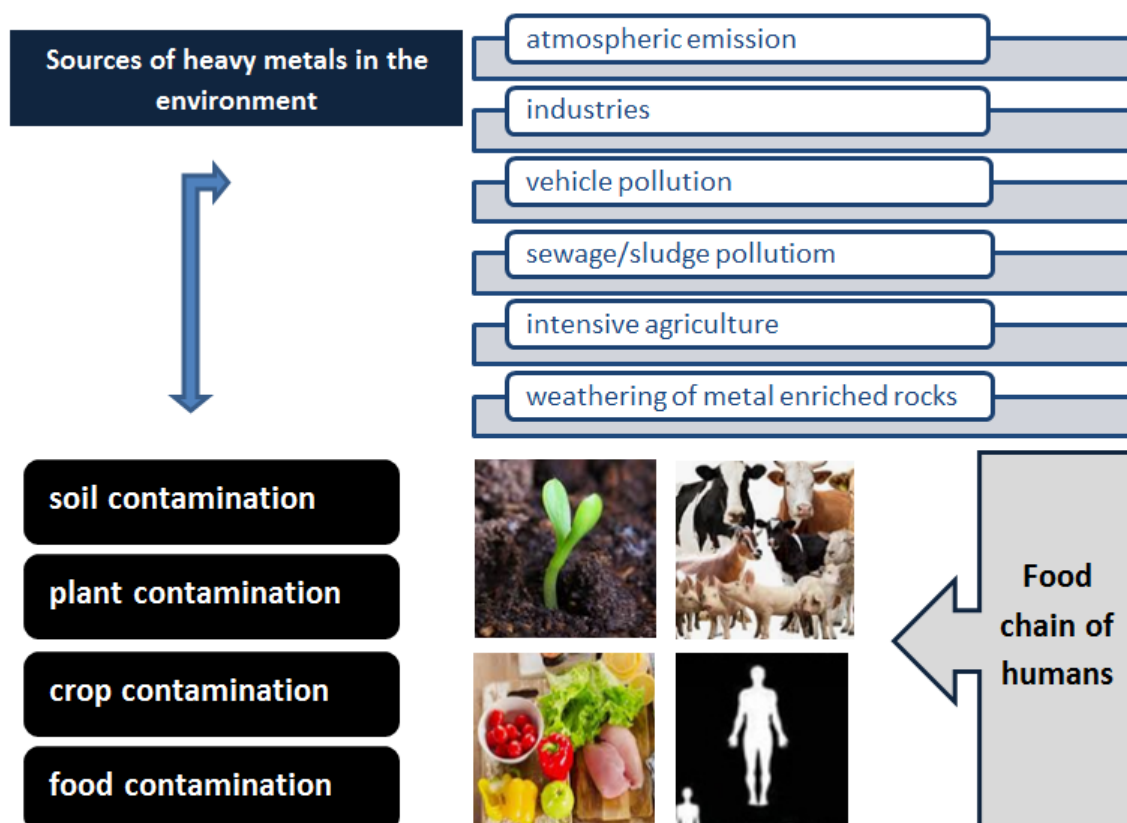


3.2.7 Key points

When studying nutrients, it is necessary to pay attention to:

- their structure and chemical properties
- in what food they are contained
- how they are digested, absorbed, transported and stored
- the form in which they are used
- how their excess or metabolic products are excreted
- recommended intake
- what the body needs them for
- how the body reacts to excessive or inadequate consumption
- nutrient interactions
- which individuals are prone to their deficiency
- whether there is any therapeutic use for them
- what is not known about them and further research is required

3.3 Risk factors of food chain



Man is surrounded by the environment in which different substances occur, of animal, plant, microbial, and anthropogenic origin. During a person's life there are many interactions among these substances, which affect a person's health, as well as the quality of animal products and food. Various substances after entering the body of animals and humans produce diverse effects.

In the present is exercitation of sustainable development rules which respect the environment care on the prime place. Some environmental factors, such as exposure of harmful substances in water, food or air, markedly influence the health of organisms and the exposure of animals to various xenobiotics cause biological health problems. Heavy metals are significant risk factors of environment. Contamination with toxic substances can damage animal health and markedly influence metabolism processes with serious negative consequences, for example on the immune system, productive and reproductive abilities of organism. These xenobiotics activate many intoxications and cause accumulation in organs. Relative negligible disorders can activate irreversible metabolic disorders or pathological changes of organs. They can cause mutations of some information in cell genome.

3.4 Food – history

3.4.1 5th to 15th century: Middle Ages in Western Europe

Eating, feasting and enjoying food was a fundamental part of medieval life. In Western Europe, medieval cuisine (5th – 15th century) did not change quickly.

As agriculture was predominant cereals were the most important staple during the medieval period. Oats, barley, and rye were consumed by the poor. Among the standard foods was porridge, bread, or gruel. Vegetables and fava beans remained very important additions to the cereal-based diet of the lower orders. Meat was expensive and prominent. Game stayed common only on the tables of landowners. On special cases and occasions the prosperous ate swans and peacocks. The most dominant butcher's meats were pork, chicken, and other domestic fowl. Beef which required bigger investment in land was not so common. Herring and cod stayed mainstays among the northern populations. They were prepared as smoked, dried, or salted, but many varieties of other saltwater and freshwater fish were also consumed. The foodstuffs people received were controlled by the geography, seasons, and spiritual and religious limits. For most people food source depended on what the close seas or lands could offer. Peasants realised primarily cooking over an open fire, on a spit or in a cauldron. Their ovens were situated mainly outside of the house and made on top of clay or turf. Poor people ate mostly vegetables and grains in the form of soup, stew, or pottage, and anything they were able to grow on their small plots of land. They cannot afford spices, and it was forbidden for them to hunt boar, deer, or rabbits. Their staples consist of barley, rye, bread, stews, local dairy products, cheaper meats like pork, beef, lamb, and fish if there was possibility of freshwater. They grow vegetables and herbs, fruit, nuts and honey they obtained from local trees and bushes. Cereals prepared with milk were quite common in medieval cuisine. The upper class and nobility required better food in comparison to lower classes, but food was consumed in small portions. Food was laid out with various different colours and flavours – a very diverse experience from those in the lower class. Smaller portions were typical around this time because of many cultural influences, and these huge, table-long meals were essentially picked at by the aristocracy. Meals were spiced a lot, and many of spices were expensively imported, mainly from outside Europe. The food in the middle age of the upper class and nobility involved various meals e.g. venison, pork, and lamb, fish and shellfish, cheese, spices, fruits, manchet bread, and a small number of vegetables.

During medieval times, the cooking methods and techniques that were developed were so effective that people still using them today. Most of these techniques allowed us to cook food much easier and effective, and some methods enabled them to store food properly. As food intake was controlled by geography and availability, it was also governed by the Church. Some fasts occurred throughout the year, and the longest was that of Lent. There were defined days in which people could not eat meat or fish, but this did not influence the poor significantly due to their already-lacking food choices. The Church also affected people to keep some feasts during the year, including on Christmas and for lesser holidays. The nobility and upper classes were involved in these extravagant feasts, as they often followed a fasting period.

One of the notable matters regarding food during the Middle Ages was the preservation of meals. People were not able to freeze their food (besides the winter time). Meat and fruit would have gone bad shortly (especially during the summer). Preservation was needed to export those meals for the market of foreign areas, as some food and ingredients were only found in some parts of the world. Effective method to preserve meats was smoking. But, this method required fuel which could have been scarce in some areas. Another method was drying. It was cheaper and realised mainly with fish, laying them under the sun. But this procedure had its limitations, needing several sunny days to avoid meat rotting before it got dried. Salt became one of the best methods of preservation, as it removed the moisture, making it hard for bacteria to survive in the meat.

3.4.2 16th century: Importance of Spain and Portugal

The Spanish and Portuguese Empires released sea trade routes that connected food exchange across the world. Under Phillip II, Catholic cuisine basics unintentionally helped convert the cuisine of the Americas, Hindus, Buddhists, and Islamic cuisines of the South Eastern Asian region. In Goa, the Portuguese were stimulated by the Crown to marry local women following their conversion. This mixing and integration led to mixed cuisine between Portugal and Western India. The Portuguese contributed by round raised loaves, using wheat shipped from Northern India, as well as pickled pork. The pork was pickled in vinegar or wine using garlic (carne de vinha d'alhos) tied to Portuguese cuisine that later became vindaloo.

3.4.3 18th century: early modern Europe

Grain and livestock belonged to the most important agricultural products in England and France. After 1700, innovative farmers tested the new techniques to increase yield and looked into new products such as oilseed rape, hops, artificial grasses, fruit, vegetables, dairy foods, commercial poultry, rabbits, and freshwater fish. Most people in Medieval England try to prepare their own food.

Sugar became an upper-class luxury product, but by 1700 Caribbean sugar plantations worked by African slaves had extended production, and it was much more widely available. By 1800 sugar was a staple of working-class diets. For them, it meant increasing economic freedom and status. In Western Europe in the 18th century labourers consumed bread and gruel, often in a soup with greens and lentils, a little bacon, and sometimes potato or a bit of cheese. They used to wash it down with beer (water was contaminated), and a sip of milk. Three quarters of the food was derived from plants. Meat was much more attractive, but very expensive.

3.4.4 19th century

By 1870, the West European diet formed about 16 kilos per capita per year of meat, rising to 50 kilos by 1914, and 77 kilos in 2010. Cheese and milk was seldom in the diet – even in the early 20th century, it was still uncommon in Mediterranean cuisine. In the immigrant neighbourhoods of fast-growing American industrial cities, housewives purchased ready-made food through street peddlers, push carts hucksters, and small shops worked from private homes. This showed the way for the quick entry of entirely new items such as spaghetti, pizza, meatballs, pretzels, bagels, hoagies, and perogies into American eating habits, and firmly established fast food in the American culinary experience.

3.4.5 20th century

The first half of the 20th century was marked by two world wars, which in many places resulted in rationing and hunger; sometimes the starvation of the people was used as a powerful new weapon.

3.4.5.1 *World War I and after*

During World War I in Germany the rationing system in urban areas practically collapsed, people consumed animal fodder in order to survive the Turnip Winter. Conditions in Vienna worsened as the army got priority in the food supply.

In Allied countries, meat was allocated first to the army, then to urgent civilian needs in Italy, France, Britain, and Greece. Meat production was stretched to the limit in the United States, Canada, Australia, New Zealand and Argentina, with oceanic shipping carefully controlled by the British. Food deficit was severe in Russian cities, resulting to protests that escalated and helped topple the Tsar in February 1917.

After the war ended in 1918 in the first years of peace, many people in eastern and central Europe suffered severe food shortages. The American Relief Administration (ARA) was appointed under the American wartime “food czar” Herbert Hoover and was charged with providing emergency food rations across Eastern and Central Europe. The ARA fed millions, plus the inhabitants of Germany and the Soviet Union. After U.S. government funding for the ARA expired in the summer of 1919, the ARA became a private organization, raising millions of dollars from private contributors. Under the auspices of the ARA, the European Children's Fund fed millions of starving children.

The 1920s saw the application of new foodstuffs, mainly fruit, imported from around the world. After the World War some new meals products became available to the typical household, with branded foods advertised for their convenience. An experienced cook spending hour on difficult custards and puddings was no longer used; the housewife could buy instant foods in jars, or powders that could be quickly mixed. Richer households now owned ice boxes or electric refrigerators for better storage and the convenience of buying in larger quantities.

3.4.5.2 *World War II and after*

During World War II, Nazi Germany used to feed the population by seizing foodstuffs from occupied lands, and intentionally cutting off food supplies to Russians, Jews, Poles, and the Dutch.

As part of the Marshall Plan in 1948–1950, the United States offered technological expertise and financing for high-productivity large-scale agribusiness operations in post-war Europe. Poultry became a favourite meal, with the quick expansion in production, a sharp fall in prices, and broad acceptance of the many ways to serve chicken.

The Green Revolution in the 1950s and 1960s was a technological breakthrough in plant productivity that raised agricultural production worldwide, mainly in the developing world. Research started in the 1930s and dramatic improvements in output became important in the late 1960s.

The initiatives caused the adoption of new technologies, including new, high-yielding varieties (HYVs) of cereals particularly rice and dwarf wheats, in connection with chemical fertilizers and agro-chemicals, and with controlled water-supply (involving irrigation) and new methods of cultivation, involving mechanization. All of these together were a “package of practices” to supersede “traditional’ technology and to be adopted as a whole”.

3.5 Consumption history of notable food

3.5.1 Potato

The potato was first domesticated in the region of modern-day southern Peru and extreme north-western Bolivia. It has since spread around the world and started to be a staple crop in many lands.

Some considered that the introduction of the potato was accountable for a quarter or more of the growth in Old World population and urbanization between 1700 and 1900. Following the Spanish conquest of the Inca Empire, the returning Spanish conquistadors introduced the potato

to Europe in the second half of the 16th century, as part of the Columbian exchange. Gradually people began to recognize the properties of the potato. The staple was then conveyed by European mariners to places and ports throughout the world. The potato was adopted by distrustful European farmers, but soon enough it became a main food staple and field crop that had a major role in the 19th century European population boom. But, lack of genetic diversity, because of the very limited number of varieties, left the crop sensitive to disease. There are few remarks of potato being cultivated in India in the travel accounts of Mr. Edward Terry and Mr. Fyer during 17th century. Potato is believed to be introduced in India by Portuguese in early 17th century. The Portuguese called it “batata”. Indians later settled a different term for potato, they called it “Alu” – this name came up under British Rule. In 1845, a plant disease named as late blight, caused by the fungus-like oomycete *Phytophthora infestans*, spread quickly through the poorer communities of western Ireland as well as parts of the Scottish Highlands, what led in the crop failures that caused the Great Irish Famine (Crowley et al., 2012). Currently China is the leader potato producing country followed by India as of 2017, FAOSTAT, Food and Agriculture Organization of the United Nations.

3.5.2 Rice

Rice originated from the seasonal plant *Oryza sativa* and has been cultivated since about 6000 BCE. The main rice-producing countries are in east and south Asia. The real origin place of rice has always been a hot point of discussions between India and China as both countries started cultivating it around the similar time. The average amount of rice cultivated every year was between 800 billion and 950 billion pounds. Muslims brought rice to Sicily in the 9th century. After the 15th century, rice expanded throughout Italy and later in France, then spreading to all the continents during the age of European exploration. Today it is the most widely consumed staple food worldwide. Now India is leading rice producing country according to FAOSTAT, Food and Agriculture Organization of the United Nations.

