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DEMAR

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SCRUTINY OF AVAILABLE AND NEW TECHNOLOGIES FOR TOTAL INTEGRATION OF RENEWABLE AND FOSSIL ENERGY FOR A CLEAN AND SUSTAINABLE ENERGY SYSTEM – TIRFE

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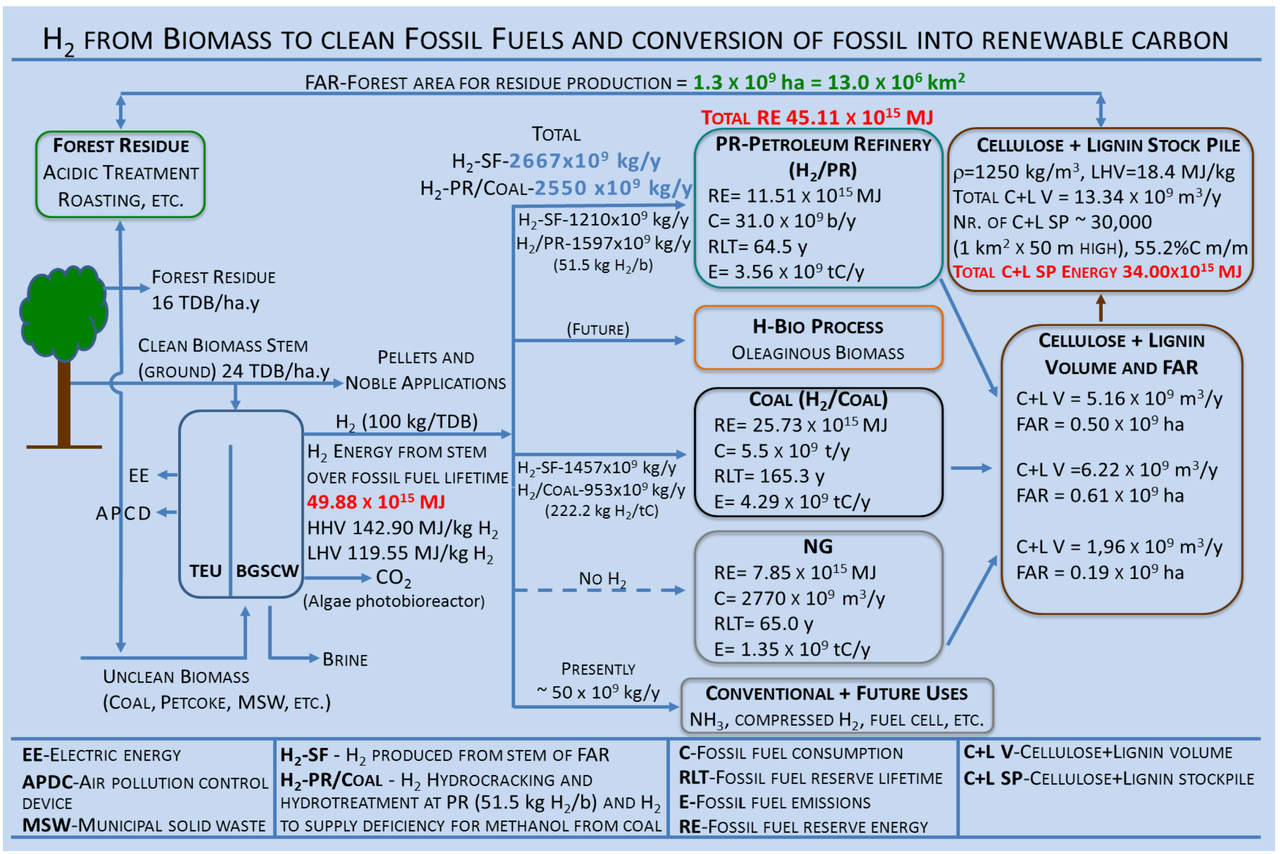
TIRFE CONCEPT

RENEWABLE ENERGY IS UNSUFFICIENT TO DEAL WITH THE DEMAND, AND FOSSIL ENERGY IS POLLUTANT. THIS WORK PRESENTS A NEW CONCEPT – **TIRFE** - AIMING TO A CLEAN AND SUSTAINABLE ENERGY SYSTEM

