NEPAL POWER INVESTMENT SUMMIT 2018
Soaltee Crowne Plaza
Tahachal Marg, Kathmandu, Nepal

Development of Francis turbine at Kathmandu University to initiate a new business in Hydropower market under Himalayan basins

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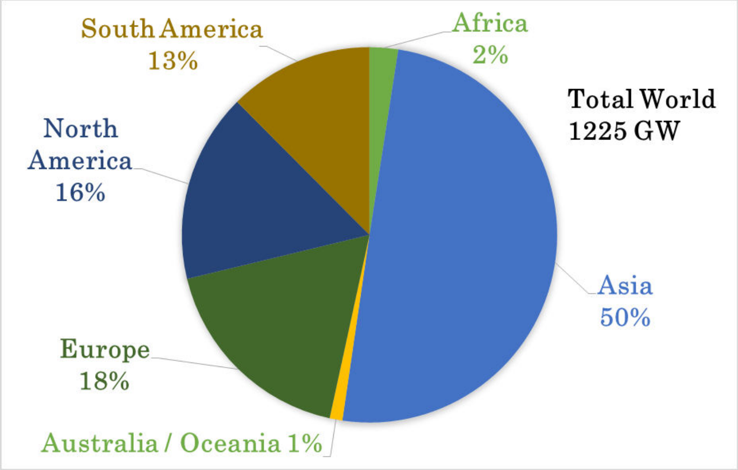
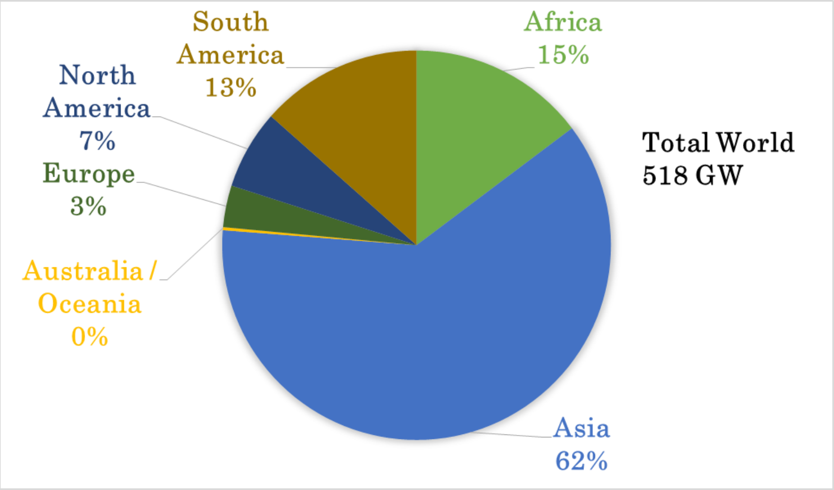
World: *Hydropower Potential*



Developed

Ref: Hydropower Status Report, IHA, 2016



Planned

Ref: World Atlas, Hydropower & Dams, 2015

Asia: *Hydropower history*

1897, India

Sidrapong Hydelpower Station

2*65 kW

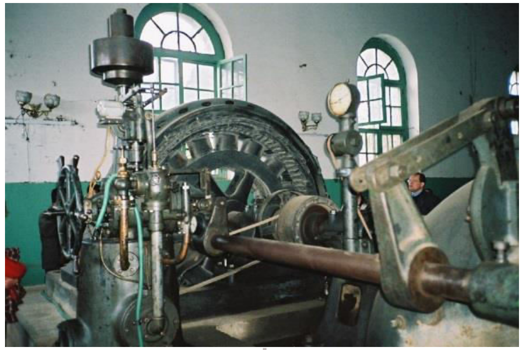
2017: 51.98 GW (61.87% of TF)

1911, Nepal

Pharping Hydro Power Project

2*250 kW

2017: 0.867 GW (1.84% of TF)



1912, China

Shilongba Hydroelectric Power Station

2*240 kW

2017: 331.11 GW (41.47% of TF)

Hydropower Development Opportunities

***Status of Hydropower Development*: Nepal**

S.N.	Summary status of hydropower development	No. of projects	Capacity (MW)
1	Completed projects	80	937.31
2	Projects under construction	57	4935
3	Issued construction licenses for generation	148	4322.59
4	Issued survey licenses	289	13397.85
5	Application received for survey licenses	23	2084.16
Total (2-5)			**24739.56**

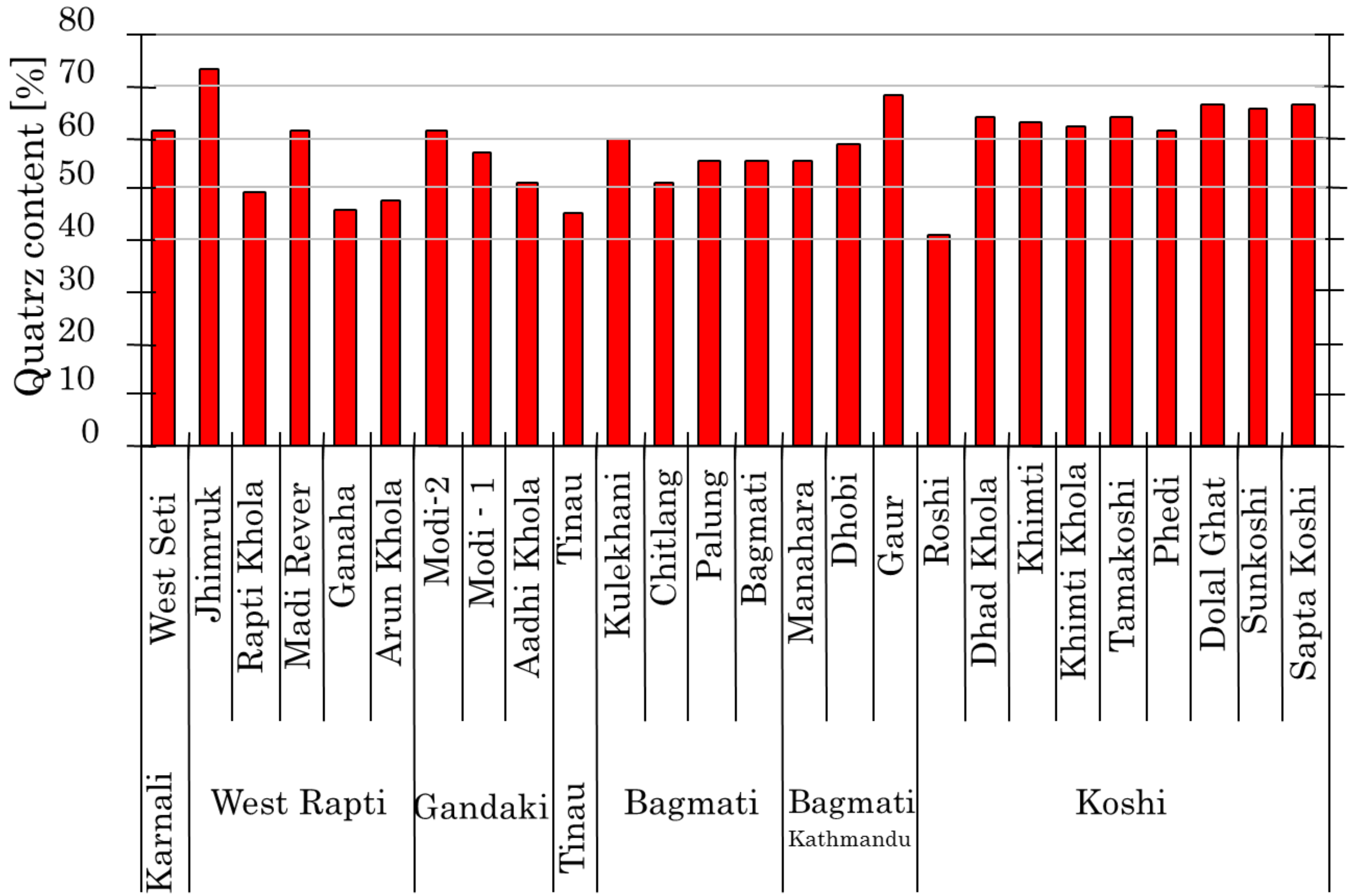
Ref: Department of Electricity Development, Government of Nepal, 2017