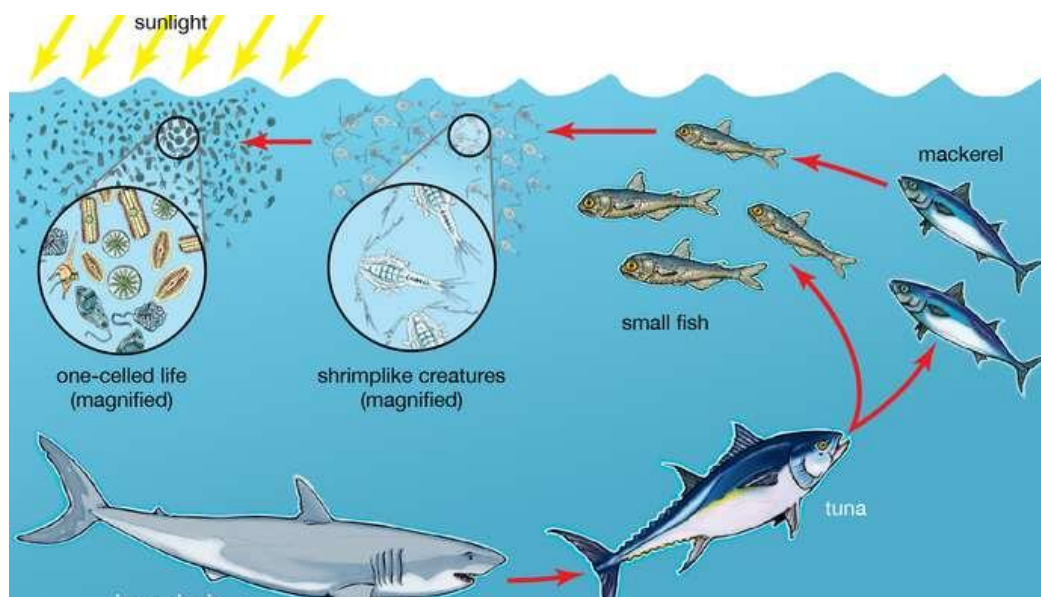
3.5.3 Sugar

Medieval people certainly had fruit, which was very sweet for someone who has never had actual sugar. The principal sweetener was honey. Peasants would not normally keep bees, but they could hope to find wild honey in the woods. Generally, sugar originated from India by taking sugarcane plant through some mechanical and chemical processes. The term sugar is derived from a Sanskrit word “sarkara”. Previously people used to chew the juice out of sugarcane to enjoy the sweetness of the plants. Then, Indians developed the technique to crystallize the sweet liquid. This technique then expanded towards the neighbouring countries of India. The Portuguese and Spanish empires produced sugar for Europe by the late seventeenth century from New World plantations. Brazil became the main sugar producer. Sugar was expensive during Middle Ages. Evidence indicated that sugar prices averaged about the same as those of common spices. Due to the increase of sugar cultivation, obtaining sugar started to be easier and more affordable. Europeans could enjoy Islamic-inspired confectionary goods that were previously costly to produce. The Jesuits were important producers of chocolate, obtaining it from the Amazon jungle and Guatemala and shipping it across the world to Southeast Asia, Italy and Spain. They put into practice Mesoamerican methods to Europe for processing and preparing chocolate. Fermented cocoa beans had to be ground on heated grindstones to prevent producing oily chocolate, a process that was unknown to many Europeans. Chocolate remained largely as a beverage within the Catholic world as it was not considered a food to the church and it could be consumed during fasting (Moss and Badenoch,

2009). Brazil is currently largest producer of sugar, followed by India, which is also the largest consumer of sugar.

3.6 Food chain

Food chain means the sequence of transfers of matter and energy in the form of food from organism to organism. Food chains interwork locally into a food web as most organisms consume more than one type of animal or plant. In a predator chain it is true that a plant-eating animal is eaten by a flesh-eating animal. In a parasite chain, a smaller organism intakes part of a larger host and may itself be parasitized by even smaller organisms. In a saprophytic chain, microorganisms live on dead organic matter.



Diatoms and other phytoplankton form the composition of ocean food chains. Shrimplike krill eat the phytoplankton, and small fishes consume the krill. At the top of the food chain, dining on smaller fishes, are predatory larger fishes (Encyclopaedia Britannica, Inc.). By reason that energy, in the form of heat, is lost at each step, or trophic level, chains do not normally include more than four or five trophic levels. People are able to increase the total food supply by interrupt one step in the food chain: the people can consume the grains instead of consuming animals that eat cereal grains. The food chain is made shorter; the total amount of energy available to the final consumers raised.

3.7 Healthy diet

A balanced and healthy diet helps to secure against malnutrition in all its forms, as well as noncommunicable diseases (NCDs), including heart disease, diabetes, stroke, or cancer. Lack of physical activity and unhealthy diet presents principal global risks to health. Healthy dietary practices begin early in life – breastfeeding supports healthy growth and ameliorates cognitive development and can have longer term health benefits such as reducing the risk obesity or onset of NCDs later in life. Energy intake (calories) should be in balance with energy expenditure. To eliminate unhealthy weight gain, total fat should not exceed 30% of total energy intake. Consumption of saturated fats should be less than 10% of total energy intake, and consumption of trans-fats less than 1% of total energy intake, with a shift in fat intake away from saturated

fats and trans-fats to unsaturated fats, and towards the goal of eliminating industrially-produced trans-fats.

Limiting consumption of free sugars to less than 10% of total energy intake is part of a balanced and healthy diet. A further reduction to less than 5% of total energy intake is proposed for additional health benefits:

- keeping salt consumption to less than 5 g per day can prevent hypertension and decrease the risk of heart disease and stroke in the adult population,
- WHO Member States have agreed to decrease the global population's consumption of salt by 30% by 2025; they have also agreed to stop the rise in diabetes and obesity in adults and adolescents as well as in childhood overweight by 2025.

Eating a healthy diet throughout the life-course is important in prevention of malnutrition in all its forms as well as a range of noncommunicable diseases (NCDs) and conditions. But, raising production of processed foods, changing lifestyles and rapid urbanization has led to a shift in dietary patterns. People are now eating more meals with high energy, fats, free sugars and salt/sodium, and many people do not consume enough vegetables, fruit and some other dietary fibre e.g. whole grains. The accurate make-up of a varied, healthy and balanced diet will fluctuate in dependence on particular characteristics (e.g. gender, age, lifestyle and degree of physical activity), cultural context, locally accessible foods and dietary customs. Nevertheless, the elementary principles of what contains a healthy diet are the same.

3.7.1 Healthy diet for adults

A balanced and healthy diet involves the following:

- vegetables, fruit, legumes (e.g. beans and lentils), whole grains (e.g. unprocessed oats, maize, millet, wheat, brown rice) and nuts,
- at least 400 g (five portions) of vegetables and fruit per day, excluding potatoes, sweet potatoes, cassava and other starchy roots,
- less than 10% of total energy intake from free sugars, which is equivalent to 50 g (about 12 level teaspoons) for a capita of healthy body weight consuming about 2000 calories per day, but ideally is less than 5% of total energy intake for further health benefits. Free sugars mean all sugars added to drinks or foods by the producer, cook or consumer, as well as sugars naturally present in syrups, honey, fruit juices and fruit juice concentrates, less than 30% of total energy intake from fats,
- unsaturated fats (in fish, avocado and nuts, sunflower, soybean, canola and olive oils) are preferable to saturated fats (butter, fatty meat, palm and coconut oil, cream, cheese, ghee and lard) and trans-fats of all kinds, involving both industrially-produced trans-fats (pre-packaged snacks and foods, such as frozen pizza, pies, cookies, biscuits, wafers, and cooking oils, spreads, baked and fried foods) and ruminant trans-fats (meat and dairy foods from ruminant animals as cows, sheep, goats and camels). It is suggested that the consumption of saturated fats be reduced to less than 10% of total energy intake and trans-fats to less than 1% of total energy intake (WHO, 2018). Industrially produced trans-fats are not part of a healthy diet and should be avoided
- less than 5 g of salt (about one teaspoon) per day. Salt should be iodized.

3.7.2 Healthy diet for infants and young children

In the first 2 years of a child's life, ideal nutrition supports healthy growth and improves cognitive development. It decreases the risk of becoming overweight or obese and developing NCDs later in life, too.

Advice on a balanced and healthy diet for infants and children is similar that for adults, but the following issues are also important:

- infants should be breastfed explicitly during the first 6 months of life,
- infants should be breastfed until 2 years of age and beyond,
- from 6 months of age, breast milk should be supplemented with a variety of adequate, safe, and nutrient-dense foods. Sugar and salt should not be added to complementary foods.

3.7.3 Practical advice on maintaining a healthy diet

3.7.3.1 *Fruit and vegetables*

Consumption at least 400 g (five portions) of vegetables and fruit per day decrease the risk of NCDs and helps to assure an adequate daily intake of dietary fibre.

Fruit and vegetable consumption can be improved by:

- including vegetables in meals every time,
- consumption of fresh fruit and raw vegetables as snacks,
- consumption of fresh fruit and vegetables that are in season; and
- consumption a variety of vegetables and fruit.

3.7.3.2 *Fats*

Decreasing the amount of total fat consumption to less than 30% of total energy intake is important in prevention of unhealthy weight gain in the adult population. Thus, the risk of developing NCDs is lowered by:

- decreasing saturated fats to less than 10% of total energy intake,
- reducing trans-fats to less than 1% of total energy intake; and
- substituting saturated fats and trans-fats with unsaturated fats – in particular, with polyunsaturated fats.

Fat consumption, particularly saturated fat and industrially produced trans-fat intake, can be reduced by:

- boiling and steaming instead of frying during the cooking,
- substitution of butter, lard and ghee with oils containing polyunsaturated fats, such as soybean, corn, canola (rapeseed), safflower and sunflower oils,
- intake of reduced-fat dairy foods and lean meats, or trimming visible fat from meat; and
- reduction in the consumption of fried and baked foods, and pre-packaged snacks and foods (pies, cakes, doughnuts, cookies, biscuits and wafers) that contain industrially produced trans-fats.

3.7.3.3 *Salt, sodium, and potassium*

Most people receive a great deal of sodium through salt (corresponding to intake an average of 9–12 g of salt per day) and not enough potassium (less than 3.5 g). Elevated sodium consumption and deficient potassium intake contribute to high blood pressure, which in turn raises the risk of heart disease and stroke. Decreasing salt intake to the recommended level (less than 5 g per day) could prevent 1.7 million deaths each year.

People often do not know the amount of salt they consume. In many countries, most salt occurs in processed foods (ready meals, bacon, ham, and salami; cheese; and salty snacks) or from

meals consumed often in large amounts (bread). Salt is also added to meals when cooking (stock cubes, bouillon, soy or fish sauce) or at the moment of consumption (table salt).

Salt consumption should be reduced by:

- decreasing the amount of salt and high-sodium condiments (soy sauce, fish sauce and bouillon) during cooking and preparing foods,
- not having salt or high-sodium sauces on the table,
- decreasing the consumption of salty snacks; and
- preferring products with lower sodium content.

Some food producers are reformulating recipes to decrease the sodium concentration in their products, and people should be inspired to check nutrition labels to know how much sodium is in a product before buying or consuming it. Potassium can reduce the negative impact of elevated sodium intake on blood pressure. Consumption of potassium can be increased by eating fresh vegetables and fruit.

3.7.3.4 Sugars

In both children and adults, the intake of free sugars should be limited to less than 10% of total energy intake. A reduction to less than 5% of total energy intake could offer additional health benefits.

Intake of free sugars elevates the risk of dental caries (tooth decay). Abundance calories from caloric drinks and foods contribute to unhealthy weight gain, which can result in overweight and obesity. Present evidence reveals that free sugars affect blood pressure and serum lipids and suggests that a limitation in free sugars consumption decrease risk factors for cardiovascular diseases.

Sugars consumption can be reduced by:

- decreased consumption of foods and drinks retentive high amounts of sugars, such as sugary snacks, candies and sugar-sweetened beverages (all types of beverages containing free sugars – these involve fruit or vegetable juices and drinks, carbonated or non-carbonated soft drinks, liquid and powder concentrates, energy and sports drinks, flavoured water, ready-to-drink tea, ready-to-drink coffee and flavoured milk drinks); and
- consumption of fresh fruit and raw vegetables as snacks instead of sugary snacks.

3.7.4 Demonstration of healthy diets

Diet develops over time, being affected by many economic and social factors that interact in a complex way to shape particular dietary patterns. These factors involve income, prices of food (availability and affordability of healthy foods), individual belief and preferences, cultural traditions, and geographical and environmental aspects (including climate change). Thereby, promoting a healthy food environment – including food systems that promote a heterogeneous, balanced, and healthy diet – demands the involvement of multiple sectors and stakeholders, including government, and the public and private sectors.

Governments have a pivotal role in modelling a healthy food environment that allows people to accept and maintain healthy dietary practices. Effective actions by policymakers to generate a healthy food environment involve the following:

- Modelling adhesiveness in national policies and investment plans – involving trade, food, and agricultural policies – to propagate a healthy nutrition and keep public health through:



- increasing exhortations for retailers and producers to grow, apply and trade fresh vegetables and fruit,
 - reducing incentives for the food industry to continue or increase production of processed foods containing high levels of saturated fats, trans-fats, free sugars and salt/sodium,
 - encouraging reformulation of food products to reduce the contents of saturated fats, trans-fats, free sugars and salt/sodium, with the goal of eliminating industrially produced trans-fats,
 - implementing the WHO recommendations on the marketing of foods and non-alcoholic beverages to children,
 - establishing standards to foster healthy dietary practices through ensuring the availability of healthy, nutritious, safe and affordable foods in pre-schools, schools, other public institutions and the workplace,
 - exploring regulatory and voluntary instruments (e.g. marketing regulations and nutrition labelling policies), and economic stimuli or disincentives (e.g. taxation and subsidies) to support a healthy diet and
 - encouraging national, transnational and local food services and catering outlets to ameliorate the nutritional quality of their foods – assuring the availability and affordability of healthy choices – and review portion sizes and pricing.
- Encouraging consumer request for healthy meals and foods through:
 - promoting consumer awareness of a balanced and healthy diet,
 - assessment of school policies and programs that motivate children to adopt and maintain a healthy diet,
 - information and educating children, adolescents and adults about nutrition and healthy dietary practices,
 - stimulation of culinary skills, involving children in schools,
 - supporting point-of-sale information, also through nutrition labelling that assures punctual, standardized and understandable information on nutrient contents in meals (in line with the Codex Alimentarius Commission guidelines), with the addition of front-of-pack labelling to make easier consumer understanding and
 - providing nutrition and dietary consulting at primary health-care facilities.
 - Promoting suitable infant and young child feeding practices through:
 - implementing the International Code of Marketing of Breast-milk Substitutes and subsequent relevant World Health Assembly resolutions,
 - implementing policies and practices to support protection of working mothers and
 - promoting, protecting and supporting breastfeeding in health services and the community, including through the Baby-friendly Hospital Initiative.

3.7.5 WHO response

The “WHO Global Strategy on Diet, Physical Activity and Health” was accepted in 2004 by the Health Assembly. The strategy called on governments, WHO, international partners, the private sector and civil society to perform at global, regional and local levels to promote healthy diets and physical activity.

In 2010, the Health Assembly approved a set of references on the marketing of foods and non-alcoholic beverages to children. These recommendations led countries in suggesting new

policies and upgrading existing ones to decrease the effect on children of the marketing of foods and non-alcoholic beverages to children. The organization (WHO) has also developed region-specific aids (e.g. regional nutrient profile models) that countries employ to implement the marketing suggestions.

In 2012, the Health Assembly adopted a “Comprehensive Implementation Plan on Maternal, Infant and Young Child Nutrition” and six global nutrition goals to be achieved by 2025, involving the reduction of stunting, wasting and overweight in children, the improvement of breastfeeding, and the reduction of anaemia and low birth weight.

In 2013, the Health Assembly agreed to nine global voluntary aims for the precaution and control of NCDs. These goals involve a halt to the rise in diabetes and obesity, and a 30% relative reduction in the consumption of salt by 2025. The “Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013–2020” offers consulting and policy options for Member States, WHO and other United Nations agencies to achieve the targets.

With numerous countries now seeing a rapid increase in obesity among infants and children, in May 2014 WHO set up the Commission on Ending Childhood Obesity. In 2016, the Commission propounded a set of suggestions to successfully tackle childhood and adolescent obesity in various contexts around the world.

In November 2014, WHO arranged, together with the Food and Agriculture Organization of the United Nations (FAO), the Second International Conference on Nutrition (ICN2). ICN2 adopted the Rome Declaration on Nutrition, and the Framework for Action (WHO, 2014) which recommends a set of policy possibilities and strategies to support diversified, balanced, safe and healthy diets at all stages of life. WHO is assisting countries to implement the commitments made at ICN2.

In May 2018, the Health Assembly authorized the 13th General Programme of Work (GPW13), which will guide the work of WHO in 2019–2023. Reduction of salt/sodium consumption and elimination of industrially produced trans-fats from the food supply are identified in GPW13 as part of WHO’s priority actions to achieve the aims of assuring healthy lives and promote well-being for all at all ages. To support Member States in taking necessary steps to reduce industrially produced trans-fats, WHO has developed a roadmap for countries (the REPLACE action package) to help accelerate actions.

