M1 Intro to sustainable development

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Drivers

- World population growth (primary)
  - Expected to be 10 billion in 2050
  - Since early 1950, post industrial human development has generated a growing global focus on sustainable development
- Per-capita (per-person) consumption rates of material is increasing (primary)
  - Canada is among the highest rate
  - Stock/accumulation is also higher
- IPAT equation: $Impact=Population\times Affluence\times Technology$
  - It only shows the degree of impact
  - Decrease
    - Infant mortality rate
    - Biodiversity
    - Air/water quality
  - Increase
    - Green house gas emission
    - Education rates

Concepts and definitions

- Constructively ambiguous definition of sustainable development: development that meets the needs of present without compromising the ability of future generations to meet their own needs
- SDG (sustainable development goals)
  - A total of 17 created in 2015 by UN
  - Each has several global targets, guide national sustainable development strategies, indicators, measure progress
- Carrying capacity
  - The number of people who can be supported over a very long period of time, by natural, social, human and built capital existing within a specified area
- Bio capacity (related but different)
  - The productivity of land areas (forests, pastures, cropland and fisheries)
  - 1.7 hectare/person estimated in 2010
- Eco footprint (area/year)
  - Measurement of the current human demand on the earth's ecosystems
  - An estimate of the area of biologically productive land and sea needed to sustainably support human activities in a given year
  - Less is better, we need EF<bio capacity
  - Average EF per person: 2.6 global hectare
    - Canadian 5.8 global hectare
  - Ecological deficit=total EF-bio capacity
    - 86% of people live in ecological deficit
- Natural capital
  - Land, air, water, living organisms and all formations of the Earth's biosphere that provide us with ecosystem goods and services imperative for survival and well-being
  - Basis for all human economic activity

Climate change

- Nationally determined contribution (NDC)
  - Paris agreement: keep temperature rise below 2°C, and limit to 1.5°C.
- Green house gas (GHG)
  - Any gas in the atmosphere which absorbs and re-emits heat and keeps the atmosphere

warmer than it otherwise would be

- Global warming potential (GWP)
  - An index expressing the amount of atmospheric warming a gas causes over a period of time in comparison to CO_2
  - Base unit: kg of CO_2 over 100 year time period
  - Common unit for emission amount: CO_2e
  - Amount of $GHG = CO_2e \times GWP$
- Carbon footprint (global hectares)
  - The area of productive land and sea required to absorb the equivalent CO_2 emitted by the human activity
  - Easy measurement: tons of GHG emitted (unit tons CO_2e)
- Vulnerability, hazards, exposure influence the risks associated with climate change
- Adaption (short term) and mitigation (long term) are complementary activities in reducing climate change risks
  - Adaption: flood barriers, evacuation from low lying countries, air filters, reforestation
  - Mitigation: bicycle routes

Biodiversity and loss

- Biological diversity (Biodiversity)
  - The variety of species and ecosystems on Earth and the ecological processes of which they are a part
  - Areas are described as possessing/not possessing biodiversity
  - Components: ecosystems, species, genetic
- Biodiversity loss occurs naturally, normally low-level, can recover
  - Other causes
    - Climate change
    - Increasing human population (use of natural resources)
    - Poaching and unsustainable hunting
    - Pollution
  - Impacts
    - Reduces the healthy function of ecosystems (crop yields, wood production, fodder production, fisheries, resistance to virus, fungal and invasive plants)
- Ecosystem services (benefits to human provided by healthy ecosystems)
  - Provides support to human in physical, mental, socioeconomic, community level
  - E.g.
    - Air/water purification
    - Water decomposition
    - Soil/nutrient cycling
    - Climate/radiation regulating
    - Habitat preservation
    - Noise reduction
    - Aesthetic and culture
    - Raw material and products

M2 Critical skills

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Professionalism

- Obligation
  - EGBC code of ethics and bylaw
- Engineers work at the interface between human activities(economy, society) and environment
- EGBC sustainability guidelines
  - Maintain a current knowledge of sustainability
  - Integrate sustainability into professional practice
  - Collaborate with peers and experts from conception to completion
  - Develop, prepare clear justification to implement solutions
  - Assess sustainability performance and identify opportunity for improvement