South &South East Asia

Country	Tech feasible (GWh/year)	Installed (MW)	Planned (MW)
Afghanistan	25000 MW	400	~500-1000
Bhutan	>99250	1615	8530
Cambodia	8600 MW	1267	4378-6513
India	660000	51494	~10000-98500
Laos	20000 MW	4168	4000-17000
Lebanon	1500	221	200-300
Myanmar	39720 MW	3140	10000-17000
Pakistan	204000	7264	~17000-20000
Sri Lanka	8250	1624	>267
TOTAL		**71423**	**54975-169425**

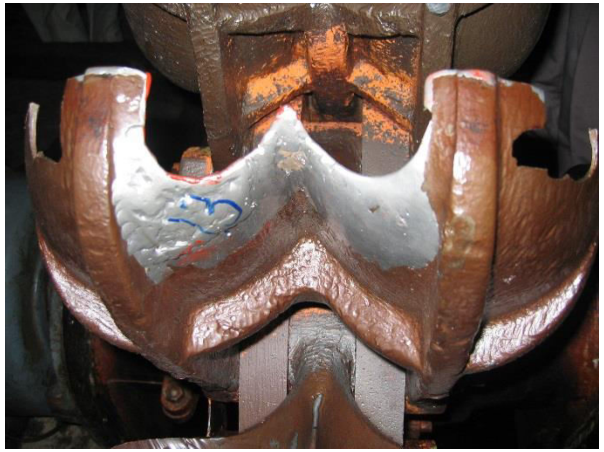
Ref: World Atlas and Industry Guide 2012, Int. Journal of Hydropower and Dams
Hydropower Status Report 2016, Int. Hydropower Association

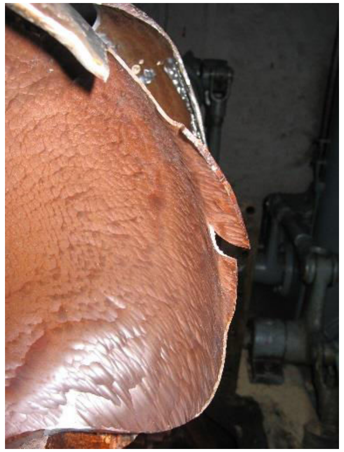
Hydropower Challenges in Nepal



Sediment Concentration and Erosion rates for major river basins in Nepal

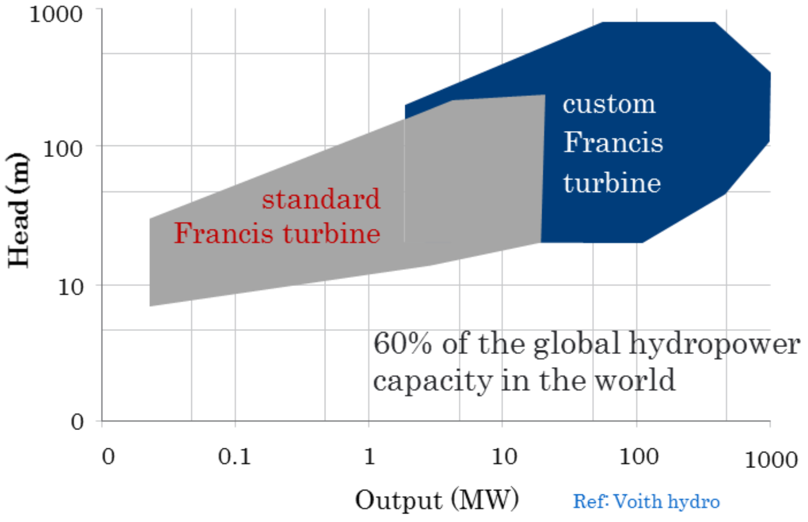
4 MW*3 Francis runner at Jhimruk Hydroelectric Center, Nepal Ref: O.G. Dahlhaug, 2004