3.8 Food consumption

3.8.1 Global and regional food consumption patterns and trends

Promoting balanced and healthy diets and lifestyles to decrease the global burden of noncommunicable diseases requires a multisectoral approach including the various relevant sectors in societies. The food and agriculture sector postures markedly in this enterprise and must be given due importance in any consideration of the support of healthy diets for individuals and population groups. Food strategies must not only be directed at ensuring food safety for all but must also reach the intake of adequate quantities of safe and good quality meals that together make up a healthy diet. Any recommendation to that influence will have impact for all parts in the food chain. It is therefore helpful at this juncture to examine trends in consumption patterns worldwide and reconsider on the potential of the food and agriculture sector to meet the request and challenges posed by this report. Consumer request for health-enhancing food products (e.g. functional foods) is increasing rapidly. The idea of “functional food” is commonly used for the food giving health benefits or that the meal dispose of potential in preventing disease or in promoting a better quality of life.

Economic progress is normally attended by improvements in a country's food supply and the progressive reduction of dietary deficiencies, thus improving the general nutritional status of the country's population. Additionally, it also brings about qualitative changes in the processing, production, distribution and marketing of food. Increasing urbanization will also have implication for the dietary patterns and lifestyles of people, not all of which are benefit. Alternations in nutrition, patterns of work and leisure - often referred to as the "nutrition transition" - are already assisting to the causal factors underlying noncommunicable diseases even in the poorest countries. Moreover, the tempo of these changes seems to be accelerating, mainly in the low-income and middle-income countries.

The nutrition changes that characterize the "nutrition transition" involve both quantitative and qualitative changes in the diet. The adverse dietary changes involve shifts in the structure of the nutrition towards a higher energy density diet with a bigger role for fat and added sugars in meals, greater saturated fat consumption (mainly from animal sources), reduced consumption of complex carbohydrates and dietary fibre, and reduced fruit and vegetable consumption. These dietary alterations are compounded by lifestyle changes that reflect decreased physical activity at work and during leisure time. At the same time, however, poor countries continue to face food shortages and diet inadequacies.

A diet developed over time and is affected by many factors and complex interactions. Salary, individual preferences, prices and beliefs, cultural traditions, environmental, geographical, social and economic inputs all react in a complex manner to form dietary consumption patterns. Data on the national accessibility of the main food commodities offer a valuable insight into nutrition and their evolution over time. FAO produces annual Food Balance Sheets which give national data on food availability (for almost all commodities and for nearly all countries). Food Balance Sheets provide a complete view of supply (involving production, stock changes, imports and exports) and utilization (including final demand in the form of food use and industrial non-food use, intermediate demand such as animal feed and seed use, and waste) by commodity. From these data, the average per person supply of macronutrients (fats, protein, and energy) can be derived for all food commodities (FAO, 2002a). However, such average per capita supplies are derived from national data; they may not reflect to actual per capita availability, which is determined by many other points such as inequality in access to food. Similarly, these data refer to "average food available for consumption", which, for several arguments (e.g. waste at the household level), is not equal to average food consumption or average food intake. Hence, the terms "food consumption" or "food intake" should be read as "food available for consumption".

Actual food availability may be different by region, socioeconomic level and season. Certain harnesses are encountered when estimating trade, production and stock modifications on an annual scale. Therefore, three-year averages are calculated to decrease errors. The FAO statistical database (FAOSTAT), being based on national data, does not give information on the distribution of food within countries, or within communities and households.

3.8.2 Developments in the availability of dietary energy

Food intake expressed in kilocalories (kcal) per capita per day is a key variable used for calculating and assessing the evolution of the global and regional food situation. A more suitable term for this variable would be "national average apparent food consumption" since the data are from national Food Balance Sheets rather than from food consumption surveys. Analysis of FAOSTAT data displays that dietary energy measured in kcals per capita per day has been steadily growing on a worldwide basis; obtainability of calories per capita from the mid-1960s to the late 1990s increased globally by approximately 450 kcal per capita per day and by over 600 kcal per capita per day in developing countries. This alteration has not,

however, been equivalent across regions. The per capita supply of calories has remained almost stagnant in sub-Saharan Africa and has lately fallen in the countries in economic transition. In contrast, the per capita supply of energy has risen radically in East Asia and in the Near East/North Africa region.

Table 1. Global and regional per capita food consumption (kcal per capita per day)

Region/Period	1964	- 1974	- 1984	- 1997	- 2015	2030
	1966	1976	1986	1999		
World	2358	2435	2655	2803	2940	3050
Developing countries	2054	2152	2450	2681	2850	2980
Industrialized countries	2947	3065	3206	3380	3440	3500
Transition countries	3222	3385	3379	2906	3060	3180
Near East and North Africa	2290	2591	2953	3006	3090	3170
Sub-Saharan Africa ^a	2058	2079	2057	2195	2360	2540
Latin America/ the Caribbean	2393	2546	2689	2824	2980	3140
East Asia	1957	2105	2559	2921	3060	3190
South Asia	2017	1986	2205	2403	2700	2900

^a Excludes South Africa

The world has realized significant movement in raising food intake per person. The increase in the world average intake of food would have been higher but for the declines in the transition economies that occurred in the 1990s. It is commonly agreed, but, that those declines are likely to come back soon. The increase in food intake has been accompanied by notable structural changes and a shift in nutrition away from staples such as tubers and roots towards more livestock products and vegetable oils.

Table 1 presents that current energy consumption range from 2681 kcal per capita per day in developing countries, to 2906 kcal per capita per day in transition countries and 3380 kcal per capita per day in industrialized countries. Data in Table 2 recommend that per capita energy supply has decrease from both vegetable and animal sources in the countries in economic transition, whereas it has increased in the developing and industrialized countries.

Table 2. Vegetable and animal sources of energy in the diet (kcal per capita per day)

Region/Period	1967	1967	1967	1977	1977	1977	1987	1987	1987	1997	1997	1997
	T	V	A	T	V	A	T	V	A	T	V	A
DC	205	189	161	225	207	184	249	224	242	268	234	337
TC	328	250	780	340	250	893	339	245	941	290	223	671
IC	300	213	871	311	220	906	328	233	950	338	243	943

DC – Developing countries; TC – Transition countries; IC – Industrialized countries
T, total kcal; V, kcal of vegetable origin; A, kcal of animal origin (including fish products).

Parallel trends are visible for protein availability; this has increased in developing and also in industrialized countries but declined in the transition countries. However, the global supply of protein has been rising; the distribution of the increase in the protein supply is unequal. The per capita supply of vegetable protein becomes slightly higher in developing countries, while the supply of animal protein is three times higher in industrialized countries.

Overall, the share of dietary energy supplied by cereals seems to be relatively stable over time, representing about 50% of dietary energy supply. Lately, however, subtle changes appear to be taking place. A closer analysis of the dietary energy consumption shows a decrease in developing countries, where the share of energy derived from cereals has decreased from 60% to 54% in a period of only 10 years. Much of this restriction trend is attributable to cereals, mainly wheat and rice, becoming less favored foods in middle-income countries such as Brazil and China, a model likely to continue over the next 30 years or so.

3.8.3 Availability and changes in consumption of dietary fat

The growth in the quality and quantity of the fats in the diet is a significant feature of nutrition transition mirroring in the national diets of countries. There are huge variations across the regions of the world in the amount of total fats (in foods, plus added fats, and oils) available for human nutrition. The lowest quantities intake is noted in Africa, while the highest consumption in parts of North America and Europe. The significant point is that there has been a notable increase in the consumption of dietary fats over the past three decades and that this increase has taken place virtually everywhere except in Africa, where consumption levels have stagnated. The per capita supply of fat from animal foods has raised, respectively, by 14 and 4 g per capita in developing and industrialized countries, while there has been a drop of 9 g per capita in transition countries.

Table 3. Trends in the dietary supply of fat (g per capita per day)

Region/Period	1967 - 1969	1977 - 1979	1987 - 1989	1997 - 1999
World	53	57	67	73
North Africa	44	58	65	64
Sub-Saharan Africa ^a	41	43	41	45
North America	117	125	138	143

Latin America and the Caribbean	54	65	73	79
China	24	27	48	79
East and South-East Asia	28	32	44	52
South Asia	29	32	39	45
European Community	117	128	143	148
Eastern Europe	90	111	116	104
Near East	51	62	73	70
Oceania	102	102	113	113

^a Excludes South Africa

The rising in dietary fat supply worldwide exceeds the increase in dietary protein supply. The average global supply of fat has increased by 20 g per capita per day since 1967-1969. This rise in accessibility has been most pronounced in the Americas, East Asia, and the European Community. The proportion of energy contributed by dietary fats exceeds 30% in the industrialized regions, and in almost all other regions this share is increasing.

The fat-to-energy ratio (FER) is characterized as the percentage of energy derived from fat in the total supply of energy (in kcal). Country-specific analysis of FAO data for 1988-1990 (FAO, 1994) found a range for the FER of 7-46%. A total of 19 countries fell below the minimum recommendation of 15% dietary energy supply from fat, the most of these being in sub-Saharan Africa and the remainder in South Asia. In the contrary, 24 countries were above the maximum recommendation of 35%, the majority of these countries being in North America and Western Europe. It is beneficial to note that limitations of the Food Balance Sheet data can contribute much of this modification in the FER among countries. For example, in countries such as Malaysia with substantial accessibility of vegetable oils at low prices, Food Balance Sheet data may not reflect real intake at the individual household level.

Increasing incomes in the developing world have also resulted in an increase in the availability and intake of energy-dense high-fat diets. Food balance information can be used to examine the shift in the proportion of energy from fat over time and its relationship to rising incomes.

In 1961-1963, a diet supplying 20% of energy derivable from fat was linked only with countries having at least a per capita gross national product of US\$ 1475. By 1990, even the poor countries having a gross national product of only US\$ 750 per capita had access to an parallel diet containing 20% of energy from fat. This modification was predominantly the result of an increase in the intake of vegetable fats by poor countries, with smaller increases in middle-income and high-income countries. By 1990, vegetable fats accounted for a bigger proportion of dietary energy than animal fats for countries in the lowest per capita income category. Alternations in edible vegetable oil supply, in prices and in intake equally affected rich and poor countries, although the net effect was relatively much bigger in low-income countries. Equally large and notable shifts in the proportion of energy from added sugars in the diets of low-income countries present also a feature of the nutrition transition.

Analysis of the purchasing habits of population, aimed at comprehension the connection between level of education or income and the various amounts or types of commodities purchased at different times were also revealing. Research exercised in China reveals that there have been serious shifts in purchasing practices in relation to income over the past. These data show how extra income in China influence rich and poor people in a various manner, improving the fat consumption of the poor more than that of the rich.

A flexible proportion of these fat calories are offered by saturated fatty acids. Only in the two of the most plentiful regions (parts of North America and Europe) is the consumption of saturated fat at or above 10% of energy intake level. In other less affluent regions, the proportion of dietary energy contributed by saturated fatty acids is lower, from 5% to 8%, and generally not modifying much over time. National dietary analyses conducted in particular countries support these data. The ratio of fat from animals to total fat is a pivotal index since foods from animal sources are rich in saturated fat. Data sets used to calculate country specific FERs may also be used to compute proportions of animal fat in total fat. Such data revealed that the proportion of animal fat in total fat was lower than 10% in some countries (Nigeria, Democratic Republic of Congo, Sao Tome and Principe, Mozambique and Sierra Leone), while it is above 75% in some other countries (Finland, Denmark, Hungary, Mongolia, Poland and Uruguay). These data are not strictly divided along economic lines, as not all the countries in the high range are the most affluent countries. Country-specific food accessibility and cultural dietary norms and preferences to some extent determine these patterns.

The types of edible oils consumed in developing countries are also varying with the increasing use of hardened margarines (abundant in trans fatty acids) that do not need to be refrigerated. Palm oil is increasingly important edible oil in the nutrition of much of South-East Asia and is likely to be a major source in the coming years. Actual, palm oil consumption is low and the FER ranges between 15% and 18%. At this low level of intake, the saturated fatty acid content of the diet comprises only 4% to 8%. Possible developments in the edible oil sector may affect all stages of the oil production process starting with plant breeding to processing methods, involving the blending of oils aimed at manufacturing edible oils that possess a healthy fatty acid composition.

Olive oil is notable edible oil consumed mostly in the Mediterranean region. Its production has been powered by rising request, which has shifted olive cultivation from traditional farms to more intensive forms of cultivation. There is some apprehension that the intensive cultivation of olives can have damaging environmental effects, such as soil erosion and desertification. But, agricultural production methods are being developed to assure less harmful effects on the environment.

3.8.4 Availability and changes in consumption of animal products

There has been a rising pressure on the livestock sector to meet the increasing request for high-value animal protein. The world's livestock sector is increasing at an unprecedented rate and the propulsive force behind this enormous surge is a mix of population growth, growing incomes and urbanization. Annual meat production is planned to increase from 218 million tons in 1997-1999 to 376 million tons by 2030.

The intake of meat and meat products is expected to grow in developing economies. The request for meat is expected to increase. In fact the trend towards a lower intake in developed economies is predicted to be mostly balanced by a rapidly rising request in economically emerging countries, because of the increase in population and incomes.

There is a powerful positive relationship between the level of income and the intake of animal protein, with the intake of milk, meat and eggs rising at the expense of staple foods. Due to the recent steep decrease in prices, developing countries are embarking on higher meat intake at much lower levels of gross domestic product than the industrialized countries did some 20-30 years ago.

Urbanization is a main driving force affecting global request for livestock products. Urbanization motivates improvements in infrastructure, involving cold chains, which allow trade in perishable goods. In comparison with the less diversified diets of the rural communities, city inhabitants have a varied diet rich in animal proteins and fats, and characterized by higher

intake of milk, meat, poultry and other dairy products. There has been a special increase in the intake of animal products in countries such as China and Brazil, although the levels are still well below the levels of intake in North American and most other industrialized countries.

As nutrition become richer and more different, the high-value protein that the livestock sector proposes improves the diet of most of the world. Livestock products not only give high-value protein but are also notable sources of a wide range of essential micronutrients, mainly minerals such as iron and zinc, and vitamins such as vitamin A. For the most people in the world, mainly in developing countries, livestock products are a desired food for nutritional value and taste. Redundant intake of animal products in some countries and social classes may, however, results in excessive consumption of fat. In affluent economies, modifications in meat intake habits are driven by the heterogeneity in the valuations of product characteristics by individuals and by the rising relevance of health concerns, ethical and ecological issues.

Table 4. Per capita consumption of livestock products (meat and milk per year)

Region	Meat (kg per year)			Milk (kg per year)		
	1964	- 1997	- 2030	1964	- 1997	- 2030
	1966	1999		1966	1999	
World	24.2	36.4	45.3	73.9	78.1	89.5
Developing countries	10.2	25.5	36.7	28.0	44.6	65.8
Near East and North Africa	11.9	21.2	35.0	68.6	72.3	89.9
Sub-Saharan Africa ^a	9.9	9.4	13.4	28.5	29.1	33.8
Latin America and the Caribbean	31.7	53.8	76.6	80.1	110.2	139.8
East Asia	8.7	37.7	58.5	3.6	10.0	17.8
South Asia	3.9	5.3	11.7	37.0	67.5	106.9
Industrialized countries	61.5	88.2	100.1	185.5	212.2	221.0
Transition countries	42.5	46.2	60.7	156.6	159.1	178.7

^a Excludes South Africa

The growing request for livestock products is likely to have an undesirable effect on the environment. For instance, there will be more large-scale, industrial production, often situated close to urban centres, which brings with it a range of public and environmental health hazards. Attempts have been realized to assess the environmental effect of industrial livestock production. For example, it has been surveyed that the number of people fed in a year per hectare ranges from 22 for potatoes and 19 for rice to 1 and 2, respectively, for beef and lamb. The low energy conversion ratio from feed to meat is another apprehension as some of the cereal grain food produced is declined to livestock production. Moreover, land and water request for meat production are likely to become a huge concern, as the rising request for animal products results in more intensive livestock production systems.