H_2 FROM BIOMASS TO CLEAN FOSSIL FUELS AND CONVERSION OF FOSSIL INTO RENEWABLE CARBON



EE-ELECTRIC ENERGY	**H_2-SF** - H_2 PRODUCED FROM STEM OF FAR	**C**-FOSSIL FUEL CONSUMPTION	**C+L V**-CELLULOSE+LIGNIN VOLUME
APDC-AIR POLLUTION CONTROL DEVICE	**H_2-PR/COAL** - H_2 HYDROCRACKING AND HYDROTREATMENT AT PR (51.5 kg H_2/b) AND H_2 TO SUPPLY DEFICIENCY FOR METHANOL FROM COAL	**RLT**-FOSSIL FUEL RESERVE LIFETIME	**C+L SP**-CELLULOSE+LIGNIN STOCKPILE
MSW-MUNICIPAL SOLID WASTE		**E**-FOSSIL FUEL EMISSIONS	
		RE-FOSSIL FUEL RESERVE ENERGY	

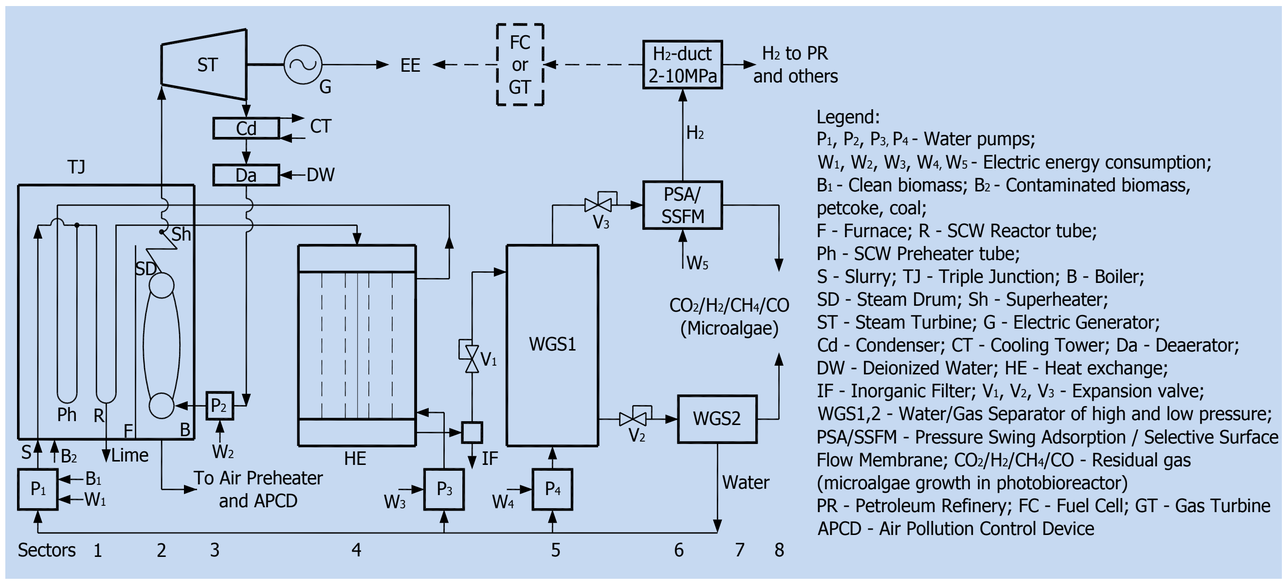
STRATEGY OF DEVELOPMENT AND COMMERCIALIZATION

- MAJOR ENERGIES: CLEAN OIL, NATURAL GAS, CLEAN COAL PRODUCTS, BIOMASS PELLETS, EFFICIENCY
- EOLIC AND SOLAR ENERGIES SHOULD BE DIRECTLY CONNECTED TO ELECTRIC NETWORK OF THE ABOVE SYSTEMS, WITHOUT STORAGE (HYDRAULIC, ETHANOL AND BIO-OIL ARE COMPLEMENTARY CONTRIBUTIONS)
- LARGE SCALE-HIGH PRODUCTIVITY REFORESTATION IN NON-AGRARIAN LAND, MAINLY IN TROPICAL COUNTRIES, FOR SELF-CONSUMPTION, AND BIOMASS PELLETS EXPORTATION TO CONSUMER COUNTRIES
- NOBLE APPLICATIONS OF STEM (H_2, SOLID WOOD AND PANELS, ETC.) FOR GOOD REMUNERATION OF REFORESTATION AND EXTRACTIVE NATIVE FOREST
- MODULAR H_2-BGSCW/TEU FOR SMALL/DISTRIBUTED ENERGY GENERATION (30 MW, 3,750 kgH_2/h) UP TO LARGE SCALE CAPTIVE PRODUCTION (600 MW, 75,000 kgH_2/h)
- ACTIONS: 1. CONTRACTS BETWEEN PELLET PRODUCERS IN TROPICAL COUNTRIES AND CONSUMER COMPANIES; 2. BILATERAL AGREEMENTS BETWEEN COUNTRIES; 3. MULTILATERAL AGREEMENTS (UN)
- AGREEMENTS MUST COVER STEM BIOMASS PELLETS EXPORTATION, CARBON RETENTION AT C+L SP BY THE BIOMASS PRODUCER COUNTRY, AND PAYMENT OF FOSSIL CARBON POLLUTION FEES
- PAST, PRESENT AND FUTURE FOSSIL FUEL POLLUTERS (DEVELOPED AND DEVELOPING COUNTRIES) SHOULD PAY A DIRECT FEE FOR C+L SP FORMATION BY MAXIMUM MARKET CONTROL, AVERAGE CONSUMER ACCEPTANCE (HUMAN PREDATOR WILL ALWAYS RESISTS SUSTAINABILITY), AND MINIMUM, BUT NOT ZERO, COMMAND-AND-CONTROL REGULATION (IPCC, COP'S, KYOTO AND RIO+10+20+n)