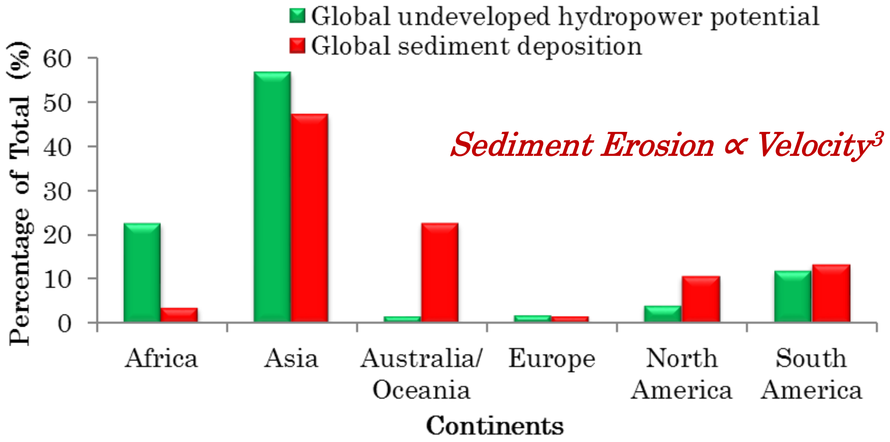


1.7 MW*3 Pelton turbine Andhi Khola Hydro power plant Nepal,
Ref: B. Ole G. Dahlhaug, 2004

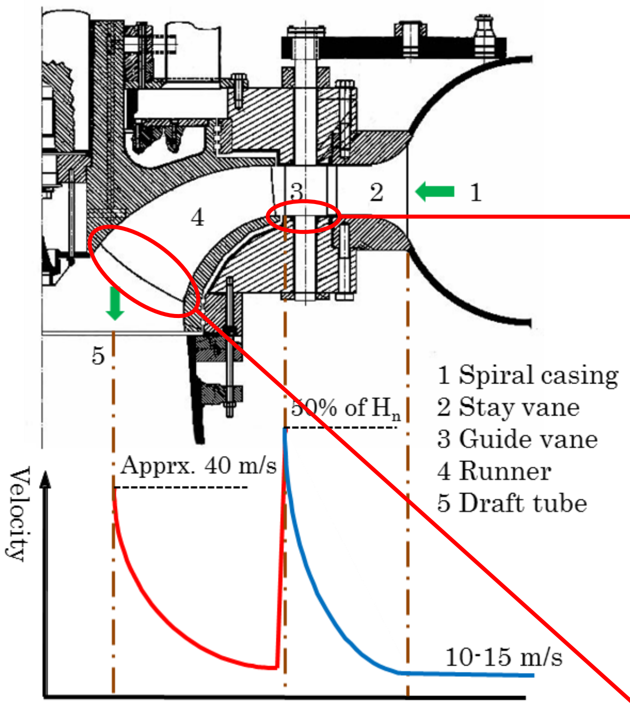
Turbine Design Philosophy and Performance



Operational range of Francis turbine



Sediment Erosion ∝ Velocity³



250 MW*6 Francis runner at Nathpa Jhakri Powerplant, India

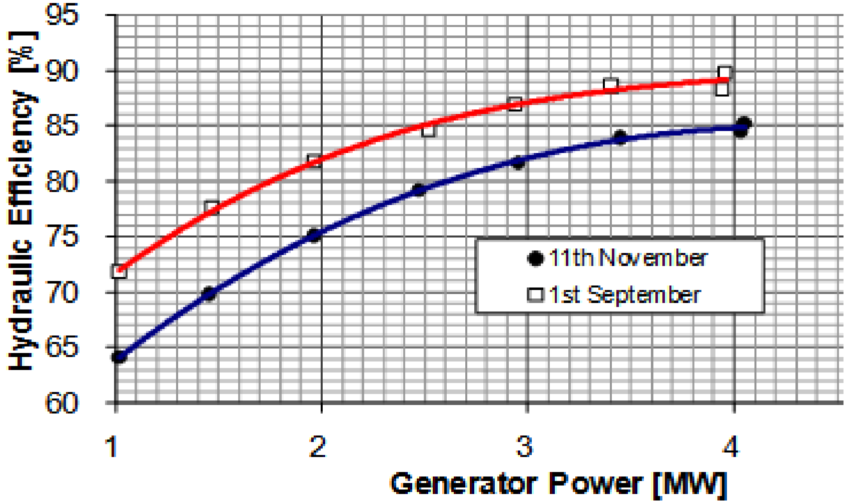
Ref: H.K. Sharma, 2010

48 MW*3 Francis turbine at Kaligandaki-A Hydroelectric Center, Nepal,

Ref: B. Chhetri, 2013

Loss of Energy Generation

S.N	Plant Name	Owner	Installed Capacity [MW]	Annual energy generation [GWh/yr]	Energy Price [¢/kWh]	1% Loss of Turbine Efficiency [GWh/yr]	1% Loss of Turbine Efficiency [USD/yr]
1	Kaligandaki 'A'	NEA	144.00	750.84	0.78	7.51	583,178.25
2	Mid-Marsyangdi	NEA	70.00	435.56	0.78	4.36	338,298.07
3	Marsyandi	NEA	69.00	441.74	0.78	4.42	343,096.39
4	Kulekhani I	NEA	60.00	71.36	0.78	0.71	55,422.14
5	Kulekhani II	NEA	32.00	36.06	0.78	0.36	28,004.16
6	Trishuli	NEA	24.00	125.03	0.78	1.25	97,107.34
7	Modi	NEA	14.80	62.79	0.78	0.63	48,766.76
8	Devighat	NEA	15.00	94.31	0.78	0.94	73,247.76
9	Sunkoshi	NEA	10.05	35.99	0.78	0.36	27,956.66
10	Jhimruk	BPC	12.00	72.00	0.78	0.72	55,922.33
11	Khimti I	HPL	60.00	350.00	0.78	3.50	271,844.66
12	Chilime	CHC	22.1	137.90	0.78	1.38	107,106.80
13	Bhote Khosi	BKPC	45	293.2	0.78	2.932	227,728.16
		Total	**555.85**	**2906.76**		**29.07**	**2.25 Million**



Thermodynamic efficiency measurement a Jhimruk HPP

Ref: O.G. Dahlhaug, 2003

Other Financial Losses

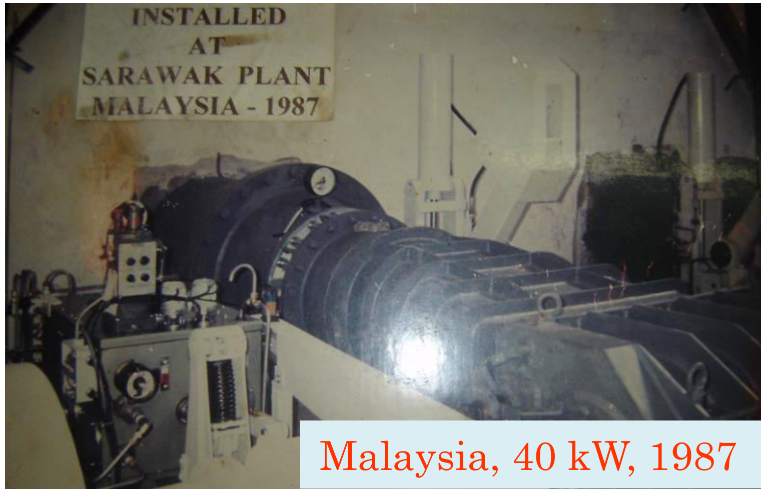
Repair and Maintenance Costs

Downtime Costs

Annual generation for NEA's power plants are given for 2072-2073
Ref. Nepal Electricity Authority, Annual Report 2073
PPA rates: http://www.moen.gov.np/pdf_files/PPA-Rate-Storage-PROR-ROR.pdf