3.8.5 Availability and consumption of fish

Despite variations in supply and request caused by the changing state of fisheries resources, the economic situation and environmental conditions, fisheries, involving aquaculture, have traditionally been, and remain a notable source of employment, food and revenue in various countries and communities. After the noticeable grow in both marine and inland capture of fish during the 1950s and 1960s, world fisheries production has levelled off since the 1970s. This levelling off the total catch follows the general tendency of most of the world's fishing localities, which have evidently reached their maximum potential for fisheries production, with most stocks being fully utilized. It is therefore very unprovable that considerable increases in total catch will be acquired in the future. On the contrary, aquaculture production has followed the opposite path. Beginning from an insignificant total production, inland and marine aquaculture production has been rising at a noticeable rate, offsetting part of the decline in the ocean catch of fish.

The total food fish supply and hence intake has been increasing at a rate of 3.6% per year since 1961, while the world's population has been expanding at 1.8% per year. The proteins obtained from fish, molluscs and crustaceans account for between 13.8% and 16.5% of the animal protein consumption of the human population. The average apparent per capita intake increased from about 9 kg per year in the early 1960s to 16 kg in 1997. The per capita accessibility of fish and fishery products has therefore nearly doubled in 40 years, outpacing population growth.

As well as income-related modifications, the role of fish in diet revealed significant continental, regional and national distinctions. In industrialized countries, where foods generally include a more heterogeneous range of animal proteins, grow in per capita provision from 19.7 kg to 27.7 kg seems to have occurred. This represents an increase rate close to 1% per year. In this class of countries, fish contributed a rising share of total protein consumption until 1989 (accounting for between 6.5% and 8.5%), but since then its significance has gradually decrease and, in 1997, its percentage contribution was back to the level prevailing in the mid-1980s. In the early 1960s, per capita fish supply in low-income food-deficit countries was, on average, only 30% of that of the richest countries. This gap has been in stages reduced, such that in 1997, average fish intake in these countries was 70% of that of the more affluent economies. In spite of the relatively low intake by weight in low-income food-deficit countries, the contribution of fish to total animal protein consumption is substantial (about 20%). Over the past four decades, however, the share of fish proteins in animal proteins has decreased slightly, due to faster increase in the intake of other animal products.

Today, two-thirds of the total food fish supply is derived from capture fisheries in marine and inland waters, while the remaining one third is obtained from aquaculture. The contribution of inland and marine capture fisheries to per capita food supply has stabilized, around 10 kg per capita in the period 1984-1998. Any later increases in per capita accessibility have, therefore, been derived from aquaculture production, from both traditional rural aquaculture and intensive commercial aquaculture of high-value species.

Fish contributes up to 180 kcal per capita per day, but achieves such high levels only in a few countries where there is an insufficiency of alternative protein foods grown locally or where there is a forceful preference for fish (Japan, Iceland and some small island states). More typically, fish contributes about 20-30 kcal per capita per day. Fish proteins are necessary in the nutrition of some densely populated countries where the total protein consumption level is low and are very significant in the diets of many other countries. Worldwide, about a billion people rely on fish as their major source of animal proteins. Dependability on fish is mostly higher in coastal than in inland areas. About 20% of the world's population obtains at least one-fifth of its animal protein consumption from fish, and some small island states depend almost explicitly on fish.

Commendatory the increased intake of fish is another area where the possibility of dietary recommendations needs to be balanced against apprehensions for sustainability of marine stocks and the potential running out of this important marine source of high-quality nutritious food. Added to this is the concern that an important proportion of the world fish catch is transformed into fish meal and used as animal feed in industrial livestock production and thus is not accessible for human nutrition.

3.8.6 Availability and consumption of fruits and vegetables

Intake of fruits and vegetables plays an important role in providing a diversified and nutritious diet. Allow intake of fruits and vegetables in various regions of the developing world is, however, a permanent phenomenon, confirmed by the findings of food intake surveys. Nationally representative investigation in India (India nutrition profile, 1998), for example, denote a steady level of consumption of only 120-140 g per capita per day, with about another 100 g per capita originated from roots and tubers, and some 40 g per capita from pulses. This may not be verity for urban population in India, who have rising incomes and greater possibility to a different and varied diet. On the contrary, in China, - a country that is undergoing quick economic growth and transition - the quantity of fruits and vegetables intake has raised to 369 g per capita per day by 1992.

In recent times, only a small and ommissible minority of the world's population consumes the large recommended high average consumption of fruits and vegetables. In 1998, only 6 of the 14 WHO regions had an accessibility of fruits and vegetables equal to or greater than the earlier suggested intake of 400 g per capita per day. The relatively propitious situation in 1998 seems to have developed from an evident less favourable position in previous years, as documented by the great increase in vegetable accessibility noticed between 1990 and 1998 for most of the regions. On the contrary, the accessibility of fruit generally lowered between 1990 and 1998 in most regions of the world.

The rise in urbanization globally is next challenge. Increasing urbanization will move away more people from main food production, and in turn have a negative effect on both the accessibility of a different and nutritious diet with sufficient amount of fruits and vegetables, and the access of the urban poor to such nutrition. However, it may accelerate the gaining of other aims, as those who can afford it can have better access to a different and varied nutrition. Investment in periurban horticulture can offer an opportunity to elevate the accessibility and intake of a healthy diet.

Global tendencies in the production and supply of vegetables show that the present production and intake differ widely among regions. It should be remarked that the production of wild and indigenous vegetables is not considered in production statistics and can therefore be underestimated in consumption statistics. In 2000, the global annual average per capita vegetable supply was 102 kg, with the highest level in Asia (116 kg), and the lowest levels in South America (48 kg) and Africa (52 kg). These data also involve the large amount of horticultural produce that is consumed on the farm. Table 5 and Figure 3 show the regional and temporal differences in the per capita accessibility of vegetables per capita over the past few decades.

3.8.7 Future trends in demand, food availability and consumption

Generally, the global dynamics in food production and consumption have evolved rapidly. However, recently the growth rates of world agricultural production and crop yields have slowed. This has increased fears that the world may not be capable to grow enough food and other commodities to assure that future populations are sufficiently fed. But, the slowdown was

not due to shortages of land or water but rather because request for agricultural products has also slowed. This is predominantly because world population growth rates have been decreasing since the late 1960s, and considerably high levels of food intake per person are now being reached in many countries, besides which further rises will be limited. It is also likely that a high share of the world's population remains in poorness and hence insufficiency the necessary income to translate its needs into effective request. Then, the growth in world request for agricultural products is expected to decrease from an average 2.2% per year over the past 30 years to an average 1.5% per year for the further 30 years. In developing countries, the deceleration will be more dramatic, from 3.7% per year to 2% per year, partially because of China having passed the phase of quick growth in its request for food. Global food insufficiencies are unlikely, but real problems already exist at national and local levels and can worsen unless focused efforts are realised (WHO, 2002). The evolution in food processing technologies is necessary to face food security and safety, nutrition request, its accessibility and also other global challenges in the food system.

The annual growth rate of world request for cereals has decreased from 2.5% per year in the 1970s and 1.9% per year in the 1980s to only 1% per year in the 1990s. Annual cereal intake per person (including animal feeds) peaked in the mid-1980s at 334 kg and has since decreased to 317 kg. The decrease is not a reason for alarm, it is mostly the natural result of slower population growth and shifts in human nutrition and animal feeds. During the 1990s, however, the decrease was clear by several temporary parameters, involving serious economic recessions in the transition countries and in some East and South-East Asian countries.

The growth rate in the request for cereals is expected to increase again to 1.4% per year up until 2015, slowing to 1.2% per year thereafter. In developing countries exactly, cereal production is not expected to keep tempo with request. The net cereal shortage of these countries, which amounted to 103 million tons or 9% of intake in 1997-1999, could rise to 265 million tons by 2030, when they will be 14% of intake. This spacing can be bridged by increased abundances from traditional grain exporters, and by new exports from the transition countries, which are assumed to shift from being net importers to being net exporters.

Oil crops have seen the fastest grow in area of any crop sector, expanding by 75 million hectares between the mid-1970s and the end of the 1990s, while cereal area decreased by 28 million hectares over the same period. Future per capita intake of oil crops is expected to increase more rapidly than that of cereals. These crops will account for 45 out of every 100 extra kilocalories added to average nutrition in developing countries between now and 2030.

There are three predominant sources of increase in crop production: widening the land area, raising the frequency at which it is cropped (through irrigation), and redundant yields. It has been recommended that increase in crop production may be approaching the ceiling of what is potential in respect of all three sources. A detailed verification of production potentials does not support this view at the global grade, however in some countries, and actually in whole regions, serious problems already occur and could deepen.

Nutrition in developing countries are modifying as incomes increase. The share of staples, such as roots, cereals and tubers, is decreasing, while that of meat, dairy products and oil crops is increasing. Between 1964-1966 and 1997-1999, per capita meat intake in developing countries increased by 150% and that of milk and dairy products by 60%. By 2030, per capita intake of livestock products could increase by a further 44%. Poultry intake is predicted to increase the fastest. Productivity betterments are likely to be a predominant source of increase. Milk yields should improve, while breeding and improved management should raise average carcass weights and off-take rates. This will admit increased production with lower growth in animal amount, and a corresponding decrease in the growth of environmental damage from grazing and animal wastes.

In developing countries, request is predicted to grow quicker than production, resulting in a growing trade deficit. In meat products this deficit will increase precipitously, from 1.2 million tons per year in 1997-1999 to 5.9 million tons per year in 2030 (despite increasing meat exports from Latin America), while in the case of milk and dairy products, the increase will be less steep but still substantial, from 20 million tons per year in 1997-1999 to 39 million tonnes per year in 2030. A rising share of livestock production will presumably come from industrial enterprises. Recently, production from this sector has increased twice as fast as that from more traditional combined farming systems and more than six times faster than that from grazing systems.

World fisheries production has remained ahead of population growth over the past three decades. Total fish production has nearly doubled, from 65 million tonnes in 1970 to 125 million tonnes in 1999, when the world average consumption of fish, crustaceans and molluscs reached 16.3 kg per person. By 2030, annual fish intake is likely to increase to some 150-160 million tonnes, or between 19-20 kg per person. This quantity is significantly lower than the potential request, as environmental factors are expected to limit supply. This impressive development of global fish intake has been driven by a combination of population growth, increasing incomes and changes in food habits, as well as strong expansion of fish production. During the 1990s the marine catch levelled out at 80-85 million tonnes per year, and by the turn of the century, three-quarters of ocean fish stocks were overfished, exhausted or exploited up to their maximum sustainable yield. Next growth in the marine catch can only be moderate.

Aquaculture compensated for this marine decrease, doubling its share of world fish production during the 1990s. It is expected to proceed to grow quickly, at rates of 5-7% per year up to 2015. In all segments of fishing, it will be necessary to pursue forms of management helpful to sustainable exploitation, mainly for resources under common ownership or no ownership. To conclude, the trends in the global food industry are mirroring the increasing use of functional foods, the development of novel foods industries, and the emergence of nanotechnologies in the food sector. They are likely to represent new frontiers worth great attention. The most important factor that limits the diffusion of nanotechnology applications in the food market is the existing scientific gaps in knowledge about their potential risks for human health and environment.

3.9 Food control

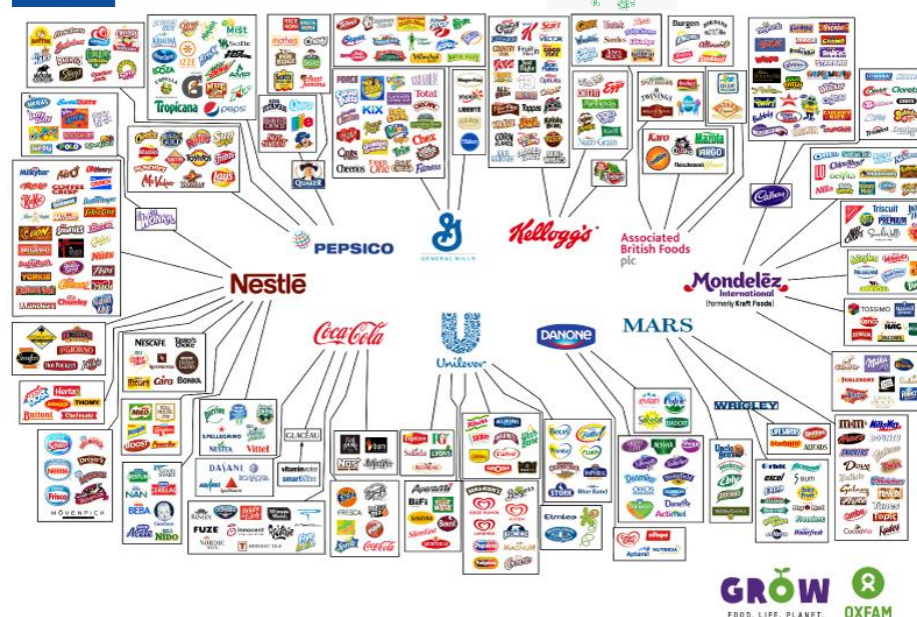
Only 10 companies inspect almost every large food and beverage brand in the world. These companies – Nestlé, PepsiCo, Coca-Cola, Unilever, Danone, General Mills, Kellogg's, Mars, Associated British Foods, and Mondelez – each employ thousands and make billions of dollars in income every year.



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In a world of globalized industry, where many states' policy has more and more been dictated by private segment interests and transnational corporations (TNC), it is worth examining how the right to food and the emergence of social movements that represent peoples' local food systems and food sovereignty are waddle the balance in their favour.

Food is an elementary right. People need to eat. So naturally controlling the food system has, in the last 50 years, become one of the pivotal areas where TNCs are attempting to check the system. But before investigation the various angles of the power and interplay between corporate interests and those of our world's current 7 billion people, we need to inquire a few key questions.

In both Europe and North America, the food systems began to shift from self-sufficiency and traditional local shops and markets to food chains after the Second World War. In the South of Europe, street markets stayed alive in most towns and villages. Allotments present still a strong part of the Northern European culture. In Africa and Asia, many people living in cities still obtain much of their meals from those remaining on the land outside the cities. But the complete trend of corporations has been to attempt to totally take over our food systems on all continents. With the market 'saturated' in marketing terms in developed countries, the corporations are now working hard to hold market share in Africa and Asia.

Official controls are realized by the competent authorities in the EU countries to authenticate business compliance with the requirements set out in agri-food chain legislation. The agri-food chain includes activities preceding and inclusive the production of food, i.e., from farm to fork, (stable to table). It ranges from plants and animal production to food production and supply; involving activities that are held at the farm level, but also processing and distribution to the consumer. Agri-food chain standards hereby cover the safety and quality of food and feed, animal and plant health and welfare. They also cover import inspections on animals and goods entering the EU from third countries (countries outside the EU). **The EU countries are accountable for the displacement** of agri-food chain legislation. Competent authorities arrange official controls systems on their area to authenticate those operators' activities and goods placed on the EU market (either EU produced or imported from non-EU countries) comply with relevant standards and requirements. All **business operators must assure fulfilling** with EU agri-food chain requirements in their daily activities. They are subject to official controls regardless of their size, depending on the risk posed by various activities to the

safety of the agri-food chain. The role of the EU is to ensure that the control systems at national level are efficiency. This is the role of Directorate-General for Health and Food Safety (DG SANTE), through its Health and Food Audits and Analysis Directorate (previously “Food and Veterinary Office” – FVO). It realizes inspections in the EU countries and in non-EU countries exporting to the EU to estimate compliance with EU standards. The food industry has to face consumers' expectations and global challenges such as the need to assure safe food, while keeping in mind the global sustainability.