Argumentation

- Argumentation occurs in some sort of a social environment in which arguments are presented
  - Form of communication that aids the consideration of issues and may lead to at least the tentative, perhaps temporary, resolution of an issue
- Arguments components
  - Claims: statements about what is true/good/should be done
  - Reasons: justification for the claim
  - Evidence: substantiates the reasons, validates an idea
  - Warrants/inferences: connects the reason to the claim

Self-regulated learning (SRL) procedures

- Set learning goals
- Select strategies
- Reflect on progress
- Revise goals/strategies
- Self-evaluate
- Adapt future methods

Code of ethics

- Hold paramount the safety, health and welfare of the public, the protection of the environment and promote health and safety within the workplace.
- Undertake and accept responsibility for professional assignments only when qualified by training or experience.
- Provide an opinion on a professional subject only when it is founded upon adequate knowledge and honest conviction.
- Act as faithful agents of their clients or employers, maintain confidentiality and avoid a conflict of interest but, where such conflict arises, fully disclose the circumstances without delay to the employer or client.
- Uphold the principle of appropriate and adequate compensation for the performance of engineering and geoscience work.
- Keep themselves informed in order to maintain their competence, strive to advance the body of knowledge within which they practice and provide opportunities for the professional development of their associates.
- Conduct themselves with fairness, courtesy and good faith towards clients, colleagues and others, give credit where it is due and accept as well as give, honest and fair professional comment.
- Present clearly to employers and clients the possible consequences if professional decisions or judgements are overruled or disregarded.
- Report to their association or other appropriate agencies any hazardous, illegal, or unethical professional decisions or practices by engineers, geoscientists, or others.
- Extend public knowledge and appreciation of engineering and geoscience and protect the profession from misrepresentation and misunderstanding.

M3 Systems & sustainability

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Systems theory
- Traditional engineering perspective (Cartesian, reductionist thinking)
  - Divide larger problem into predictable constituent parts, then address each of the issues associated with each part
- New ways of thinking (complexity)
  - It is required to manage large, complex and changing systems
- Simple systems and complex systems
  - Simple: whole is equal to sum of its parts, can be modelled by normal science techniques
  - Complex: whole is greater than sum of its parts
- System is a type of mental model, systems thinking is away of viewing the world around us as the interplay between overlapping/layered systems
- Systems thinking means being aware of interplay between a variety of different systems at different scales with different themes
  - Aware of physical structure and scale, context, relationships, processes, patterns of behavior

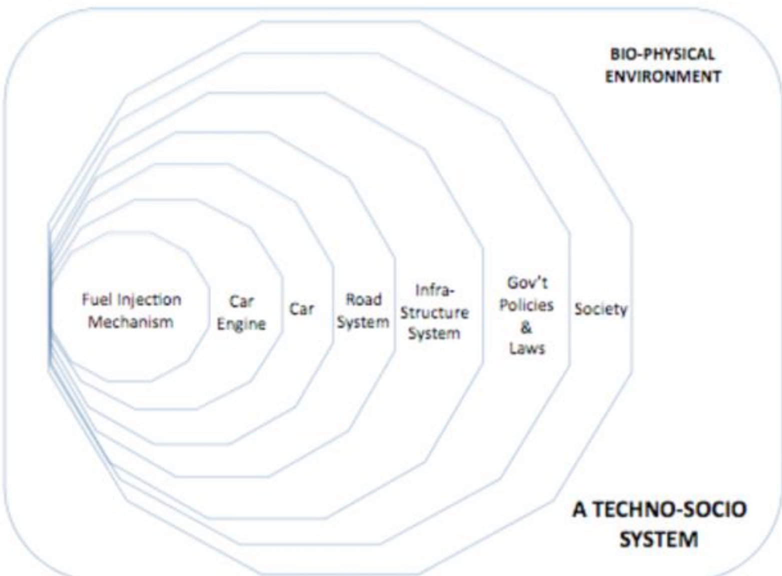
Complexity science and resiliency
- Complex system
  - It is a system in which large networks of components, with no central control and with simple rules of operation, give rise to complex collective behavior sophisticated into processing and adaption via learning or evolution
  - Complex collective behavior: collective actions of components give rise to complex, hard-to-predict and changing patterns of behavior
  - Signalling and info processing: all complex systems produce, use info and signals from internal and external environment
  - Adaption: all complex systems change their behavior to improve their chances of survival and success through learning/evolutionary processes
  - Self-organizing: organized behaviors arise, without internal/external controller/leader
  - Emergent: simple rules produce complex behavior in hard-to-predict ways
- Resilience
  - Protects the complex system's nested group of interacting sub-systems from devastating disturbances
  - To maintain a resilient system, the system must always be experimenting with the boundaries of what kind of disruption the system can(not) handle
- Adaptive cycle
  - Rapid growth (r): social, economic, environmental resources are abundantly available and facilitate rapid growth (fast)
  - Conservation (K): resources not plentiful, slowing growth
    - Slow, little capacity to change
    - Less flexible, more vulnerable
  - Release/disturbance (Ω): causes system to collapse (quick, chaotic)
  - Reorganization (α): system reorganize into a different structure, new entities formed, innovation achieved