Turbine Manufacturing Experiences of Nepal

- 1962: First turbine manufactured in Nepal, 5 kW Propeller
- 1973: First Crossflow turbine manufactured in Nepal
- 1975: First Pelton turbine manufactured in Nepal
- 2016: Turbine manufactures 58, Unit Capacity upto 100 kW
  Total capacity 30 MW, Export 0.6 MW



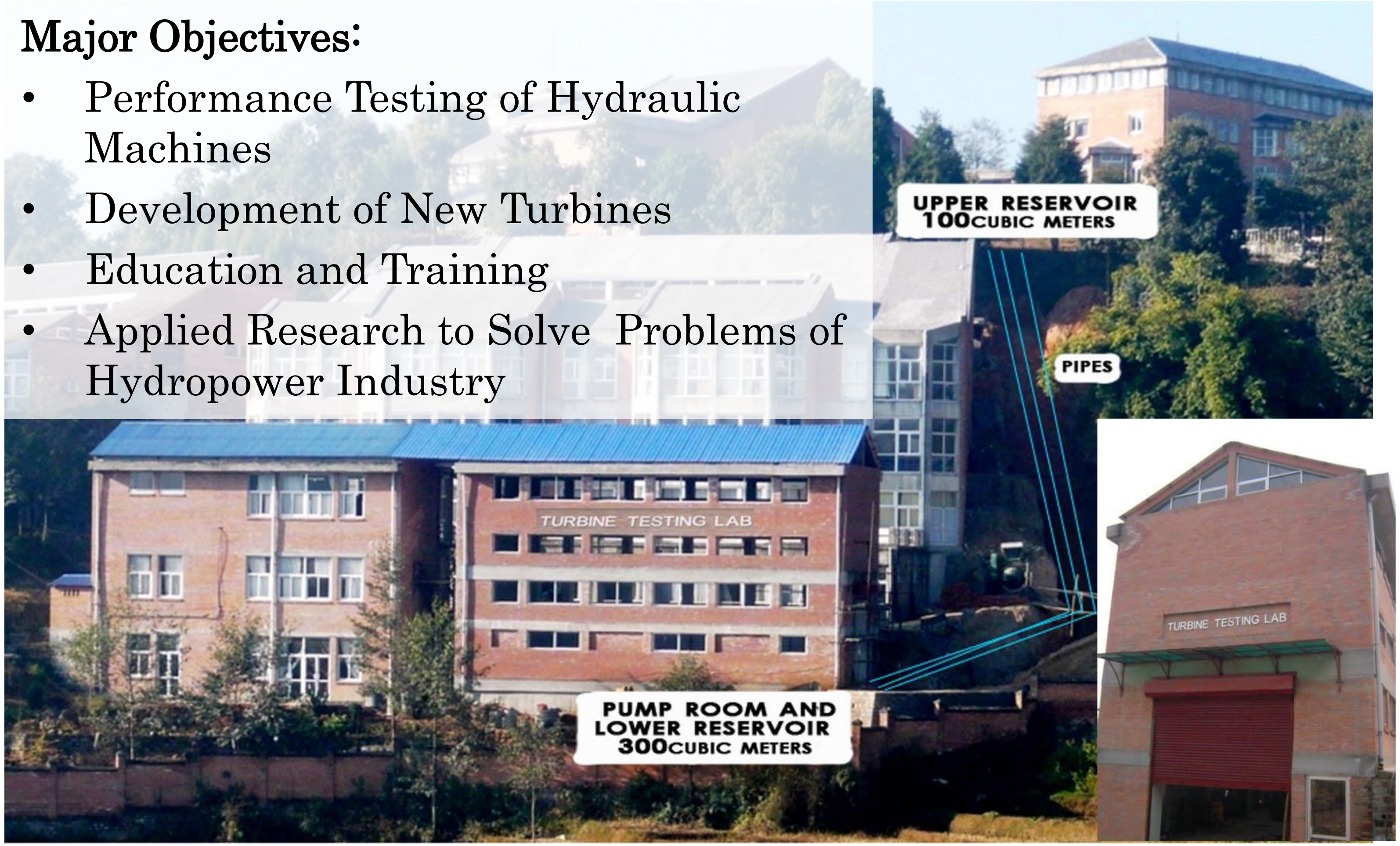
Malaysia, 40 kW, 1987

Bhutan, 100 kW, 1997

Turbine Testing Lab at KU

Major Objectives:

- Performance Testing of Hydraulic Machines
- Development of New Turbines
- Education and Training
- Applied Research to Solve Problems of Hydropower Industry



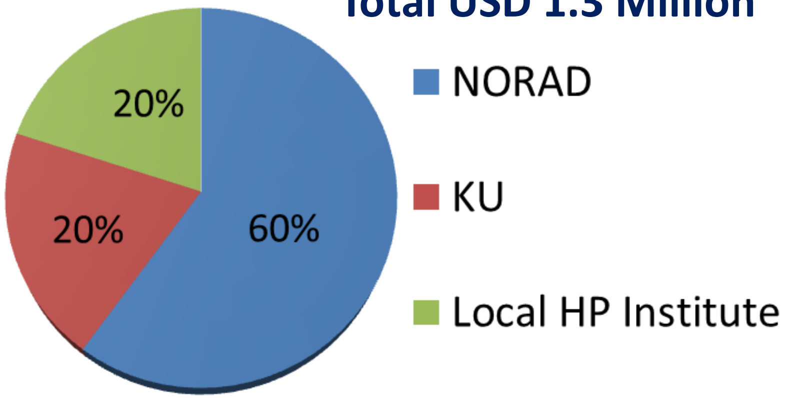
Inaugurated on 10 November 2011

Specifications:

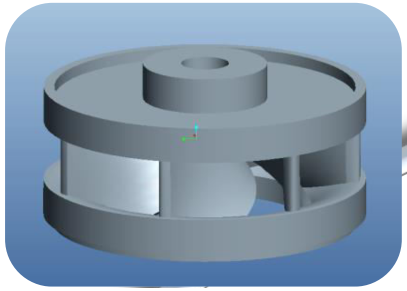
- 30 m Open System Head
- 150 m Closed System Head
- 500 l/s Maximum Flow
- 300 kW Maximum Testing Capacity
- 300 m^3 Lower Reservoir
- 100 m^3 Upper Reservoir
- 5000 kg EOT Crane Capacity