3.9.1 Food control systems

A national food control system assures that food accessible within a country is safe, healthy, and fit for human intake, conforms to food safety and quality requirements and is fair and correctly labelled as prescribed by the law. As such, food control systems keep the health and safety of consumers and help ensure the safety and quality of foods being traded both nationally and internationally. Protecting the health of people of a country is one of the base roles of a government and closely linked to the accomplishment of several Sustainable Development Goals (SDG), SDG 2 and 3. Equally, food control is critical to assure fair practices in the food trade to support economic opportunities of all stakeholders along the food chain. In an age of quickly modifying food technologies and ever-increasing global food trade, controlling foodborne risks along the whole food chain has taken on a key role. In order to cope with comprehensive emerging challenges of the 21st century, food control systems require to be up to date with the latest developments, work based on the concept of risk analysis and be harmonized with international standards and best practices developed by Codex Alimentarius. To act effectively, a food control system demands suitable legal and policy tools, well-qualified human resources, sound institutional concept as well as financial assets, equipment and infrastructure (involving access to laboratories) as its foundation. The supervisory authorities assigned under the food control system (known as competent authorities) help assure food safety and quality along the food chain and manage food safety risks, deceit issues, emerging hazards and emergencies. This work involves supervision and inspection of Food Business Operators (FBOs), data collection processes that contribute to an improved understanding of the food chain; and programmes intended at preparing for and managing food safety emergencies. Suitable connections to the foodborne disease investigation systems are pivotal to assure an entire chain approach, up to the consumer, and in instance of need, properly address food safety events and emergencies, both upstream (recognising the source of an outbreak) and downstream (being capable to identify the population at risk). In addition to compulsory activities done by competent authorities under their monitoring mandate, the “non-regulatory” activities of that system need to be taken into consideration, too; these involve communication and capacity development programmes. Procedures for constructive relations with stakeholders (such a FBOs, consumers and the international community) are significant to permit the system to take into account the evolving requirements of both national and international stakeholders, to motivate confidence and to keep them well informed about their responsibilities. Additionally, in order to manage present and emerging challenges, it is significant for a food control system to be grounded in indication and science, incorporate hazard analysis principles and keep abreast of advanced scientific developments and innovations to continuously improve the effectiveness and productivity of food control activities.

3.9.2 Food control authorities

Comprehension how an adequate food security can be determined, how nutritional consumptions evolve over time and are affected by global dynamics are questions for food

control authorities. There is a register of organizations and associated posts which are linked to food safety, either as a main interest or through statutory responsibility. National organizations are clustered by the UN geoscheme

There are specific multinational (European Union: Committee on the Environment, Public Health and Food Safety; European Food Safety Authority; SAFE FOODS; Food Safety Promotion Board) as well as national organizations (Africa: Ghana Food and Drugs Authority; National Agency for Food and Drug Administration and Control; Americas: Argentina: Minister of Economy; Secretariat of Agriculture, Livestock, Fishing and Food; National Food Safety and Quality Service (SENASA) Servicio Nacional de Sanidad y Calidad Agroalimentaria; Canada: Minister of Agriculture; Agriculture and Agri-Food Canada (AAFC); Canadian Food Inspection Agency (CFIA); Minister of Health; Health Canada; Health Products and Food Branch; Guelph Food Technology Centre; United States of America: U.S. Food and Drug Administration (FDA); Center for Food Safety and Applied Nutrition (CFSAN); International Food Protection Training Institute (IFPTI); Joint Expert Committee on Food Additives (JECFA); United States Department of Agriculture (USDA); Under Secretary for Food Safety; Food Safety and Inspection Service (FSIS); Asia: Saudi Arabia: Saudi Food and Drug Authority; Bangladesh: Bangladesh Food Safety Authority (BFSA); Burma: Food and Drug Administration (Burma); China: General Administration of Quality Supervision, Inspection and Quarantine; State Food and Drug Administration; Hong Kong; Centre for Food Safety; India: Food Safety and Standards Authority of India; Nepal; Department of Food Technology and Quality Control; Philippines; Food and Drug Administration (Philippines); South Korea; Ministry of Food and Drug Safety (MFDS); Minister for Health, Welfare and Family Affairs; Ministry for Health, Welfare and Family Affairs; Office for Healthcare Policy; Taiwan; Ministry of Health and Welfare (MHW); Food and Drug Administration (TFDA); Malaysia; Ministry of Health (MOH); Food Safety and Quality Division (FSQD); Europe: Belgium; Federal Agency for the Safety of the Food Chain; Greece; Hellenic Food Authority; Germany; Federal Ministry of Food, Agriculture and Consumer Protection; Federal Institute for Risk Assessment (BfR) Bundesinstitut für Risikobewertung; Federal Office of Consumer Protection and Food Safety Bundesamt für Verbraucherschutz und Lebensmittelsicherheit; Bundesanstalt für Landwirtschaft und Ernährung; Netherlands; Ministry of Economic Affairs, Agriculture and Innovation (ELI); nieuwe Voedsel en Waren Autoriteit (nVWA); Rijks Kwaliteitsinstituut voor Land- en Tuinbouwproducten (RiKILT); Rijksinstituut voor Volksgezondheid en Milieu (RIVM); Stichting Voedingscentrum Nederland; Norway; Minister of Agriculture and Food; Norwegian Ministry of Agriculture and Food Landbruks- og matdepartementet; Norwegian Food Safety Authority Mattilsynet; Portugal; Ministry of Economy; Economic and Food Safety Authority Autoridade de Segurança Alimentar e Económica, ASAE; Spain; Ministerio de Sanidad, Consumo y Bienestar Social, Gobierno de España; Agencia Española de Seguridad Alimentaria y Nutrición (AESAN).

In the United Kingdom there is Department for Environment, Food and Rural Affairs; Animal Health; Pesticides Safety Directorate; UK Government Decontamination Service; Veterinary Medicines Directorate; Food Standards Agency; British Retail Consortium (BRC) Global Standard (Baines, R. (2010) Quality and Safety Standards in Food Supply Chains, Royal Agricultural University, UK); Advisory committee on the microbiological safety of food and Food Standards Scotland.

In Oceania, there is a Multinational organization Food Standards Australia New Zealand (FSANZ) and local Australia; Minister for Agriculture, Drought and Emergency Management; Department of Agriculture, Water and the Environment; Government of New South Wales; Minister for Primary Industries (NSW); New South Wales Food Authority; New Zealand; Minister for Food Safety; New Zealand Food Safety Authority (NZFSA).

The key goal of the tool is to recommend a harmonized, consensual, and objective basis to examine the performance of a national food control system. It is proposed to be used by countries as a sustaining basis for self-assessment to classify priority areas of improvement and plan consecutive and coordinated activities to reach expected outcomes, and by repeating the appreciation on a regular basis, countries may monitor their progresses. The implement is based on Codex principles and Guidelines for National Food Control Systems as well as other applicable Codex guidance for food control systems. The scope is linked to the dual purposes quoted in Codex guidance for these systems: protect health of consumers and assure fair practices in the food trade. FAO/WHO Food Control System Assessment Tool offers background to development and outlining its key scope and aims. There is also valuation approach, from the ratings to the descriptive examination supporting the determination of scores.

National food control systems are important key in protecting the health of consumers and assuring fair practices in the food trade.

Within the scope of Codex Alimentarius Principles and Guidelines for National Food Control Systems (CAC/GL 82-2013), countries possess flexibility to set how best to design their food control systems and put into practise detailed control measures. National conditions (e.g., suitable levels of public health protection; legal and institutional frameworks; accessibility of support services, such as analytical resources) will affect the design of particular systems; thus, no two systems are similar. But, whatever the architecture of the national food control system, determining its effectiveness is universally significant to confirm that resources are being well-used and consumers' health and economic benefits are protected. Being capable to demonstrate performance may also be very significant to notify plans for next strengthening of the system and to open new markets, increase trading relations and build stakeholder confidence domestically. To this end, FAO and WHO have operated on designing this assessment tool, to assist Member countries in evaluating the effectiveness of their food control system, whatever the grade of its maturity. In developing this tool, FAO and WHO sought to learn from and build upon current tools. FAO did an initial review of all publicly accessible tools connecting to the food chain or assessing SPS functions – counting the Performance-Vision-Strategy tool of the Inter-American Institute for Cooperation on Agriculture (IICA), the World Organization for Animal Health (OIE) tool for the estimation of the Performance of Veterinary Services, and the International Plant Protection Convention (IPPC) Phytosanitary Capacity Evaluation tool – to recognize possible approaches and build on existing information and experience. A consultative approach was set through the establishment of a Review Committee including other international, regional, and national agencies and academia to regularly review progress. An order of pilots in various regions (Africa, Europe, Asia, and Near East), were arranged to test the tool at several stages of development; findings emerging from the process and feedback by the various stakeholders included in the assessment were incorporated into the document to refine its approach and assure adaptation to very altered contexts.

The cold chain presents one of the most significant links in assuring the integrity of food and reducing foodborne illness. Examination of quality damage with temperature and storage time was founded on microbiological and physicochemical factors. Food safety stakeholders in the global food supply chain – industry, regulators, international standard-setting agencies, and researchers – have answered to the necessity for better food safety assurance to support international trade in an assortment of ways. Industry stakeholders from the rising, processing and foodservice/retail sectors are keeping cold chain systems, Hazard Analysis and Critical Control Points (HACCP) and other food safety management systems (FSMSs) such as the recently established ISO 22000 as models to accomplish food safety to improve trade opportunities in international markets. Progressive knowledge of food risks has resulted in new

regulations, which involves mandatory HACCP system implementation in processing plants in some countries. Food laws focus to protect consumers' interests, their well-being, and to a degree, simplify fair trade. Food safety-related legislation is constantly under review as it needs to reflect new knowledge, technical innovation and modifications in the pattern of the distribution. As a result, national regulatory authorities throughout the world are in a continuous catch-up mode. Correspondingly, international food safety standard-setting bodies look to address present issues and to develop rules on systems and methods that will help streamline food safety best practices within and between nations. As such, it makes sense to survey the international compatibility of these food safety systems, while also considering that incorrect use can cause the loss of valuable markets. Increasingly, it is becoming advantageous to gain political support for these systems. Equally, this support can at times present an inconvenience to the needed transparency required for viable food safety programs. Some nations, such as Canada, toughly encourage HACCP-based systems throughout the food continuum, from farm gate to consumer plate. The latter is notably obvious through voluntary industry codes of practice/guidelines, which become industry-enforced standards. Such standards are the favoured method of self-regulation in the refrigerated food sector due to its product variety and the rate of production innovation.

International food agreements offer a rationally uniform level of protection in terms of public health and food standards. Continuous efforts to harmonize them are being made to diminish, if not remove totally, technical barriers to trade across limits. Legislation varies from country to country. It is consequently paramount that food traders stay up to date with the massive array of legislation and standard-setting as it applies to their operations.

3.9.3 Codex alimentarius

Members of the World Trade Organization (WTO) recognize Codex Alimentarius standards as the elementary standard upon which national arrangements will be judged. The "Recommended International Code of Practice. General Principles of Food Hygiene," for instance, sets out the position to be followed in the production of foods from on-farm to final preparation.

A HACCP-based approach to improve food safety is suggested as described in "Principles of HACCP" and "Hazard Analysis and Critical Control Point (HACCP) System and Guidelines for its Application". The precaution or reduction of food safety risk leaves an important degree of flexibility to manufacturers/operators and regulatory bodies if they prove the goals. As defined in the Time and Temperature Control section of the latter document, users of temperature control systems require considering numerous factors, such as the nature of the food, the intended shelf-life, the technique of packaging and processing, and how the product is to be used. Such systems require also specifying tolerable limits for time and temperature deviations.

The Codex Alimentarius "Code of Hygienic Practice for Refrigerated Packaged Foods with Extended Shelf Life" is mainly relevant to refrigerated meals. The code states: "For refrigerated foods, a significant safety hurdle to check microbial growth is refrigeration. Any reference for specific temperatures should be qualified as guidelines only. The concrete temperatures used will depend upon the claims for the product, and processes used in terms of safety."

An example of temperature request of a food is determined in the Codex "Proposed Draft Code of Hygienic Practice for Fresh Meat". It states: "Storage of meat at temperatures that achieve the safety and suitability requirements...meat should be transported at temperatures that achieve safety and suitability objectives." For fish, however, the "Proposed Draft Code of Practice for Fish and Fishery Products" states: "Refrigerated processed products should be maintained at the temperature specified by the processor but generally should not exceed 4°C...frozen

products should be maintained at -18°C or below (maximum fluctuation 3°C)...fresh fish, shellfish and their products should be kept at a temperature as close as possible to 0°C ".

Shorter-shelf-life products fall within the scope of the Codex "Code of Hygienic Practice for Precooked and Cooked Foods in Mass Catering". But, this does not appeal to chilled foods for retail sale. This code deals with the hygienic requests for cooking raw foods and handling cooked and precooked foods designed for feeding large groups of population and is not intended for using to the industrial production of complete foods. Chilled meals are characterized in this code as "product intended to be kept at temperatures not exceeding 4°C in any part of the product and stored for no longer than five days." Other suggested Codex Alimentarius codes of relevance to chilled and frozen food production involve the "Code of Hygienic Practice for Primary Production, Harvesting and Packaging of Fresh Produce/Fruits and Vegetables," "Code of Hygienic Practice for Pre-Cut Raw Fruits and Vegetables," and the "Code of Practice for the Processing and Handling of Quick Frozen Foods".

There exists an agreement (ATP – Advanced Training Partnership), adopted by no less than 20 countries, called "Agreement on the International Carriage of Perishable Foodstuffs and on the Special Equipment to be Used for Such Carriage". Its aim is to direct participants to follow common criteria for the temperature-controlled equipment (railway wagons, road vehicles, containers etc.) within Europe, thereby facilitating international traffic in certain perishable foodstuffs. The target meals are quick (deep) frozen, frozen and foodstuffs that require to be transported at refrigerated temperatures. Chilled meals would involve dairy products (butter, pasteurized, industrial or raw milk, kefir, yogurt, cream, fresh cheese), meat products, poultry, offal, fish, seafood and game. Refrigerated and frozen meals are subject to special regulatory controls, and as such, serve as a good base for a discussion of global coordination of food safety laws and standards. For instance, in Canada, controls are in place at the national level and fit hand-in-glove with the international community necessities where HACCP-based approaches to hygiene have been established. The trend, worldwide, is to progress and implement HACCP-based food safety systems counting food hygiene legislation. These strategies are being established at all levels of food production and handling, led by Codex Alimentarius. Given the highly dynamic, advanced and innovative nature of the cold chain sector, the practical application of HACCP relies on the ease with which "best practice guidelines" can be updated. In order to make HACCP a reality, regardless of the operation in question, it is an essential requirement that operators and enforcers have a strong understanding of food safety and technology.

The novel International Standards Organization (ISO) 22000:2005 international standard incorporates the principles of the HACCP system and application steps developed by Codex, and provides a scope of internationally consistent requirements for a global approach. This international standard is determined to permit all types of organizations within the food supply chain to implement a food safety management scheme (e.g., HACCP). As the cold chain is fragment of the food continuum, ISO 22000 functions in adjacent alliance with all food sectors counting feed producers and food manufactures, primary producers, transport and storage operators and subcontractors to retail and food service outlets, included with related organizations such as producers of equipment, cleaning agents, packaging material, additives and ingredients.

Temperature inspection is not the solitary factor which affects the safety of foods throughout its journey along the continuum. Each sector, from manufacturer, distributor, warehouser, transporter and retailer are charged with the liability of adhering to, and utilizing, correct handling techniques. These programs are consisting of codes of practice, good manufacturing practices, codes of hygiene and suitable industry practices for which no legislation occurs. Liability is not waived at the checkout counter of the local grocery store. Government programs

are being organized to inspire the consumer to take responsibility for handling products in a way that contributes to quality and safety.