CELLULOSE + LIGNIN STOCKPILE (C+L SP)

- CARBON RETENTION OF FOSSIL FUEL RESERVES (CFFR) IN 30,000 STOCKPILES OF 1 km^2 X 50 m HIGH
- C+L SP FORMATION DURING CFFR WEIGHTED AVERAGE LIFETIME (110.4 y) USING LANDFILL AND ROAD PAVIMENTATION TECHNOLOGY WITHOUT SOIL (ρ=1,250 kg/m^3, 55.2% C m/m, σ=100 MPa, BOTTOM/TOP/LATERAL IMPERMEBILIZATION, pH < 4, 500 wppm SO_4^- FOR BIOMASS NON-DEGRADATION)
- C+L SP FROM BIOMASS RESIDUE (PREHYDROLYSIS, TORREFACTION, ETC.), MAINLY SITUATED NEAR TO REFORESTATION AREAS, AND PARTIALLY IN HIGH-ENERGY CONSUMER COUNTRIES, FOR ENERGY SECURITY
- ECONOMICAL CONTRIBUTION FOR C+L SP FORMATION:
  - 20% FROM ETHANOL FROM SUGAR SOLUTION OF THE HYDROLYSATE: USD 10.00/t C+L
  - 35% FROM SOLAR FARM AT THE TOP OF C+L SP DURING LIFETIME OF FOSSIL FUEL:USD 10.10/t C+L
  - ENERGY SECURITY: 25% OF C+L HEATING VALUE: USD 9.20/t C+L
  - GHG RETENTION/SEQUESTRATION (FOSSIL FUEL CARBON FEE: USD 10.00/t CO_2): USD 20.20/t C+L
  - TOTAL: USD 49.50/t C+L, SUFFICIENT FOR C+L SP FORMATION
- C+L SP CONVERTS FOSSIL INTO RENEWABLE CARBON, AND CAN CLEAN PAST, PRESENT AND FUTURE GHG FROM DEVELOPED AND DEVELOPING COUNTRIES (EVERYONE SHOULD PAY FOR THE CO_2 POLLUTION)
- TOTAL CARBON STORED ON THE SOIL OF SHORT ROTATION FOREST IS SMALL: 150 tC/ha X 1.3 X 10^9 ha = 195 X 10^9 tC. THIS CORRESPONDS TO 19.2% OF 1,016 X 10^9 tC RETAINED AT C+L SP

H_2-BGSCW/TEU FLOW CHART: H_2 AND ELECTRIC ENERGY GENERATION BY BIOMASS GASIFICATION IN SUPERCRITICAL WATER INTEGRATED WITH THERMOELECTRIC UNIT



HISTORY OF AND PRESENT OPTION FOR SCW PROCESSING

- SUPERCRITICAL WATER OXIDATION (SCWO 1980): APPLICATION IN INDUSTRIAL, MILITARY AND MUNICIPAL SOLID WASTE DESTRUCTION. HIGH CORROSIVE MEDIUM

CORROSION RATE OF SOME ALLOYS CAUSED BY SUPERCRITICAL WATER IN DIFFERENT ACID SOLUTIONS

ALLOY	P MPa	TEMPERATURE OR $\Delta T = T_F - T_I$, °C	ACID SOLUTION O_2 wppm	ACID wppm	SCW DENSITY $\rho(T_I)/\rho(T_F)$ kg/m^3	CORROSION RATE MAX. IN ΔT μm/h	CORROSION RATE ANNUAL μm/y.wppm
625	24	T_I = 330 - T_F = 380	16,000	HCL – 1,825	700 / 170	3.00	14.40
Ti GR2	24	0 – 600	48,000	HCL – 3,650	1,000 / 70.7	< 0.20	< 0.48
		0 – 600	96,000	H_2SO_4 - 19,600	1,000 / 70.7	< 1.10	< 0.50
E2535NbY	24	0 – 650	---	HCL + H_2SO_4 = 50	1000 / 64.8	≈ 0.10	≈ 15.0