Financial Contributions

Total USD 1.3 Million



Kickoff Francis Turbine R&D at TTL, 2012



CAD Model

3D Printer

Plastic section of a runner sector

Wax section

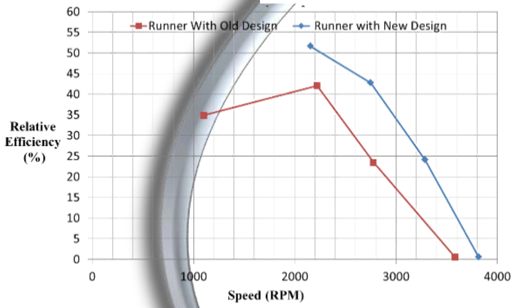
Development of 2 kW Francis Runner

Wax runner with vents

Plaster mold for runner

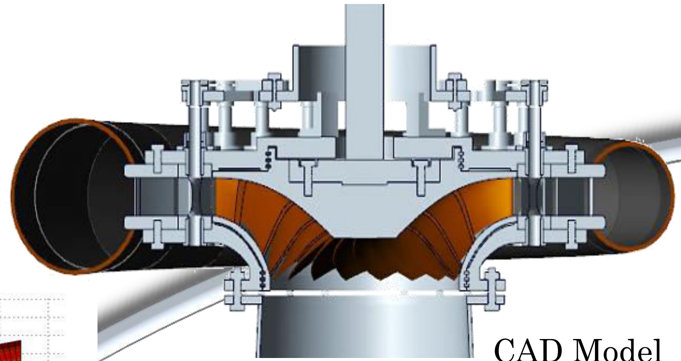
Casted runner after finishing

Rig for turbine testing



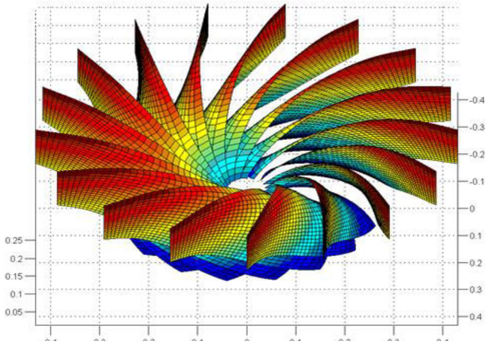
Test results

A milestone for Francis Turbine Manufacturing, 2013


CAD Model


Stay ring with stay vane


Spiral Casing Sections


Hydraulic Design and Optimization

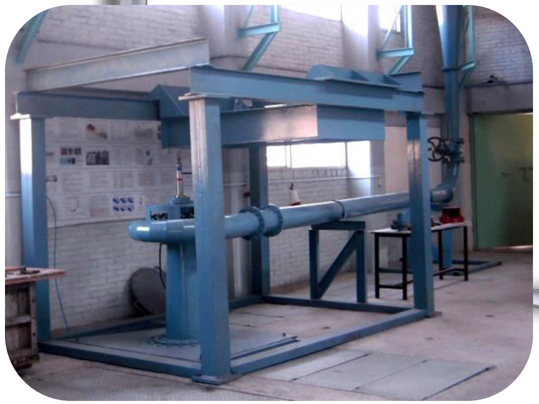
Development of 92 kW Francis Turbine


Casted Runner Blades


Guide vanes

Assembly of the runner blades


Complete runner



Turbine in test rig at TTL

TTL Activities and Achievements

Academic Activities:

Activities	Completed	Ongoing	Total
PhD	2	2	4
MS by research	5	1	6
Masters Thesis	17	2	19
Undergraduates thesis	51	8	59
Journal Publications	35	5	40

Test Facilities:

- 5 kW Crossflow turbine test rig and procedures, *KETEP, 2013*
- 20 kW Crossflow turbine test rig and procedures, *AEPC, 2014*
- 22 kW Pelton turbine test rig and procedures, *AEPC, 2014*
- 92 kW Francis turbine test rig and procedures, *EnergizeNepal, 2016*

Certification and Services:

Activities	Client	year
Test certification of 1 kW Pico-propeller turbine	PEEDA	2012
Design validation of 100 kW Crossflow turbine	UTS	2013
Detail study of root crack in 12 MW Pelton runner	HPL	2014
Design and analysis of penstock bifurcation for 6 MW HPP	Daraudi HPP	2014
Detail design of 300 kW Francis turbine (under discussion)	IPS	2017

Future Strategy:

Center of Excellence (CoE)