EUROPEAN UNION

The European Union (EU) has been active for numerous years in developing harmonized food laws to simplify trade for a population of some 460 million within its participant nation community. The EU agri-food sector makes about 670 billion. The ACP (Africa, Caribbean, and Pacific) countries, with inhabitants of some 600 million, have a trading settlement with the EU that now makes them responsible for creating operative control systems for food and feed sector operators under the new food hygiene legislation. The use of ISO 9000 series standards on quality guarantee, generated food safety management systems, which revealed the updated ISO 22000 series. EU participant countries developed the responsibility for compulsion of food safety standards and the basic principles of food law were registered in Regulation 178/2002. This developed into the present “good hygienic practices” under new controls, for food and feed production, which were accepted in 2004 and went into effect on Jan. 1, 2006. Food safety has also been coordinated for the transportation of food within the new hygiene code. The consistent food hygiene package now influences every point of the EU food chain. Food hygiene legislation administers compulsory, self-run, confirmation programs to industry and combines them with HACCP principles. The legislation is proposed to result in good practice guides for the EU food industry, which, along with self-run verification programs, inspires food operators to be registered. Significant features of the new regulation involve microbiological standards, to lower foodborne disease for food products.

The European Food Safety Authority (EFSA) is contemplated to list principles for additional pathogens in the future. This coordinated EU control system applies to all EU member countries and others that request to export to the EU. It is worth mentioning that import controls for products destined for the EU need the presentation of EU standard conformance guarantees.

RISK FACTORS OF FOOD CHAIN

There is an annual international conference “Risk Factors of Food Chain” organized by Slovak University of Agriculture in cooperation with Pedagogical University in Kraków (Poland), Szent István University in Gödöllő (Hungary) and University of Rzeszów (Poland) discussing the problems related to risk factors of food chain related to animal and human health. In the scientific committee there are very recognized researcher in the field related to evaluate different risks related to food production, technology, and estimation of possible negative effects.

As the quantity of transboundary pest and animal and foodborne disease outbreaks increases, so does the number of people who are chronically hungry due to these and other features. The correlation can be clarified by the link between our health and that of the planet. We depend on land and sea to produce safe and quality foods and meals for our daily nutrition. Pests and disease epidemics damagingly influence the quantity, quality and safety of our food sources, and cripple economic growing and efficiencies in production. Besides, the epidemic and endemic levels of the pathogens and disease vectors can be problematic to control. Consequently, FAO pressures and promotes the special efforts required for cost-effective preventive procedures rather than the more expensive control, disinfection, action, and disposal measures. When preventive measures are late or problematic, preparedness and prospective plans must be in place to allow quick response. Early warning systems, founded on close monitoring, surveillance, and timely reporting are necessary to warn and empower communities to safeguard their livelihoods and assets by enhancing disease and pest prevention arrangements and for government services to take instantaneous measures to protect

communities and national economies. This is an example of Fall armyworm. When the caterpillar-like insect expands from the tropical and subtropical areas of the Americas, where generations of farmers have handled it, to West and central western Africa in early 2016, FAW instantly began depriving local populations of their maize and other crops. Its gluttonous hunger for a wide range of crops (up to 80), together with an capability to fly up to 100 km per night in moth stage, allowed FAW to expand southward and spread beyond continental Africa, threatening livelihoods mainly in sub-Saharan Africa, North Africa, Near East and South Asia. Obviously, this transboundary threat to the food chain calls for urgent and synchronized international action.

In reaction, FAO is leading the global coordinated response and offers countries with support, beginning with recommendations on pest and pesticide management. FAO has established tools to build prompt warning, monitoring and response mechanisms, involving farmers' manuals or guides, web platform and mobile applications to conduct risk assessment, risk modelling and mapping. To diminish the damage, FAO has operated with countries to develop action plans and policies and train farmers and extension workers.

The fruitful recording of emerging risks is at the heart of protecting public health and the environment. The food sector should be more focused on the protection of the environment, the preservation of the natural resources to simplify the emergence of strategies able to promote the circular economy and to decrease food wastage. By classifying emerging risks in the food chain early, EFSA sustains risk managers in anticipating risks and taking effective and timely prevention actions to protect consumers. Identifying emerging risks also assist to improve EFSA's capability to meet future challenges. EFSA describes an emerging risk as: "A risk resulting from a newly identified to which a significant may occur, or from an unexpected new or increased significant exposure and/or susceptibility to a known hazard". Identification is a multipart process needing broad expertise and close cooperation with Member States, stakeholders, and EU and international agencies. Dedicated networks offer the structures necessary to exchange experience, methods, and data and to assess emerging matters.

3.9.4 The role of Codex in Contaminants

The Codex maximum level (ML) for a contaminant in a food or feed product is the maximum concentration of that substance recommended by the Codex Alimentarius Commission to be legally allowed in that commodity. As numerous contaminants exist naturally it would be impossible to lead to a zero limit on these substances. To protect human health Codex works to keep these levels as low as possible founded on sound scientific evidence.

The Codex Committee on Contaminants in Food (CCCF) establishes and endorses permitted maximum levels or guideline levels for contaminants and naturally occurring toxicants in food and feed. It also prepares priority lists of contaminants and naturally occurring toxicants for risk assessment by the Joint FAO/WHO Expert Committee on Food Additives. The CCCF considers methods of analysis and sampling for the determination of contaminants and naturally occurring toxicants in food and feed and develops and elaborates standards or codes of practice for related subjects. It also considers other matters assigned to it by the Commission in relation to contaminants and naturally occurring toxicants in food and feed.

3.10 Foodborne diseases

Over 200 illnesses are caused by consumption of food contaminated with viruses, bacteria, parasites, or chemical substances such as heavy metals. This rising public health problem imposes considerable socioeconomic influence though strains on health-care systems lost productivity, and damaging tourism and trade. Foodborne diseases are due to contamination of

food and exist at any stage of the food production, delivery, and consumption chain. Studies have revealed the causality relationships between dietary patterns and lifestyle habits versus chronic illnesses. These diseases continue to cause remarkable morbidity and mortality both in developed and developing countries. They may result from some forms of environmental contamination involving pollution in soil, water, or air, as well as unsafe food storage and processing. Foodborne diseases include a wide range of illnesses from diarrhea to cancers. The enhancement in international travel and request for exotic and raw food points out the importance of traveller's diarrhoea. Most present as gastrointestinal issues, although they can cause neurological, gynecological, and immunological symptoms. Diseases causing diarrhea are a main problem in all countries of the world, though the weight is carried disproportionately by low- and middle-income countries and by children less than 5 years of age.

3.11 Risk factors affecting animal and human health – food production and food control

SLOVAK REPUBLIC

Food Production

In former Czechoslovakia, a self-sufficient food producing country, Slovakia served as an agricultural and food processing powerhouse. It was caused by a strong local agricultural sector. This offers a lot of potential, as some of these opportunities remain undiscovered. Food processing continues to be an integral part of the Slovak economy and contributes more than 4% to the entire industry (excluding beverages). There are more than 2,100 food processing companies divided into various segments based on the main ingredient being processed. Slovakia is praised as one of the most productive countries in the CEE region. Combined with cost-effectiveness and a high education level, the Slovak labor force excels in the three areas that often concern investors the most — labor costs, productivity, and qualification. The AgroBioTech Research Centre established by the Slovak University of Agriculture in 2015, this specialized facility performs concentrated innovative research in the relevant fields aimed at conducting new methods and procedures in applied research, with the express goal of transferring its results into practice. ABT RC's research is consistent with the core needs of the priorities of agrobiological, the processing technology of agricultural products and the agri-food industry, biotechnology, genetic technologies, agroecology, bioenergetics, and bioeconomy. The SUA leads National Platform AgroBioFood Nitra supported by the Ministry of Education, Science, Research and Sport of the Slovak Republic, recognizing it as an expert partner for R&D in the field of foodstuffs and biotechnology. National platform AgroBioFood Nitra was set up in 2016 by the Memorandum of Cooperation concluded between Slovak University of Agriculture in Nitra, National Agricultural and Food Centre (NAFC) based in Lužianky and Bioeconomy Cluster (BEC) based in Nitra. Establishment of the Platform was one of the first steps to present Slovak Republic in the field of foodstuffs and biotechnology. The Platform acts as the national node and official representative of the Slovak Republic in relation to the European and international initiatives and programs.

Food Control

The State Veterinary and Food Administration of the Slovak Republic is a state administration authority pursuant to Act of the Slovak National Council No 39/2007 Coll. on veterinary care and in the field of the food surveillance pursuant to Act of the Slovak National Council No 152/1995 Coll. on foodstuffs as amended. The Chamber is a self-governing professional organisation associating private veterinary practitioners that carry on a private veterinary practice on the basis of registration and registers all veterinarians entitled to provide veterinary

services in Slovakia. Objectives of the control: Animal health and welfare, food of animal and non-animal origin in all stages of production, processing and distribution except in the catering sector; feeding stuffs - feed materials of animal origin, feeding stuffs used directly at farm level and medicated feeding stuffs; veterinary medicines and their residues, animal by-products.

The Public Health Authority is a budgetary organization of the state with competence on the territory of the Slovak Republic with the registered office in Bratislava, linked with the financial relations to the budget of the Ministry of Health. Objectives of the control: Catering premises, of food in catering premises and of production and placing on the market of certain products (novel foods, food supplements, foods for specific groups (including food for infants and young children), people with specific medical conditions, people with gluten intolerance, people undertaking energy-restricted diet to lose weight), natural mineral water and spring water for infants and young children, food treated with ionising radiation and food contact materials). It is also responsible for official control of epidemiologically risky activities of staff involved in production, manipulation and placing the food on the market.

BULGARIA

Food Production

Bulgaria has prerequisites for the development of agri-food sector due the unique natural conditions for sustainable production of wide variety of crops. Bulgaria is also an important market because of its geographical location and Black Sea port access. The agricultural area in the country represents more than 47% of the territory. On the other hand, the data show downward trends in share of agriculture in Bulgarian GDP and in 2019 the sector accounts for only 3.7% of the GDP. The observed negative trends are related to substantial structural and sectorial challenges in Bulgarian agriculture.

According to National Statistical institute data in 2019 the value of gross output in the sector (current prices) is 8,319.1 million BGN. The crop production forms more than 69% of agricultural output while livestock production accumulates 22.4%. Cereals and oilseeds account for more than half (51.1%) of agricultural output in the sector. According to the primary data from 2020 Agricultural census the number of agricultural holdings is 132 400, which is 64% lower compared to their number in 2010. The largest number of agricultural holdings is in Blagoevgrad and Plovdiv districts, respectively 10.2% and 8.2% of the total number. The lowest share is in Gabrovo and Sofia districts. In addition to the conventional agriculture, in Bulgaria the organic farming is increasing. The organic area in Bulgaria is 117 779 hectares and increases with more than 200% compared to 2010. On that basis the organic area made up 2.3 % of total agricultural land. However, the food industry still has low processing capacity and around 80% of organic products are export oriented.

Agri-food sector is one of the traditionally well-developed sectors in Bulgaria. In 2018 food and beverage processing accounts for about 15 % of Bulgaria's total industrial production. The employed in the sector are almost one hundred thousand and over 6,300 companies are operating on the market. Nearly half of them are in the South Central and South-West region. After 2014, the share of food industry in the gross value-added decreases due the higher production costs in the industry. Important sectors within Bulgaria's food processing industry are meat and meat products, bakery, and dairy products.

Based on Agrostatistics data in 2019, the registered share of the agricultural sector in total export and import increases slightly compared to the previous year, to 16% and 11% respectively. In 2019 the highest contribution to the export growth has cereals which form more than 28% of total agricultural export. The export of oilseeds ranks second with a share of 12.4%. In 2019, there is an increase in imports of most agricultural products groups. The highest share is related to the import of meat and meat products, which forms 11.6% of the total value.

The food industry has lost its competitive advantages compared to other sectors of the national economy. These trends are related to the export orientation of Bulgarian agri-food sector. The agricultural export structure is dominated by raw materials, while lower share is represented by processed products with higher value added.

Food Control

Bulgarian Food Safety Agency (BFSA) is an integrated body that controls safety and quality of food and feed in Republic of Bulgaria. Established in 2011, BFSA follows the best European practices for implementation of highest standards of controls in the areas of safety and quality of food, food- and feed additives and drinks, veterinary medicine and animal welfare, plant protection and fertilizers, phytosanitary controls, border inspections and others. BFSA experts, are performing strict controls throughout the whole food chain, i.e., from the field, farm and/or stable up to the table on daily basis. BFSA is in cooperation with all interested parties countrywide and with their industrial associations. Together with those, BFSA is developing and establishing standards aimed to raise the quality of certain basic food products, such as bread and other bakery or pastry products, milk, milk- and meat products, together with some other traditional Bulgarian foodstuffs.

The BFSA is part of the RASFF – the Rapid Alert System for Food and Feed. Additional measures directed in reducing the communication risk are the maintenance of national food register and non-permanent "cross-checks" that are carried out in cooperation with other authorities related to food safety: the Ministry of Health, the Ministry of Environment and Water, Ministry of Agriculture, Food and Forestry, Consumer Protection Agency, National Veterinary Service, National Plant Protection Service, Bulgarian Small and Medium Enterprises Promotion Agency (BSMEPA), etc.

By virtue of Art. 17 of the Food Safety Act and the analyses of Risk Assessment Centre on the Food Chain - the ministers of the departments related to food and human health should ensure harmonization of country's legislation with the EU law, as well as a balance regarding control as an activity of public interest and the private interests of farmers and food producers.

The proportionality of all acts set by the food control and safety authorities should be a guiding principle in accordance with the requirements from the precautionary measure applied in Art. 168 and Art. 191 of the TFEU and at the same time, leading to the best agricultural practices for food production and the requirements adopted by the Codex Alimentarius.

BFSA is exercising regular cooperation with European Food Safety Agency (EFSA), with all other EU authorities related anyhow with BFSA scope of activities and with all other EU Member States' or third countries' competent authorities (CAs) responsible for food safety in their homelands. The structural approach applied in the legal basis for and the establishment of BFSA is based on the unification of the previous national CAs that have operated as National Veterinary Service (NVS), National Plant Protection Service (NPPS), National Grain and Feed Service, administrative districts' (called "regional") public health inspectorates and the units of the administrative districts' "Agriculture" Directorates, which activities are consistent with the BFSA functions pursuant to Article 3(1) of the Law on Bulgarian Food Safety Agency.

NETHERLANDS

Food Production

The Netherlands is by many accounts quite a small country. The land mass is only 41,543 km² and the total Dutch population of just over 17 million people is smaller than some of the world's current largest cities. And yet, this country is the world's second largest exporter of food. According to Wageningen Economic Research, in 2019 the Netherlands exported almost €85 billion worth of agricultural produce (excluding floriculture), second only to the USA. Besides

this, the country also exported € 10 billion worth of agricultural machinery and fertilizers and € 5 billion worth of agricultural services. This means that Netherlands exports more food than any other European country, including much larger neighbors like Germany, France, and Italy. However, of the export €27,3 billion worth of products concerns re-exportation of products that are not or hardly processed in the Netherlands and €68,3 billion has been produced in the Netherlands. 54% of the agricultural exports go to neighboring countries, China is an important trade partner for milk powder and pig meat.

The way that the country has achieved this has been a relentless focus on finding innovative ways to produce higher yields with fewer inputs. Dutch agribusiness companies spent more than €900 million on research & development, some larger food companies, spent around 30% of their budget on research & development.

The Netherlands plays a major role in propagation materials: almost 40% of global trade in seeds for horticulture and arable farming comes from the Netherlands, the share of Dutch seed-potatoes in global trade mounts to 60%. The Dutch greenhouse construction sector earns 80% of its revenues abroad.

According to a review in National Geographic, this has led to some of the most effective farming methods in the world – while the global average yield of potatoes per acre is approx. 9 tons, many farms in the Netherlands produce more than 20 tons; water usage for many crops using Dutch methods is 90% lower; usage of chemical pesticides in their large greenhouses has been almost eliminated; 2009 Dutch poultry and livestock producers have cut their use of antibiotics by as much as 60%; between 2003 – 2014, new production technologies have resulted in: 28% increase in vegetable yields, 6% reduction in energy used and 29% reduction in fertilizer required.