System thinking in action
- Contextual issue may not necessarily be a component (part/element) of a system
- Elements in a system model can be either physical or conceptual
- System learning can
  - Reveal how groups of interacting, interconnected and interdependent elements affect each other within a greater whole
  - Provide insights into how underlying relationships drive human activity patterns and

behaviors
    - Unearth pathways to affect change and resolve complex problems
- Important characteristic of complex system
    - While individual elements within a system may not influence behavior, the group of elements together may interact in a broader pattern or arrangement to trigger a desirable outcome
- Feedback loop
- Causal loop diagram illustrates the system dynamics
    - Each arrow links a cause to an effect
    - + or - sign shows the positive/negative relationship between cause and effect
    - Used in an ever-changing complex system to identify unintended consequences of design decisions

Concepts and causes
- Concept map can provide context for the situation/event
    - Concepts (word/symbols): a perceived regularity in events/objects or records of events/objects, designated by a label
    - Linking words (semantic units/ units of meaning): connects two or more concepts in propositions to form a meaningful statement
        - Propositions are statements about object/event in universe
    - Concept hierarchies: in a concept map, concepts are represented in a hierarchical fashion
    - Cross links: relationships/links between concepts in different segments/domains of the map
    - Examples: may not be included in ovals/boxes, since they are not concepts
- Build a concept map:
    - Begin with a domain of knowledge (focus question)
    - Create a ranked list of key concepts (general to specific)
    - Construct a preliminary concept map
    - Add cross-links
- Causal loop diagrams (CLDs)
    - Feedback loops
        - Reinforcing (R): a loop with all same sign, cannot last forever
        - Balancing (B)
    - Double slash means a significant lag time between the initial change in A and the response in B

Built and natural systems
- Simple systems can be nested within complex systems
- In a tecno-socio, smallest sub-systems are simple, largest sub-systems are complex



    - Traditional engineering activities take place in the core of the system
    - Categorizing a system as simple/complex help guide which analysis tools are best used
    - While the scale determines what analysis tools to apply, system thinking can be considered in all decisions
    - Decisions made at one scale of the system can have unintended consequences at a different scale
- An ecosystem is a natural and highly complex system consisting of a functioning subset of biological organisms and the physical environment occupied by the same subset
    - It is a metaphor for built systems
- Urban areas are dominated by people and artifacts, but they can nurture biodiversity
    - Urban ecology is the study of ecology within cities but it is also the study of the ecology of cities

M4 Sustainable cities

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Components of the urban ecology

- Three primary subsystems
  - Built environment
  - Urban social systems
  - Bio-physical environment
- Urban metabolism
  - Cities are complex, they are dynamically open and self-organizing
- Urban societies
  - Cities bring together an array of different socio-economic, national and professional cultures
  - Social systems (families, neighborhoods, organizations) influence human behavior
  - Rules exist
- Livability
  - It is the quality of interactions between people and their urban environment
  - It encompasses human needs such as food, security, physical health…
  - Indicators
    - Air quality
    - Walkability
    - Working conditions
    - Cultural activities
    - Sports
    - Volunteerism
    - Affordability of housing
- Ecosystem services