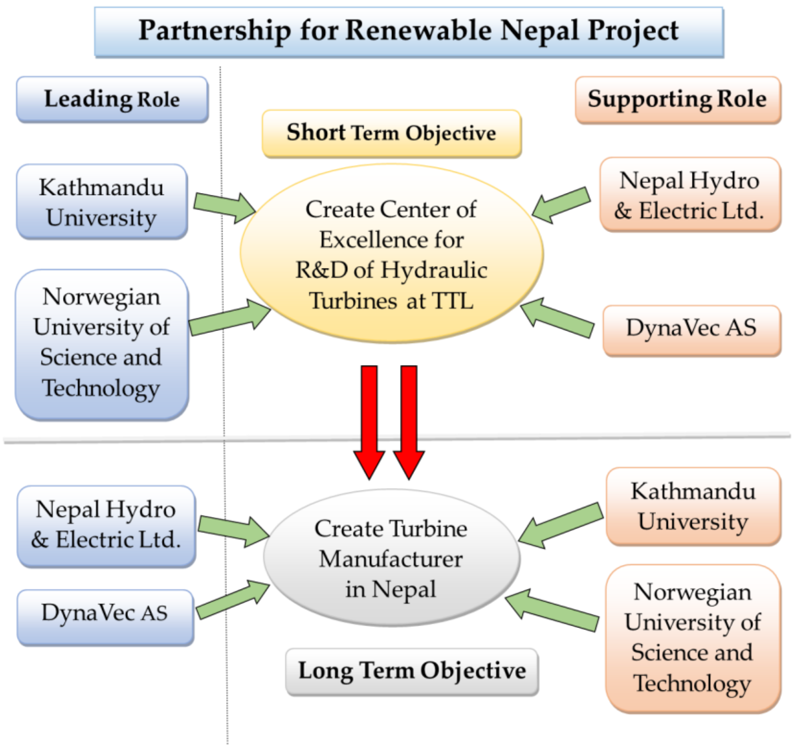
Technology and Entrepreneurship

CoE at TTL for Hydropower Development

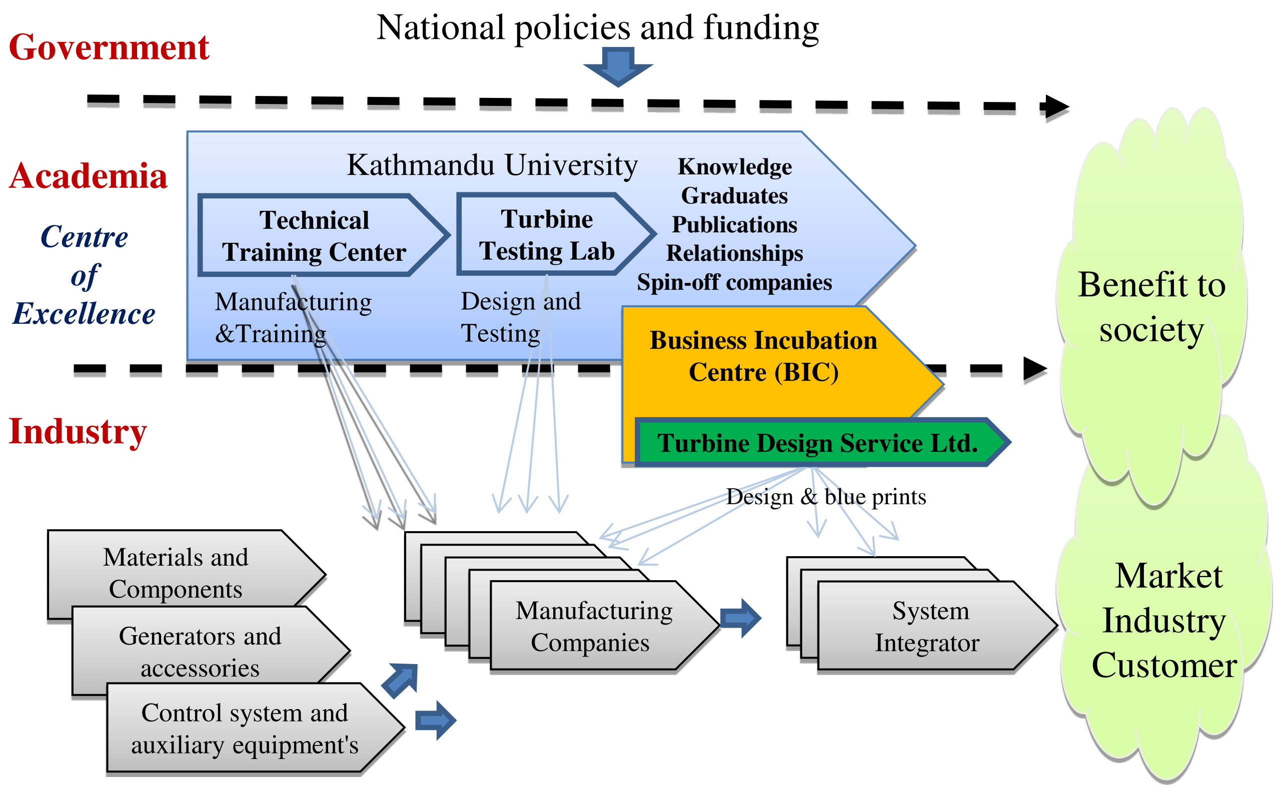
Aim: *Nepalese hydropower industries capable to produce hydro turbines addressing local and regional technical challenges through continuous research and development activities*

Components	*Goals*	*Vision 2022*
Model Testing	Establish IEC standard Francis turbine test facilities serving at the regional level.	Model test of commercial projects, at least one, at each national and regional level.
Turbine Design and Manufacturing	Initiate turbine manufacturing in Nepal with the new design technology for reducing sediment erosion.	System design of electromechanical components with 5 MW unit size Francis turbine manufactured in Nepal.
Services and Training	Provide technical services and trainings for repair, maintenance and operation of turbines in sediment-laden projects.	Third party quality control of turbine repair. Services for efficient power plant operation. Training packages for different target groups.

Previously Proposed Models for Business



RenewableNepal Project, 2010-2013



Feasibility study Project, 2012

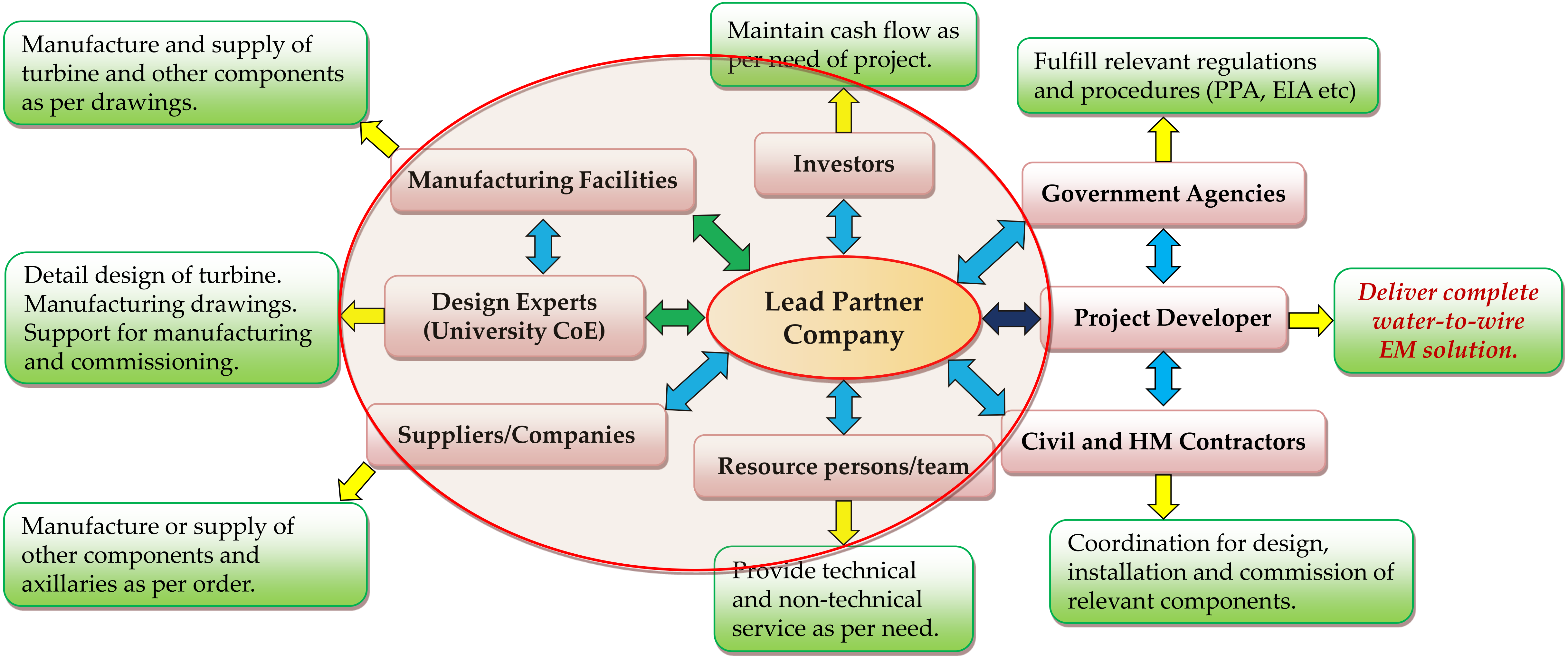
- **Both model were focused to develop technical competence in University and transfer it to Industry.**
- **University was in leading role to initiate new business, which was not successful.**