The Dutch ministry of agriculture concluded in 2018 (Ministerie Landbouw, Natuur en Visserij, 2018) that the emphasis on cost reduction and increase in production had a negative impact on biodiversity, environment, the quality of drinking water and landscape. Therefore, the government choose as a goal to become a leading country in circular agriculture. The transition towards circular agriculture requires a system change in Dutch food production, aiming for a production system that closes nutrient and waste streams, contributes to biodiversity, reduces negative environmental impact while simultaneously resulting in fair business models for farmers. Currently, the Dutch agri-food sector, knowledge institutes and the government are collaborating on innovations that support this system change. Innovative knowledge and technology for climate smart and sustainable food systems should further strengthen the Dutch export position.

In the Netherlands, the development of local food value chains is becoming an important niche in the food market. Local food chains offer a strong revenue model for farmers. A growing group of consumers take a greater interest in the quality of food and the way food is produced. Farmers sell their products directly to consumers, or food cooperatives or SME's coordinate and compose 'food boxes' that can be ordered via the internet and are delivered to the doorstep. Especially during the recent covid pandemics more consumers were interested in sustainable and healthier food and purchased products directly from local farmers. How these new routines will transform the post-covid food system remains uncertain.

On the other hand, a study by the Vrije Universiteit Amsterdam found a 35% increase of food delivery outlets and restaurants, and a 24% decrease in local food shops, between 2004 and 2018. The researchers found an increase in the availability of supermarkets and convenience stores in the more urbanized and lower SES neighborhoods, while a decrease was observed in the less urbanized and higher SES neighborhoods.

How the covid pandemics will influence the Dutch food system remains uncertain. However, new trends are occurring, which indicates that aspects of health (obesity!) and safety,

regionalization, role of animals for food production and responsibilities of the government the food system will be on the agenda the coming years.

Food Control

The EU General Food Law (GFL) regulations, that have been adopted in 2002 by the European Union contains rules on food safety and food quality and apply in all member states. The GFL comprehends the entire production chain of food and feed and its main objectives are to 1) assure a high level of protection of human life and health, consumers' interest as well as fair practice in food trade, 2) warrant free movement of food and feed that is marketed in the EU, and 3) facilitate worldwide trade of safe feed and safe and healthy food.

The rules in the GFL are the starting point of food law in The Netherlands and have been put in Dutch laws. The Dutch Commodities Act is a framework act of separate regulations and decrees and applies to food and non-food products that are used by consumers. Examples of food related subjects that are issued in specific decrees are food labeling, preparation and handling of food, food supplements, herbal preparations, food hygiene.

In the Netherlands the Ministry of Agriculture, Nature and Food Quality is, next other policy topics, responsible for food, livestock farming, agriculture, and animal welfare and disease. Companies themselves are responsible for the production of safe and reliable food. Each company that produces, processes or distribute food or animal feed needs to have a Hazard Analysis and Critical Control Points (HACCP) food safety plan or use an officially recognized hygiene code. Besides this, VACCP (vulnerability oriented) and TACCP (threat oriented) analysis are being applied in food management systems more and more to prevent intentional adulteration of food, which is economically or ideologically motivated respectively.

On behalf of the government, the Netherlands Food and Consumer Product Safety Authority (NVWA), supervises compliance with the law and regulations on food and non-food products. Inspections performed by the NVWA are carried out risk-oriented and knowledge-driven, which in practice means that inspections are carried out more frequently at companies where violations are expected based on, for example, reports or results of previous inspections. For some tasks, the Ministry appointed specific control authorities, for example, supervising compliance with the rules concerning the organic sector by Skal Biocontrol¹³. Laboratory analysis of samples for food and safety control can be performed by the national reference laboratory or sometimes also by different independent laboratories. The national reference laboratory for microbiology, is the National Institute for Public Health and the Environment (RIVM). Wageningen Food Safety Research (WFSR) is the major national reference laboratory for many chemical analysis and GMO, and is a EU reference laboratory for several specific analysis. Food safety issues that concern complex and supply chain-related, organized national and international crime are carried out by NVWA Intelligence and Investigation Service (NVWA-IOD).

HUNGARY

Food Production

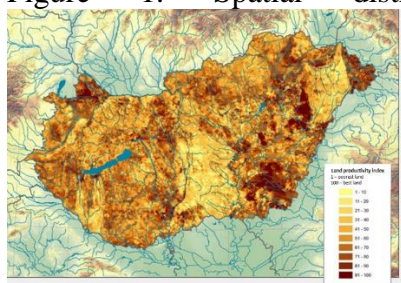
The Hungarian agriculture and food industry is a sector of high importance, its share in GDP growth was 0.2 percentage points in 2018 and while contributing to the performance of the national economy it is resistant to crises.

The growth in agricultural output, which has been going on since 2010, continued also in 2018 reaching HUF 2,720 billion representing a 3.6 per cent increase at constant prices compared to the previous year. In 2018, employment in agriculture was 214.9 thousand people. The sector's share in employment within the national economy was 4.8 percent. Agriculture is an outstanding strategic sector of the Hungarian national economy. In Hungary, the share of agricultural area, in particular arable lands, within the total area is high even in international

comparison. 58 percent of the territory of the country, i.e., 5.3 million hectares are under agricultural cultivation. Agriculture provides 9.8 million Hungarian consumers with high quality, safe food and, in addition, has a significant share in the food supply of other countries. In the past years, the joint share of agriculture and the food industry has been some 6-7% in total gross value added, 7-8% in investments and 8% in employment. The Hungarian agriculture has accounted for about 2% of the EU's agricultural output and added value for years, while its share of factor income has been higher, at 2.3–2.4%. In recent years, the share of the Hungarian agriculture in the output of plant products was 2.2–2.4% and 1.5–1.7% in livestock production. The labor input of the Hungarian agriculture was 404.9 thousand AWU in 2018 which represents 4.4 of the EU28 agricultural labor input.

While much of Hungary is suitable for agricultural production, spatial distribution of agricultural potential is rather complex, based on soil, terrain, hydrological and climatic conditions (Figure 1)

Figure 1. Spatial distribution of agricultural productivity in Hungary



Food Control

There are several laws, government decrees and ministerial regulations in force related to the protection of the environment, including water and soil, the media which in the first place may carry substances that may present risk to the food chain.

The Environment Act (1995, LIII) lays down the “General Rules of Environmental Protection” The Act is a central policy document, followed by decrees on a number of environmental topics. The Act provides a framework for the administrative system of environmental protection and prescribes measures to prevent pollution. The overarching soil protection legislation was passed in 2007 (Law no. CXXIX.) and it prescribes the procedures of good practices including soil conservation, including contamination. Obligations of land users include protection of soil against erosion, acidification, salinization and pollution. The application of certificated amendments only is also one of the obligations of the land user. According to the legislation the land protection authority - which today is the National Food Chain Safety Office (NÉBIH) - controls soil protection.

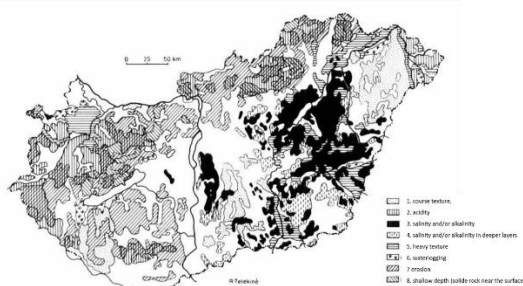
NÉBIH is the food chain safety authority of Hungary with control responsibilities covering the whole food chain from farm to fork, including soil protection, agricultural production, forestry, food processing, retail, and catering. Besides this, the most significant suppliers of the food chain are also registered by NFCSO (for instance private laboratories, input material suppliers). The National Food Chain Safety Office operates the food chain laboratory system and the national reference laboratory network. The NFCSO has been operating successfully under the auspices of the Ministry of Agriculture of Hungary since March 2012. The Office is responsible for ensuring that everyone involved in the production, processing, distribution, and preparation of food acts in compliance with legal regulations so that consumers can be provided with high quality and safe food. As a trustworthy and competent authority, the NFCSO has nationwide competence. One of the main objectives of NFCSO is to support the functioning of the fair enterprises. The basic principle of organizing the activities of NFCSO is food safety risk

analysis as defined by the Codex Alimentarius Commission. Accordingly, besides food risk assessment and risk management, the Office also deals with food safety risk communication (both preventive and crisis communication) and consumer related programs, such as campaigns for conscious shopping, responsible animal keeping, prevention of food waste, prevention of forest fires. The Food Chain Safety Strategy document and a Food Chain Safety Program were created with the aim of further developing the competitiveness of the Hungarian food sector between 2013 and 2022.

Risks to food production and food quality

Land resources of Hungary provide a sufficient basis for food supply satisfying local demand as well as to export agricultural products. However, a number of threats present risk for long term supply of healthy food. Some are principally of natural origin and present since long time (Figure 2), some, including soil sealing have been expanding recently.

Figure 2. Map of limiting factors of fertility and threats to soil resources in Hungary



Contamination, which is the most important soil threat from the viewpoint of human and animal health may present problems locally and outside agricultural areas only and is kept under control. The level of heavy metal concentration, in general is well below the intervention and even the observation level, therefore food quality is not jeopardised by soil heavy metal. Furthermore, Hungary is a low-risk country regarding pollution from surface waters. As far as groundwater pollution is concerned, there are strict thresholds indicating limits for backgrounds and contaminations, including for intervention measures and targets.

Despite the rather safe general conditions regarding soil contamination, there are some cases reported on residues from pesticides. This fact highlights the importance of monitoring of soils and continuous control of pesticide use.

Soil monitoring

The Hungarian Soil Information and Monitoring System (TIM) was initiated in 1992 for monitoring changes in soil conditions. The monitoring can provide information for the legal regulation of the management and protection of soil resources. Soil samples are taken annually and tested for individual parameters with different frequencies ranging from 1 to 6 years. The system is based on altogether 1236 points representative both for the geographical regions and land use types. There are 864 points in agricultural lands, 183 in forests, 189 points such as polluted industrial and urban areas, areas affected by heavy traffic, areas beside military installations and waste storage facilities. Since 2009 monitoring points from the LUCAS topsoil survey of the EU supplements this information base. Current efforts aim to harmonise methodologies of the national and the EU soil monitoring which may further increase the reliability of information for food safety as well.

Food control

NĚBIH in its responsibility of food safety risk analysis and food control applies a number of mechanisms to fulfil its duties.

Main activities involve control of production sites (commercial sites, animal farms, waste treatment sites etc.), border control, registration of products, product certification, allowance to establish new animal farms and food industrial sites, disease control etc.

Through its laboratories NĚBIH test all products of the food chain from pesticide to foodstuff.

CZECH REPUBLIC

Food Production

In the Czech Republic, as it is in the entire European Union, the production of food products is one of the key sectors of the manufacturing industry. Food and food business operators are inspected by the supervisory institutes, including the quality of the delivered production. From the standpoint of the number of enterprises, micro enterprises make up over 60 %, the largest share of revenues and added value, about 45 %, is taken by medium-sized enterprises. The highest share of revenues was attained by processing and preserving meat and the production of meat products, followed by the production of other food products. Almost one quarter of the added value of the section was created in the production of other food products that include a broader range of products but above all those that represent a higher stage of processing agrarian raw materials. Food production remains a significant employer in many regions. In 2016 the largest number of employees and the greatest number of units was attained by the production of bakery, confectionery, and other flour products, which was primarily due to the need to deliver fresh bakery goods to the market network throughout the Czech Republic.

With farms covering 44% of the country area, the agriculture industry is one of the most important sectors of the Czech economy. The country's agricultural production is diversified. Top export products are milk, livestock, grains, sugar, and malt. Approx. 13.7% of farmland of Czech Republic are used for organic farming (2014), which is one of the highest rates among 28 RIS (**Regional Innovation Scheme**) countries.

Agricultural production and the associated production of food is one of the traditional and important sectors of the Czech national economy. In crop production, the cultivation of cereals and oil seeds predominates. Under prevailing conditions in the Czech Republic, there is also the cultivation of grain, potatoes, sugar beet, hops, fruit, vegetables, and grapevines. Furthermore, medicinal, and culinary herbs, flowers and nursery products are also grown. Livestock production focuses on breeding cattle, pigs, poultry, sheep, and goats with the expanding areas of breeding rabbits, fish, and bees.

The Czech Republic is self-sufficient in the manufacture of beef. Despite the number of cattle decreasing in the long run, in the past two years there has been a slight overall increase. The number of milking cows has stagnated over the past two years and their yield has increased slightly. In contrast, the number of suckler cows has been increasing in recent years. Beef production, in the long term, is primarily determined by the demand on the domestic market and the export options for beef and live bovine animals to foreign markets. However, it also depends on the economics of rearing bovine animals, and on the amount of EU and national subsidy measures. Since 2020, beef production has stayed at around 164,974.2 tonnes of live weight and self-sufficiency is more than 120.9 % in 2019. Beef production has risen slightly over the long term, whilst beef consumption has fallen slightly.

The milk sector has its specific position within the food supply chain, it is a source of regular income, it creates jobs in the countryside, contributes to maintaining landscapes and improving soil quality. Despite the decline in dairy cows in recent years, the milk yield continues to increase. In 2020 the production of raw cow's milk in the CR amounted to 3,181 million litres. For a long time, pork has been the most popular type of meat in the Czech Republic. Its

consumption is 43 kg per person per year, which is 51.7 % of the total meat consumed per person per year in all. In 2019, self-sufficiency in the production of this agricultural commodity declined slightly to 50.8 %. Production of pigs were 290,797 tonnes of live weight. Consumption of poultry meat is around 29 kg per person per year with production of 259,266.6 tonnes of live weight. In the case of eggs, this indicator came to 263 per person per year, with production of 1,607,826 thousand pieces

At the start of the nineties, cereal production underwent a very difficult period. Because of social changes, transformation, privatisation and several other causes, the average yields per hectare decreased significantly, as did the production of all cereals compared to the results of harvests in the European Union. The most important cereal grains grown in the CR is winter wheat. It has a dominant position on the market, making up about 60 % of all cereals with used to produce food, feed mixtures, is the raw material for producing bioethanol and is an important export crop. The total area under wheat (winter and spring) in May 2020 was almost 798,583 ha and production reached 4,902,414 tonnes. As concerns the barley mix, spring malting barley predominates, which is a typical Czech export commodity (malt, beer, and grain for malting). It has a 5% share of the total world export of malt. In May 2020, spring barley has sown on an area of 217,279 ha, and its production was 1,118,268 tonnes. In Czech Republic, there is ever-rising interest in cultivating grain maize. Over the past 20 years, its production has grown more than seven-fold. In 2020, farmers harvested 825,499 tonnes of maize from 87,231 ha. In the context of the use of genetically modified organisms, Bt maize has been marginal grown in the CR for production purposes since 2005. Among the crops grown in the CR, oilseeds take up a significant position, which stems from their high demand on the market, both domestic and foreign. The advantages for cultivating oilseeds in the CR are the favourable climatic conditions and well-mastered large-scale production technology. The area of oilseeds fluctuated with a total amount of 450,213 ha in 2020. The oilseed rape is the most cultivated (area 368,214 ha, harvest 1,245,328 tonnes). Due to the higher market prices, the area of poppy increased to 40,255 ha and production reached 28,702 tonnes. Potatoes are among the traditional Czech crops. In May 2020 potatoes was grown in the Czech Republic on an area of 23,877 ha, 696,220 tonnes of potatoes were harvested. The Czech Republic has a long tradition of sugar beet cultivation and sugar production within Europe, that being from the very start of sugar beet cultivation and the sugar industry. Sugar production started in the Czech Republic 230 years ago. Sugar beet has grown on an area of 59,684 hectares with production 3,671,229 tonnes in May 2020. The main fruit species grown on Czech territory are apples, as well as sour cherries, plums, apricots, pears, cherries and currants. Traditionally, a large percentage of the Czech population has grown its own fruit; self-sufficiency is about 30–40 % of total fruit production in the CR. In the vegetable sector are grow primarily peas, tomatoes, cabbage and pickling cucumbers, leafy salads, cocktail and cherry tomatoes, kohlrabi, radish, onions, cabbage, carrots, bell peppers and asparagus.