Urban infrastructure

- Challenges
  - Disease epidemics
  - Criminal activities
  - Loss of housing affordability
  - Natural disasters
  - Social dysfunction
  - Increased airborne particles
  - Flooding and droughts
  - Storm
  - Increasing sea level
  - Decrease in agricultural production
- Resilience in cities
  - Capacity of individuals and systems within an urban environment to survive, adapt and grow chronic stresses, acute shocks they experience
    - Integrated plan is involved
  - Qualities
    - Reflective
    - Robust
    - Flexible
    - Integrated
    - Resourceful
    - Redundant
    - Inclusive
- City resilience framework (CRF)
  - Health and well being

        - Meets basic needs
        - Supports livelihoods and employment
        - Ensure public health services
    - Economy and society
        - Promote cohesive and engaged communities
        - Ensure social stability, security and justice
        - Foster economic prosperity
    - Leadership and strategy
        - Promote leadership, effective management
        - Empower a board range of stakeholders
        - Foster long term, integrated planning
    - Infrastructure and environment
        - Provide and enhances protective natural and human-made assets
        - Ensure continuity of critical services
        - Provide reliable communication and mobility
- For large systems to be resilient, the subsystems must also be resilient

Resiliency in urban system design

- Ecosystem approach
    - Non-linear approach
    - Direct and indirect relations, interactions
    - Different elements, scales
    - Theoretical basis: complex system theory
    - E.g. CIRS
        - Reflects:
            - Materials, energy and info flows within/between built and natural environments
            - Systems and system scales
            - Life-cycles of infrastructure and infrastructure elements
        - It involves consideration of the context of the design as well as short/long term impacts, direct/indirect impacts
        - It needs the awareness of the systems and entire life cycles of infrastructures
- Storm water management: opportunity to enhance ecosystem services within cities and enhance public realm, improving human well-being and ecosystem health

Green buildings

- Integrated design process (IDP)
    - Highly collaborative, interactive design process that focuses on resource efficiency by employing system thinking
    - Stages:
        - Design preparation
        - Evaluation
        - Conceptual design
        - Schematic design
        - Design development
        - Construction documents
        - Bidding and construction
        - Post-occupancy (occupancy, operation, performance)
- IDP design goals
    - Energy reduction, generation
    - Water use reduction
    - Material recycle, locally produced
    - Optimal use of sites
    - Indoor quality (air, sound, social environment, esthetics)
- People in IDP
    - Client, project manager, architect, IDP facilitator, engineer, ecologist
    - Design Charette: the leader of the design team, intensive planning session to create an

overarching vision

- Leadership in environmental and energy design (LEED)
  - It is a building certification process to assess IDP
  - Considers
    - Location and transportation
    - Sustainable sites
    - Water efficiency
    - Energy and atmosphere
    - Material and resources
    - Indoor environment quality
    - Innovation
    - Regional priority
    - Integrative process
- Living building challenge (LBC)
  - Site integrity
  - Net zero water
  - Net zero energy
  - Health: promote health for occupants such as welcoming stairways.
  - Materials: safe and locally sourced materials
  - Equity
  - Beauty: aesthetics

M5 Sustainable supply chain

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Material resources and productivity

- Supply chain is the sequence of activities leading to the delivery of a product or service to an end user
    - Resource extraction
    - Material manufacturing and transport
    - Information transfer
    - Services
- Material consumption
    - Amount of materials extracted worldwide has doubled since 1980, 72Gt in 2010, 100Gt in 2030
    - Driven primarily by construction materials, fossil fuel energy carriers, biomass for food
    - Gradually economic growth is being decoupled from natural resource consumption (per-capita)
    - Dematerialization requires
        - Policies at all government levels
        - New business models linked to improved resource efficiency of production processes, less material means more value
        - Greater consumer awareness of the role we each can play and contribute through better product choices and behavior