The forward step: A Breakthrough

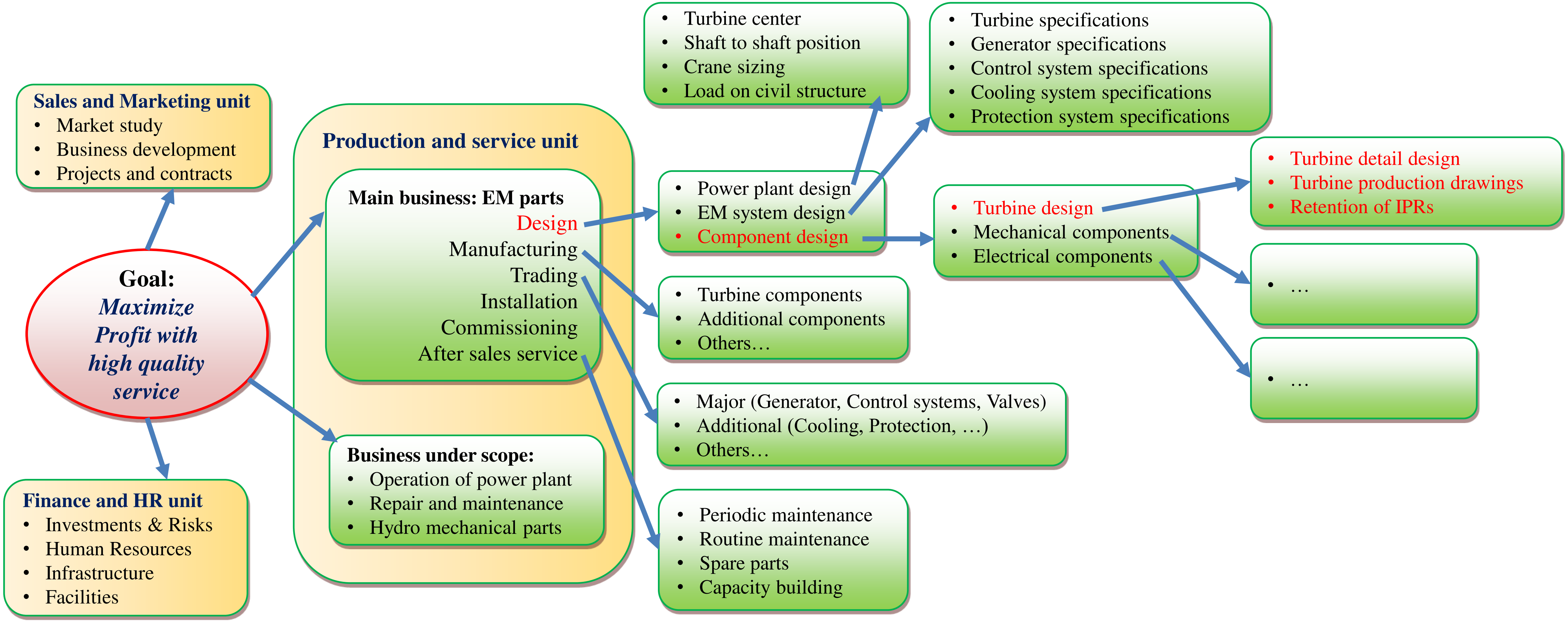
A collaborative initiative of Industries and Academia

- A private limited company by a team with high professional experience in design and development of hydropower systems in the leading role.
- Design and Research experts from Universities in supporting role.
- Consortium providing a complete '*water-to-wire'* solution for hydropower.
- The solution includes analysis, design, manufacture or supply and maintenance of all electro mechanical equipment in hydropower projects.
- By 2030 the company should aim to develop a complete in-house technology for design and manufacture of turbine components for up to 25 MW unit size.

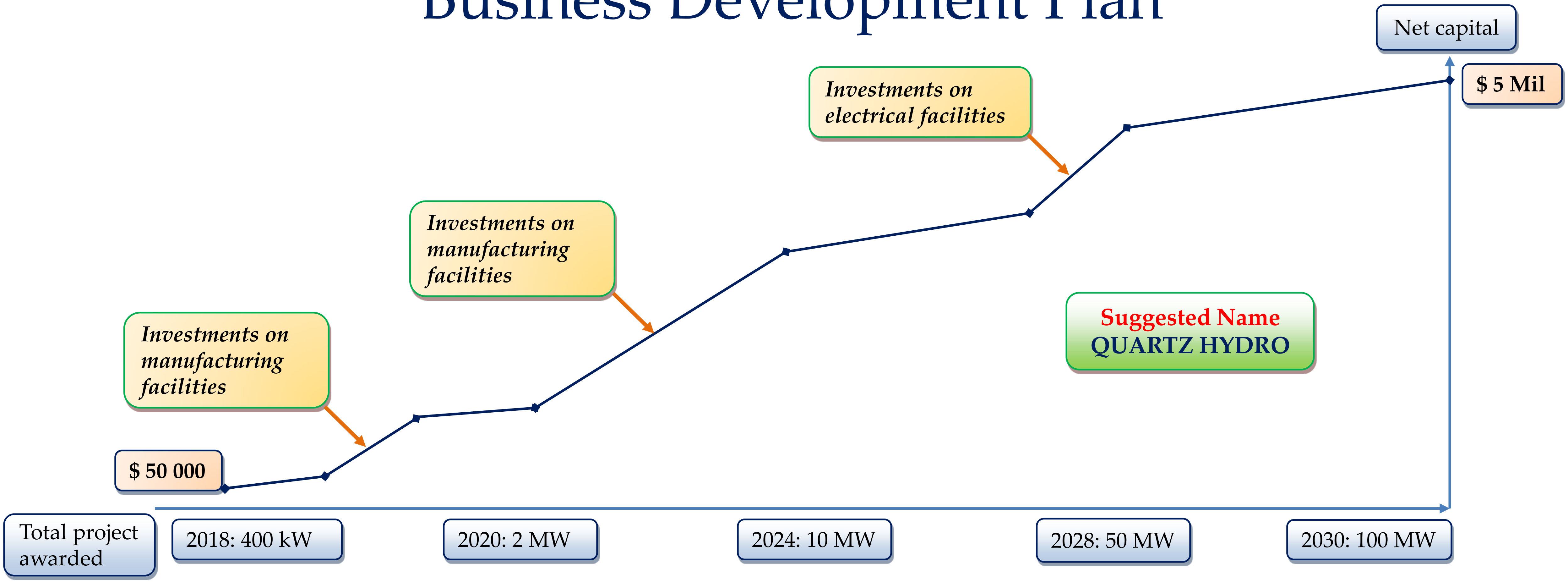
Need of Sustainable Partnership



Business Execution Chain



Business Development Plan



The Pilot Project:
- Project consortium
- Acquire pilot project
- Outsource manufacturing
- **Lesson learned**