In the sector of beverages is dominated by the production of beer, of which malt production is an intrinsic part. In 2016, beer production in the CR, including non-alcoholic beer, grew year-on-year to 20.5 million hl of beer. This growth is due to both the higher volume for the domestic market and the continuing positive trend in exports. This development is also supported by the fact that Czech beer carries a protected geographical indication. According to the CZSO, in 2016 the CR harvested 75 900 tonnes of wine grapes from 15 800 ha of productive vineyards. Wine grape production in 2016 was down by 16 % from last year. A total of roughly 565 000 hl of wine will produced from the grape harvest. The deficiency in wine is made up for by the high import of raw materials and wine and, on the other hand, there is also the export of high-quality wines from the CR. For spirits the trend is away from highly aromatic kinds to spirits that are more neutral or slightly aromatic in character. Tuzemák maintained its dominant position on the domestic market. The production of non-alcoholic beverages and mineral waters

includes flavoured or sweetened beverages (lemonades, orangeades, colas, etc.) and mineral water as well as other bottled water.

In addition to local quality and origin brands, Czech producers may also use the schemes valid and recognised throughout the European Union. Seven Czech products bear the logo of Protected Designation of Origin (PDO), namely Vřestarská cibule (Vřestary Onions), Chamomilla bohémica, Český kmín (Czech Caraway Seeds), Nošovické kysané zelí (Nošovice Pickled Cabbage), Pohořelický kapr (Pohořelice Carp), Žatecký chmel (Žatec Hops) and Chelčicko-Lhenické ovoce (Fruit from the Chelčicko and Lhenicko Districts). The logo of Protected Geographical Indication (PGI) can boast e.g. Olomoucké tvarůžky (Olomouc Cheese), České pivo (Czech Beer), Hořické trubičky (Hořice Filled Wafers), Pardubický perník (Pardubice Gingerbread), Třeboňský kapr (Třeboň Carp), Lomnické suchary (Lomnice Biscuits), Valašský frgál (Wallachian pie) or Karlovarské trojhránky (Karlovy Vary Triangles). As Traditional Speciality Guaranteed (TGS) are registered e.g. Špekáčky (Sausages), Lovecký salám (Hunters' Salami), Spišské párky (Spiš Sausages), Liptovský salám (Liptov Salami).

Food Control

The Ministry of Agriculture and the Ministry of Health, in cooperation with other ministries and other state administration authorities, non-governmental organizations, professional and consumer associations and state as well as non-state research institutes, higher education institutions and universities, coordinate the food safety system in the Czech Republic.

It has been developed ever since 2001, when in response to the White Paper on Food Safety and the related actions taken by the EC, the Resolution of the Government of the CR No 1320 concerning the Food Safety Strategy in the CR was adopted. Supervision of fulfilment of obligations ensuing from the Czech and Union law for food business operators across the food and feed chain from primary production to the consumer purchase is carried out by the competent authorities of State Veterinary Administration, Czech Agriculture and Food Inspection Authority, Central Institute for Supervising and Testing in Agriculture and the Institute for State Control of Veterinary Biologicals and Medicines (the Ministry of Agriculture) and public health protection bodies (the Ministry of Health).

Within its competencies, Czech Agriculture and Food Inspection Authority (CAFIA) checks foodstuffs, raw materials for their production, agricultural and tobacco products. The above competences apply to production, storage, transport, and sale (including import). This comprehensive conception of inspections allows focusing efficiently on commodities, analytes or places with the highest estimated number of deficiencies, or where the maximum effect of inspection could be expected. It is therefore a targeted inspection, whose objective is not only monitoring but also the protection of economic interests of both consumers and the state – consumers' protection from foodstuffs that are unsafe, misleadingly labelled, sold despite their expired use-by-date or of unknown origin. Conditions during manufacturing and sale comprise integral parts of targeted inspections. The concept and implementation of food inspection are based on new legislation (on Act No. 110/1997, Coll. on Foodstuffs and Tobacco Products, on the amendment to Act No. 146/2002 Coll. on CAFIA, or on Act No. 552/91 Coll. on State Control, as amended), and are in accordance with principles of food inspection applied in countries of the European Union. The term food safety means the check of microbiological requirements and presence of contaminants (e.g., chemical substances, additives, pesticide residues, etc.). The term quality control means the check of analytical features (e.g., the contents of fat and sugar, humidity, etc.) or check of sensory features. Product labelling and its correctness are assessed separately. When deciding about the target of an inspection, the maximum information available is considered. The decision-making criteria for performing an inspection can be of either general and broadly defined applicability (general criteria), or they are based on some specific findings – specific criteria.

The aim of the project Food Pillory is to make available news about poor quality, adulterated and unsafe food to Czech and European consumers, and thus to provide them with a tool facilitating market orientation. The application available at www.potravinynaprawyri.cz allows visitors to find the required information on substandard food by product name, type of food, vendor, country of origin and distributor. In addition, in the application, consumers will find an overview of closed establishments and results of thematic controls (e.g. on the labelling of gluten in foods). The Food Safety Information Centre (FSIC) provides the public with accurate, understandable and verified information covering the whole food chain, i.e. from the farm to the consumer. Besides the issue of food safety, the FSIC focuses on issues of food supplies for the population. The main FSIC communication channels are: www.bezpecnostpotravin.cz (the website, designated for professionals).

State Veterinary Administration (SVA) is a public administration body under the Ministry of Agriculture of the Czech Republic and it was established according to the Veterinary Act No 166/1999. Its purpose is primarily the protection of consumers from products of animal origin likely to be harmful to human health, monitoring of animal health situation and maintaining it favourable, veterinary protection of the state territory of the Czech Republic, animal welfare and animal protection.

Central Institute for Supervising and Testing in Agriculture is specialised body of the state administration established by Act No. 147/2002 Coll., an organisational part of the state system, administration authority and administrative agency subordinate to Ministry of Agriculture of the Czech Republic. The Institute performs the administration and carries out some other administrative activities, expert and testing tasks and control and monitoring activities in accordance with special acts in the areas of viticulture, feeding stuffs, varieties, seeds and seedlings of the grown plants, protection of hops, fertilisers, soil improvers, growth regulators and substrates and agrochemical examination of agricultural soil, plant variety rights protection and in the area of the animal production.

Public Health Protection bodies are regional hygienic stations ensure the protection of consumer health in the event of dangerous and suspicious products and low quality or quality violations suspicious waters. They also control public catering. The National Institute of Public Health (NIPH) is a health care establishment for basic preventive disciplines – hygiene, epidemiology, microbiology, and occupational medicine and consists of several centres – e.g., Centre for Health, Nutrition and Food. Its main tasks are health promotion and protection, disease prevention and follow-up of environmental impact on the health status of the population. The main activities of NIPH comprise science and research, reference and methodological advice, providing expert opinions on the health safety of various products (e.g. cosmetics, food supplements, items of daily use etc.), systematic monitoring of the environmental impact on population health in the Czech Republic, preparation of legislation in the field of health protection, including harmonization of Czech legislation with the norms of the European Union. The Institute was established by Act 258/2000, Article 86.

Institute for State Control of Veterinary Biologicals and Medicines has been founded by the Ministry of Agriculture of the Czech Republic. Its activities are based on provisions of the relevant pieces of legislation – Act No. 378/2007 Coll., on Pharmaceuticals. Other pieces of national legislation which provide for the activities/responsibilities of the Institute are Act No. 166/1999 Coll. on Veterinary Care; Act No.78/2004 Sb., on GMOs; Act No.477/2001 Sb., on Packaging's; Act No.40/1995 Sb., on Regulation of Advertisement. The Institute carries out responsibilities in the areas of regulation of veterinary medicines, veterinary non-medicinal products (borderline products) and veterinary technical devices. In addition to the national legislation, the Institute carries out activities according to the requirements of directly applicable EU legislation, in particular Regulation (EC) No. 726/2004, and regulation (EC) No. 470/2009.

ITALY

Food Production

Italy is the third-largest economy in the euro-zone, with a GDP estimated at \$2.3 trillion and a per capita GDP of \$38,200. Most raw materials and ingredients are imported, since being a net agricultural importer and as Italy's economic strength is in the processing and the manufacturing of goods, primarily in small and medium-sized family-owned firms.

Agriculture is one of Italy's key economic sectors, accounting for around 2.1% of GDP. Italy's agriculture is typical of the northern and southern division found within the European Union (EU). The northern part of Italy produces primarily grains, soybeans, meat, and dairy products, while the south specializes in fruits, vegetables, olive oil, wine, and durum wheat.

However, in the southern regions of Basilicata, Calabria, and Molise, agriculture accounts for just over 20% of local employment. The decline of this sector in terms of employment and the GDP is, however, compensated for by ever-accelerating productivity. The agricultural profile is in line with all other Western European countries and is due specifically to the effects of the Common Agricultural Policy (CAP) of the EU. The CAP was not very successful in Italy in its initial stages because subsidies did not cover several traditional Mediterranean products such as olives, tomatoes, oranges, and lemons. When these were finally included, the more positive aspects of the policy emerged. Finally, CAP ensures that all traditional Italian agricultural products are given some protection against cheap competition, with export traders subsidized to supply cut rates.

Even though much of its mountainous terrain is unsuitable for farming, approximately 4% of the population is employed in farming. With the average size being eleven hectares, most of Italian farms are small. Italy has a diversified industrial economy with approximately the same total and per capita output as France or the United Kingdom. Italy is one of the largest agricultural producers and food processors in the EU.

With only 5% of the land under cultivation, Italy is not self-sufficient in agricultural products, yet it enjoys an abundance of agricultural resources. Despite a negative balance of trade in agriculture, productivity is high, and the Mediterranean climate ensures that a variety of products are available both for internal consumption and external markets. Italy is a world leader in olive oil production and a major exporter of rice, tomatoes, and wine. Meat has never been a major Italian product, and most of the meat consumed in Italy is imported from other European countries, particularly Ireland and Germany. Italy is also quite weak in the dairy farming sector, although it exports a handful of distinctive cheeses such as parmesan, mozzarella, and gorgonzola. Fruit is grown almost exclusively in the south, with most of the oranges and lemons coming from Sicily. Apples grow in Trentino Alto Adige. But the real strength of Italian agriculture is the production of olives, wine, and tomatoes. While the main weakness is the highly fragmentation of the Italian food processing industry, depending almost entirely on imports of raw materials, many of which come from other EU countries. Italian consumers continue to prefer fresh products rather than canned or frozen. In Italy, the 10 leading food-processing companies account for around 40% of the sector's sales, and growth areas include chilled ready meals, frozen pizza, soups, and healthy foods.

Food Control

To the extent that EU food laws have been harmonized, Italy's food laws and regulations follow EU rules. The main principle of the single market concept is to ensure that all food products, whether produced in the EU or imported from a third country, can move freely throughout the EU if they comply with uniform requirements. In Italy, food safety is the primary responsibility of the Italian Ministry of Health, while food production is the primary responsibility of the Italian Ministry of Agriculture, setting guidelines and coordinating the national policy with

European and international standards at the national level. In some cases, other Italian Ministries may have responsibilities, such as the Ministry of Economic Development on standards, labeling and trade promotion, or the Ministry of Economy and Finance on customs and duties.

Regional authorities are responsible for all the matters which are not reserved for the State in the field of agriculture, including: relationships with the Regions, the State and the European Union; regional plan for agriculture; the control over the quality of the agricultural products; agro-industrial development; the protection and promotion of the rural territory, irrigation and rural facilities; sustainable agriculture; the protection of fauna and flora, and controls of compliance with standards.

POLAND

Food Production

The food sector is one of the most important and fastest growing branches of the Polish economy. 10.5% (1.7 million) of all employees employed in industry are involved in it. Poland is the 6th largest market in Europe, with a capacity of 38.5 million inhabitants. Polish producers are characterized by high competitiveness both in the EU and in the world. 80% of all exports, in 2017, went to the EU's internal market, which after accession became one of the main driving forces for the sector with a potential of over 508 million consumers. Poland is a leading producer of fruits (apples, raspberries, blackcurrants, blueberries), meat (poultry, pork), dairy products and mushrooms. The native processing industry is known for its diversity, including the production of tobacco and alcohol in the long list of food products.

The agri-food products that generated the highest export income in the first seven months of 2017 were meat and poultry offal (EUR 1.39 billion), bread (EUR 824 million), beef (EUR 742 million), fish (EUR 731 million), chocolate food products (EUR 659 million), prepared meats (EUR 592 million) pork (EUR 564 million), cheese and curd (EUR 421 million), wheat (EUR 312 million), fruit and vegetable juices (EUR 9274 million). High incomes were also obtained from cigarette exports (1.39 billion euros). A significant change in food production has been observed in recent years (starting from the nineties). Earlier, numerous small farms, usually led by people hired daily in the industry sector, were widespread. They were generally almost self-efficient or at least reduced the quantity of food bought. With time, their number significantly reduced, leaving place and monopoly for the big, professional farms oriented usually in a narrow product specialization. However, there is a new trend in society to do farming in small gardens (only for family purposes). Sometimes this seems to be problematic due to easy access to pesticides and their common usage. Due to a lack of training and professional knowledge on pesticides and their proper use, this may lead to additional exposure and a rising level of pesticide residues in food and the environment. Poland is also a country of significant input of branches of fish farming and hunting. The most common breed fish species is the Common Carp. The modern method of Carp breeding in the World was established in Poland. Regarding hunting, in Poland, several species belong to game, among which the most common nowadays is definitely Wild boar. Next to Wild boars, Deers, Roe deers, Pheasants and a few waterfowl species are hunted. Poland is also the home of many well-known brands from around the world. In July 2014, the food industry was included in the list of priority sectors by the Polish government.

Food Control

The Ministry of Health (MZ) is responsible for public health policy and food safety. The MZ prepares draft legislation in food hygiene, pesticide residues, contaminants and import of foods of non-animal origin. The portfolio of the MZ extends beyond food safety to, for instance, medicinal products. The Office for Registration of Medicinal Products, Medical Devices and Biocidal Products at the MZ is the regulatory authority for veterinary drugs in Poland. The

Chief Sanitary Inspectorate (GIS) is subordinate to the MZ and is the competent authority for food safety in Poland. It cooperates with the Ministry of Agriculture and Rural Development (MRiRW) on matters regarding food safety and with both the MRiRW and the Ministry of Environment (MS) on matters regarding GMOs. The GIS coordinates and supervises the activities of the State Sanitary Inspectorates (PIS) which are responsible for official control of all aspects of food safety, i.e., food hygiene, pesticide residues, contaminants, import of food of non-animal origin, food contact materials, food additives, GMOs in food, food supplements and novel foods. PIS often holds laboratories equipped with modern instrumental analyzers to control and serve as commercial laboratories to monitor food ingredients and contaminants. The GIS is also responsible for monitoring contaminants in food of non-animal origin. The meat obtained by hunters is beyond the official monitoring for contaminants (including concentrations of metals, residues of pesticides, and others). The only parameter which is demanded is to test the occurrence of Trichinosis in wild boar meat. There is a possibility of monitoring the level of contaminants voluntarily and commercially, but due to the high cost of such analyses, it is scarce. GIS risk management measures are based on scientific risk assessments carried out by the National Food and Nutrition Institute (IZŻ) and the National Institute of Public Health – National Institute of Hygiene (NIZP – PZH). 16 National Reference Laboratories belong to the GIS in accordance with Regulation (EC) No. 882/2004.

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