Biomimicry in engineering design

- Four primary stages
    - Scoping
        - Define context
        - Identify function
        - Integrate life's principle
    - Discovering
        - Discover natural models
        - Abstract bio strategies
    - Creating
        - Brainstorming
        - Emulate design principles
    - Evaluating
        - Measure using life's principles
- Life's design principles
    - Evolve to survive
    - Adapt to changing conditions
    - Be locally attuned and responsive
    - Integrate development with growth
    - Be resource efficient
    - Use life-friendly chemistry
- Earth's operation conditions
    - Sunlight, water and gravity
    - Dynamic non-equilibrium
    - Limits and boundaries
    - Cyclic processes
- Consumer products example
    - Colored fabrics without chemical dyes
- Construction materials
    - Self-healing concrete

Industrial ecology (IE)

- Thinking about a set of factories as an industrial ecosystem, and a factory as an industrial organism
- IE is a methodology of clustering manufacturing, processing and assembly plants such that the waste stream of one industry becomes the feedstock of another
    - Material flow analysis (MFA): complex due to more varied, uncontrollable activities in a city than in industry

The circular economy and construction waste

- Circular economy
    - Eliminate waste (closing the loop), minimize inputs, adopt renewable energy
    - Mimic biological cycles
    - Principles
        - Design out of waste and pollution
        - Keep products, components and materials at their highest value and in use
        - Regenerate natural systems

Life cycle assessment (LSA)

- LSA is a type of material flow analysis based on life-cycle thinking, used to determine the environmental impact of a product, process, or system over the lifetime
    - Material in/out-flows, and their influence on ecosystems
    - Life cycle
        - Raw material
        - Manufacturing
        - Transportation
        - Distribution
        - Product
        - End of life
- Formal LCA
    - Goal and scope (boundary and system)
        - Purpose, temporal/spatial scope, functional unit (basis of the assessment)
        - Who will use the result
        - What decisions will be made
    - Definition inventory
        - Identify and measure inflows and outflows to each stage of the life cycle
    - Impact assessment
        - Need to normalize the impacts
        - Typical types
            - Fossil fuel
            - Minerals
            - Land use
            - Ecotoxicity
            - Ozone layer
            - Radiation
            - Climate change
            - Acidification and eutrophication
            - Respiratory in organics
    - Interpretation
        - Organize goal and scope, result of inventory analysis and impact assessment steps
        - Best performed during the first three steps
        - Final step is to review and finalize

M6 Engineering and the least developed countries

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Introduction to engineering and LDCs

- In 2018, 783 million people lived on less than $1.9, half the number of people in 2000
- # least developed countries (LDCs): 47
- Criteria of LDC
  - Human assets
    - Secondary school enrolment
    - Under-nourishment
    - Maternal mortality
    - Adult literacy
    - Under five mortality
  - Economic vulnerability
    - Population
    - Remoteness
    - Export concentration
    - Victims of natural disasters
    - Share of agriculture and fishing in GDP
    - Share of population in costal zones
    - Instability of exports/agriculture
  - Income per capita
    - 2015 threshold: 1,242 UDS
  - Must meet 2/3 criteria at two 3-yearly reviews to graduate from LDC
- International aids
  - Special treatment for WTO members
  - 0.15%-0.2% donor GNI provided as aid
  - Climate change financing
  - Reduced UN contributions
  - Help with travel
  - Duty-free access to EU market
- Humanitarian engineering (definition from the reluctant innovation)
  - Altruistic, creative and possess engineering know-how
  - Organizations: Engineering Without Borders (EWB)
  - Website: engineers for change
- Problems
  - Engineering students: well-structured, one possible solution
  - Sustainability problems:
    - Ill-structured
    - Highly complex
    - Multiple solutions
    - Unique
    - A symptom of another problem
    - Never-ending
  - Humanitarian engineering projects are wicked (hard to define)
    - Approach: interdisciplinarity, system thinking, iterative thinking
- Ethical frameworks for international engagement
  - Ethics of care
    - Interdependence of all individuals
    - Certain communities/people are more vulnerable
    - There is no universal truth, consider contextual details
  - Non-maleficence and beneficence
    - Intention to avoid needless harm or injury
    - Promote well-being of others