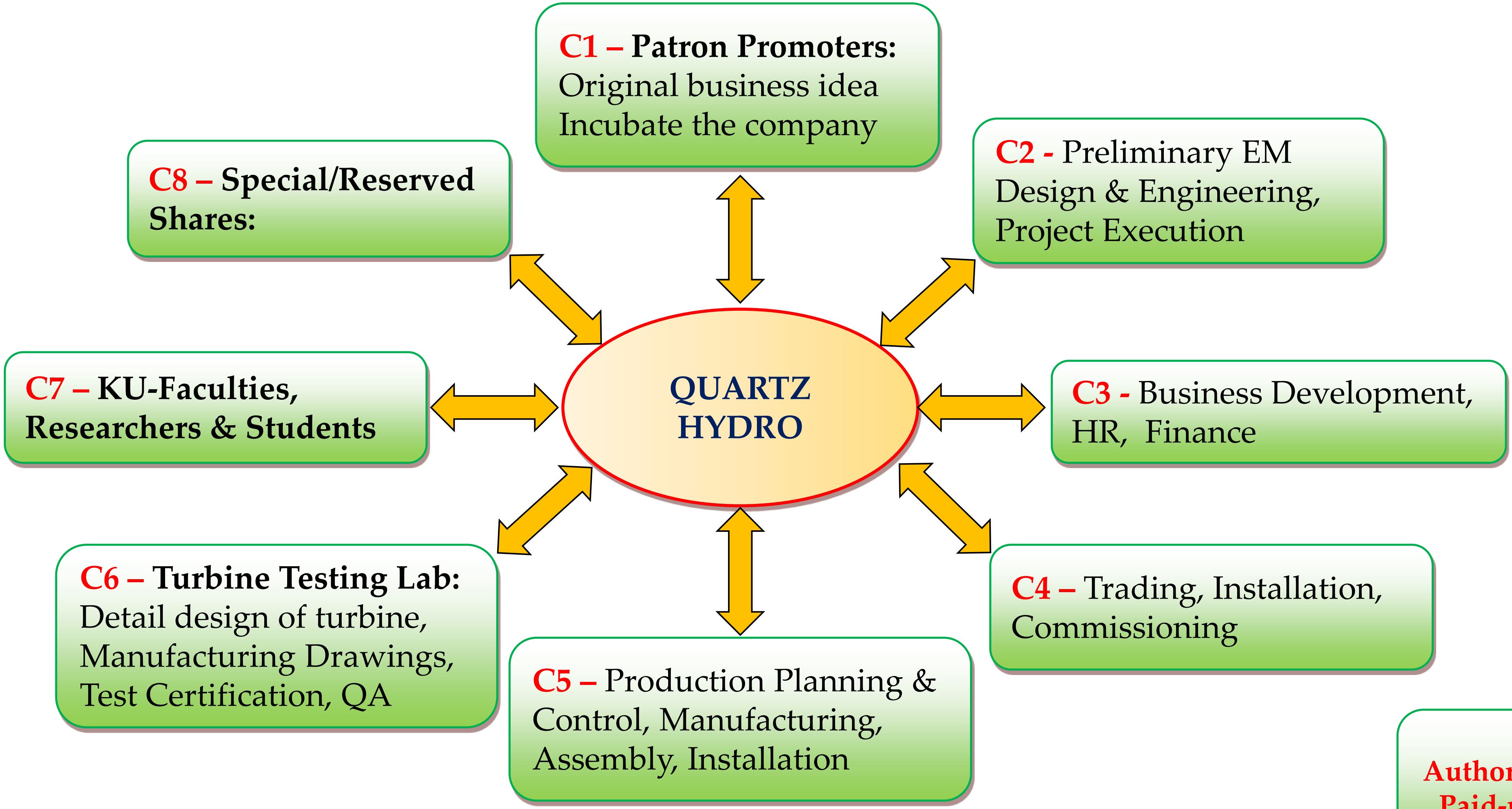
Incubating Phase:
- Acquire IPR for one reference
- Basic manufacturing facility
- Outsource only runner for manufacturing
- Start service on turbine repair

Progressing Phase:
- Acquire IPR for three references
- Well equipped facility for turbine manufacturing
- Develop turbines for rehabilitation projects

Leading Phase:
- Develop independent design competence
- Capacity for electrical equipment
- Complete EM solution up to 10 MW

Sustenance Phase:
- Capacity up to 30 MW
- Compete in international market
- Retention of HR and expertize
- Retention of partnerships

Open Discussion: *The Stakeholders*



Authorized Capital: USD 2 Mil
Paid-up capital: USD 0.5 Mil

Executing The Pilot Project

Project Specifications:
- Head=50 m
- Flow=1 m^3/s
- Rated Power= 2*150 kW

EM Specifications:
- 2*175 kW Francis turbines
- 2*200 kVA synchronous generators at 750 rpm
- 400 kVA transformer
- …

University Partners (KU-NTNU CoE)
- Turbine specifications for system design
- Detail design of turbine components
- Manufacturing drawings for industry
- Support for manufacturing and commissioning

Lead Partner
- Project administrations and management (contracts, finance, tender, risk, HR, …)
- Design of power house
- System design and selection of EM components
- Manufacturing of turbine components and accessories
- Procurement of other EM components
- Installation, commissioning and follow-ups

Project Developer
- License issues and investments
- Project site and specifications
- Civil construction, HM and other installations
- Support during installation and commissioning
- Responsible for power end use or sales

Resource persons/team
Manufacturing Industry
Suppliers/Companies
- Deliver product or services as per agreement

Objectives:
- To build the consortium.
- To validate design and manufacturing strength.
- To create a reference case for developers and investors.
- Background and motivation for future projects.
- Lesson learned.

Challenges/ Discussions

- Formation of the project consortium and company.
- Role of design experts (University CoE) in overall business.
- Response from Hydropower market and existing players.
- Design competence and guarantee issues on turbine design.
- Industrial capacity for turbine manufacturing.
- System integration of components from different suppliers.
- Acquiring and completing the pilot project.
- Conflicts of mutual interest between partners.
- Support from hydropower industry and government.

Thank you!