T_F (FINAL) – T_I (INITIAL) = ΔT = TEMPERATURE INTERVAL OF HIGH CORROSION RATE
$T < T_I$ (LOW T, HIGH SCW DENSITY), $T > T_F$ (HIGH T, LOW SCW DENSITY): NEGLIGIBLE CORROSION RATE
COMPOSITION, wt%, OF HPC E2535NbY: Fe (BAL), Cr 25.0, Ni 35.3, Mo< 0.23, Mn 1.02, Nb 0.87, C 0.41/0.44, Si 1.30/1.76, P< 0.025, S < 0.03, Ti 0.05/0.09, Y 0.035/0.085, COST USD 25.50/kg
HIGH CORROSION AT ΔT INTERVAL = 15.0 μm/y.wppm X 50 wppm = 750 μm/y; Ti GR2 LINING AT ΔT INTERVAL IN THE PREHEATER/SLURRY JUNCTION, AND IN HEAT EXCHANGE

- SUPERCRITICAL WATER POWER GENERATION CYCLES (590 °C, 35 MPa): IT IS THE CHOICE OF NEW COAL–FIRED UTILITY PLANTS WORLDWIDE; ppb RANGE IMPURITY IN THE SCW; USE OF MARTENSITIC/ FERRITIC 9% Cr AND ALLOY 625 ONLY IN THE SUPERHEATER

WATER CHEMISTRY LIMITS FOR SUPERCRITICAL FPPS AND BWRS (40-YEAR LIFETIME)

PLANT	pH	CONDUCTIVITY μS/cm	Fe wppb	Cu wppb	Na wppb	Silica wppb	O wppb
BWR	5.5	0.1 – 0.3	0.5 – 10	0.1 – 1	--	---	200
FPP	9 - 10	0.1	10	1	2	5	< 100

BWR – BOILING WATER REACTOR (NUCLEAR); FPP – FOSSIL POWER PLANT

- PRESENT OPTION FOR H_2-BGSCW/TEU
  - HIGH TEMPERATURE GASIFICATION WITH ACTIVATED CARBON + KOH CATALYST - 100 kg H_2/TDB)
  - USE OF CLEAN BIOMASS (WOOD STEM WITHOUT BARK), 5wt% DB, ppm RANGE IMPURITY IN THE SCW
  - USE OF E25cr35NiNbY HIGH TEMPERATURE STEEL WITH RECASTING AFTER AVERAGE LIFETIME OF 6 TO 10 YEARS; Ti GR2 LINING AT THE HIGH CORROSION ΔT INTERVAL (300 °C – 400 °C)
  - E25Cr35NiNbY 100,000 h CREEP RUPTURE STRESS = 100 MPa AT 650 °C

TYPICAL COMPOSITION OF 5 wt% *Eucalyptus grandis* IN SCW (NO BARK, ~7 YEAR ROTATION)

ELEMENT CONCENTRATION, wppm												
Cl^-	S	P	K	Ca	Mg	Na	Al	Mn	Si	Fe	Cu	Ni
40	10	--	40	27	9	12	2.7	0.85	0.65	0.18	0.06	0.006

CONCLUSION

- **TIRFE** ALLOWS THE USE OF ANY FORM OF ENERGY, ANYWHERE, AS LONG AS FOSSIL ENERGY PAYS A FEE FOR ITS CARBON RETENTION AND ENERGY SECURITY IN THE FORM OF C+L SP
- REFORESTATION AREA FOR C+L SP AND H_2 PRODUCTION TO CLEAN OIL AND COAL RESERVES NEEDS 1.30 X 10^9 ha AS COMPARED TO 3.64 X 10^9 ha OF NATURAL FOREST, 0.85 X 10^9 ha OF PLANTED FOREST, PREDICTED BY UNEP 2011 GREEN SCENARIO 2050
- BIOMASS PELLETS (MAINLY FROM THE TROPICS) SHOULD BE THE 4th FORM OF ENERGY AND THE CONCEPT OF ENERGY SUBSTITUTION SHOULD BE REPLACED BY **INTEGRATION**
- C+L SP FOR GHG RETENTION CAN BE EFFECTUATED BY OTHER NOBLE USES OF STEM (SOLID WOOD AND PANELS, ETC.) INDEPENDENTLY OF H_2 PRODUCTION TO CLEAN OIL AND COAL DERIVATIVES