    - Ethical pluralism
        - Carefully consider when it is appropriate to act under one norm or another
    - Feminism
        - Everyone should be included

Assessing engineering projects in LDCs

- Seven questions
    - Engagement: are engagement processes in place and working effectively
    - People: will people's well-being be maintained or improved
    - Environment: is the integrity of the environment assured over the long term
    - Traditional and non-market activities: are they accounted for in a way that is acceptable to local people
    - Institutional arrangements and governance: are rules, incentives, programs and capacities in place to address consequences
    - Synthesis and continuous learning: net result positive/negative in long term? Periodic assessment
- Framework
    - Questions (interrogative form of goal statement)
    - Ideal answer (foundation of assessment criteria)
    - Objectives
    - Indicators
    - Metrics
- Environment questions: impact on the biophysical system
    - Ecosystem function, resilience, self-organizing capacity
    - Ecological entitlement
    - Full ecosystem costs, benefits and risks
    - Responsibilities and sureties
    - Environmental stress and action to ensure ecosystem integrity

M7 Leading sustainability

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Envisioning a sustainable future

- Scenario planning
  - Traditional: take historical data and trends and generate a good enough short-term prediction
  - Scenario: simulate potential future scenarios to prepare for long term
  - Need to choose a set of future scenarios that best represent the diversity with relevant uncertainty
  - No need to predict specific event, but predict what will happen if an event occurs
- Visions of sustainable future
  - Alex Steffen
    - Cities are important in achieving sustainable world
      - Non sustainable alternatives are still profitable
      - More compact with more choices of destinations
      - Better walkability
      - More access to nearby needs
      - Less driving
      - Less energy usage
      - Less stuff-buying
    - Bright green cities refer to cities being both environmentally sustainable and economically profitable/prosperous
    - Intelligent technology can help by tracking and reducing energy usage
  - Robert Costanza
    - Human well-being will be increased if we improve in social capital, stabilize population growth and invest more in public goods, interactions with friends/family/nature
    - Material consumption only improve human well-being to a threshold. Beyond this, other things are needed for happiness
    - Highly materialistic people suffer highly rates of mental and physical health
    - Balance of material consumption is required
- Gross national happiness (GNH)
  - Sustainable approach to balance material and non-material values
  - Sustainable socio-economic development
  - Economic conservation
  - Culture preservation
  - Good governance

Adaptive leadership

- Adaptive leadership starts by engaging in an interactive process
  - Observing events and patterns around you
  - Interpreting what you are observing (developing hypotheses about what is going on)
  - Designing interventions based on the observations and interpretations to address the adaptive challenge
  - Key elements of personal reflection
    - Making sense of experience
    - Standing back
    - Repetition
    - Deeper honesty
    - Weighing up
    - Clarity
    - Understanding
    - Making judgments

        - Check leadership skills
- Fundamental attributes of leadership
    - Integrity: develop trust among people
    - Committing to something bigger than yourself
    - Authenticity
- Integrity: honoring one's word, trust and honesty
    - Do what you say
    - Do what you know
    - Do what is expected
    - What you say is so
    - Do what you say you stand for
    - The social moral standards, the group ethical standards, and the government legal standards of both right and wrong and good and bad behavior
    - Honoring one's word means:
        - Keeping your word
        - When you will not keep your word, say to everyone impacted
- Summary
    - People resist change because change involves losing something important
        - An adaptive leader needs to help people adjust the loss
    - Groups of people are willing to be influenced by trustworthy individuals who are acting towards achieving something that is bigger than themselves
    - Successful leaders have integrity, keep their word and are leading in order to achieve something that is important to the group they want to lead
- Leadership can entail/involve risk and danger because leaders sometimes need to do things that are not popular and may result in the leader failing to achieve their goals and goals of the people they serve
- Adaptive challenges/problems with solutions that require people to change their behavior requires leadership

Examples of sustainability leadership

- Successful leadership actions have
    - Successful adaptive changes build on the past
    - Organizational adaptation occurs through experimentation
    - Adaptation generates loss and is therefor difficult
    - Adaptation takes time