

## UOIT MITACS Research

We've completed 3 phases of research project with UOIT through the MITACS program: The specific objects of each project are:

### PHASE

1 - Comparative assessment of NH<sub>3</sub> production and utilization in transportation systems for Ontario

- Extensive study on the ammonia production from various types of resources such as renewable energies (wind, solar), methane steam reforming and excess power in nuclear and/or hydro power plants. Assess the emissions and pollutants discarded by each method during processes.

- Detailed study on ammonia based transportation systems and ammonia based commercial products ideas.

- Identifying opportunities for green NH<sub>3</sub> production and efficient utilization of ammonia in various sectors and especially in transportation sector.

- Implementing life cycle analysis of ammonia production methods and impact of ammonia production on environment.

- Ammonia fuel cycle comparison with conventional transportation systems in terms of sustainability and economics.

- Assess the environmental, economic, sustainability and feasibility of the conceptual systems using life cycle considerations.

### PHASE

2 - Comparative assessment of NH<sub>3</sub> production and utilization in agriculture, energy and utilities, and transportation systems for Ontario

- Oil sand and underground coal gasification based ammonia production methods will be investigated and green ammonia production from oil sands and coal reserves will be analyzed comprehensively.

- Microwave dissociation of oil sand will be investigated for ammonia production.

- Specific applications of chosen ammonia production methods will be determined based on potential scenarios in Canada.

- Case studies will be conducted for various locations, such as that low cost hydroelectric based ammonia production opportunities in Newfoundland and Labrador will be investigated, and an integrated system will be proposed to assess them thermoeconomically.

- A detailed investigation of stranded natural gas microwave dissociation of high-pressure liquefied methane into hydrogen gas and elemental carbon will be investigated.

- Direct ammonia usage opportunities in marine, mining, rail and transportation applications will be analyzed.
- Comprehensive thermo-economic evaluations of chosen ammonia production methods will be conducted for various scenarios such as low cost hydropower and oil sands.
- Experimental investigations of some novel ammonia production methods through some lab scale prototypes such as SSAS and molten salt based electrolytic ammonia synthesis will be investigated.
- Lab scale molten salt based ammonia synthesis will be experimentally realized.

## PHASE

3 - Thermo-economic assessment and experimental investigation of renewable energy based NH<sub>3</sub> production options for clean energy communities

Energy and exergy analyses of

- solar energy based electrochemical ammonia production
- low-cost hydroelectric based ammonia production
- wind energy based ammonia production
- underground coal gasification based ammonia production
- ammonia production via hydrocarbon decomposition such as dissociation of methane and oil sand bitumen
- Environmental impact assessments of
  - ammonia utilization in air transportation including freight transport
  - ammonia usage in sea transportation including ocean tankers and freight ships
- Thermo-economic analyses and evaluations of
  - hydropower, solar and wind energy based ammonia synthesis for Ontario.
  - on-site ammonia production and utilization for remote communities in Northwestern Ontario.
  - transport of ammonia vs. LNG via pipelines.
  - hydrocarbons based ammonia production for Alberta and Newfoundland.
  - ammonia utilization as a fuel for power, heating and cooling generation

- Optimization study of:
  - various resources based Haber-Bosch ammonia synthesis for lower energy requirement including wind and hydroelectric options
- Experimental investigation of:
  - molten salt based electrochemical ammonia synthesis at ambient pressure
  - concentrated solar energy based electrochemical ammonia synthesis
- Scalability and feasibility analyses of:
  - solar energy based electrochemical ammonia synthesis experimental setup
  - low-cost hydroelectric, wind, geothermal, ocean and biomass energy based ammonia synthesis methods
  - hydrocarbon decomposition based ammonia production methods

Now that Phase 3 of our ongoing research has been completed, we know which manufacturing and utilization technologies work in different applications and we will be able to move quickly into developing commercial opportunities to utilize Hydrofuel's existing retrofit diesel engine conversion systems while we do parallel development of next generation technologies already well underway.

- Scale-up of UOIT-patented technology for ammonia decomposition and separation to generate hydrogen from ammonia for the purposes of installing the system into a vehicle motor engine. The research project will build on intellectual property which is owned by UOIT: Patent US8272353, CA 2654823 "Methods and Apparatus for Using Ammonia as a Sustainable Fuel, Refrigerant and NOx Reduction".

- Develop a pre-commercial prototype of a reliable ammonia-water heat engine for power, heating and cooling generation using low-grade heat. This research will build on intellectual property which is owned by UOIT: Patent (pending) US 20140053544A1, CA 2824759A1, "Heat Engine System for Power and Heat Generation".

- Develop prototype(s) for solid state ammonia synthesis and direct ammonia fuel cells. This research will build on background intellectual property of Dr. Dincer's research group at UOIT.

