Challenges in Plasma-based Technology Implementation from Spin-Off Company and Energy Enterprise Perspectives for Sustainable Future

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EGAT

InnoPlasCM

ThEP CENTER

STeP CMU SCIENCE AND TECHNOLOGY PARK CHIANG MAI UNIVERSITY

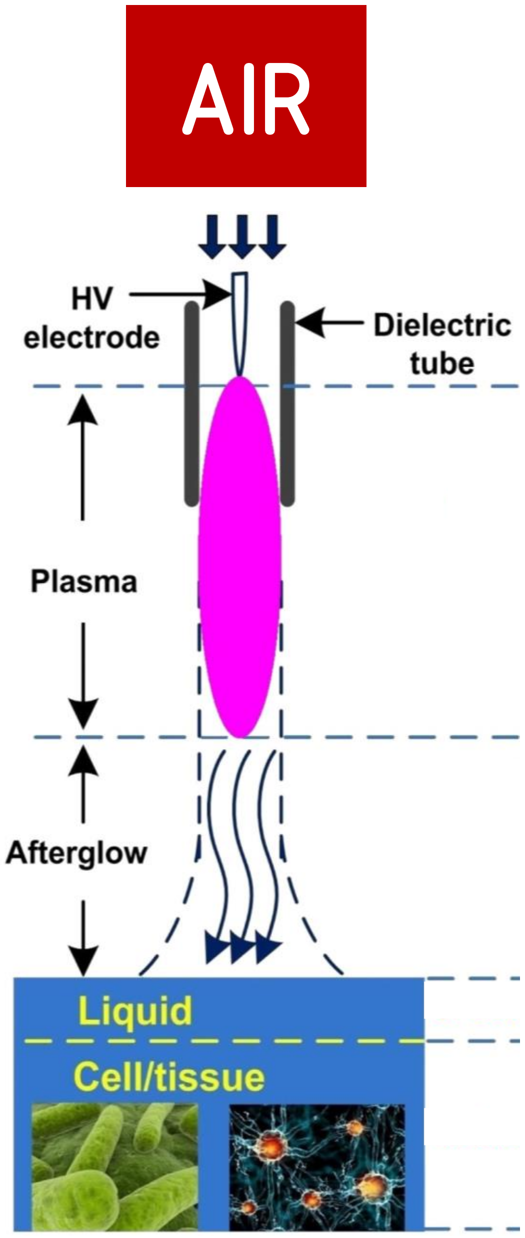
Plasma & Beam Physics Research Facility

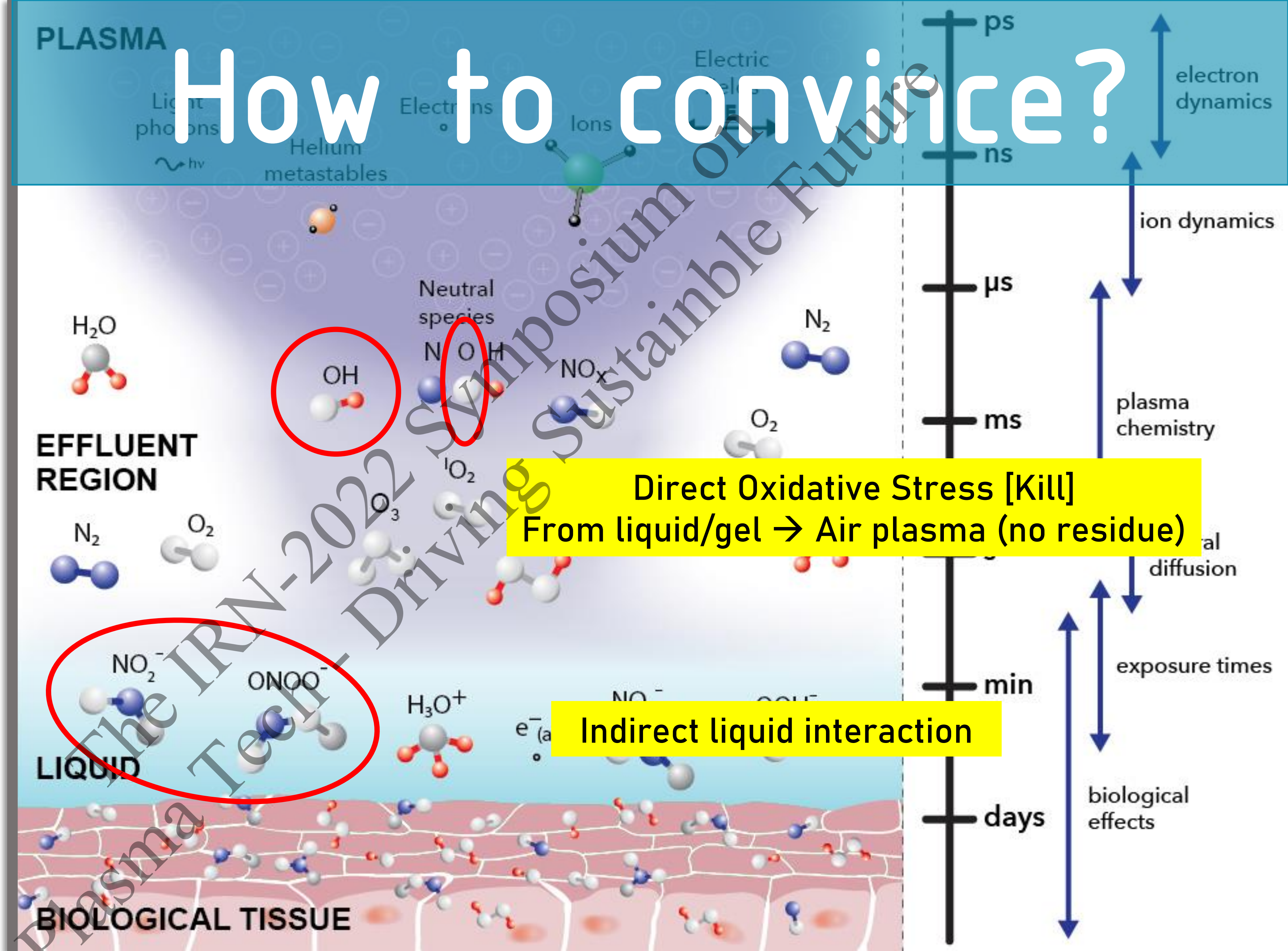
Nightingale

Compact Air Plasma Jet for Wound Healing

Delivering plasma-medical research prototype to practical use

How to convince?





Direct Oxidative Stress [Kill]
From liquid/gel → Air plasma (no residue)

Indirect liquid interaction

Preclinical Tests

(Bacterial Inactivation)

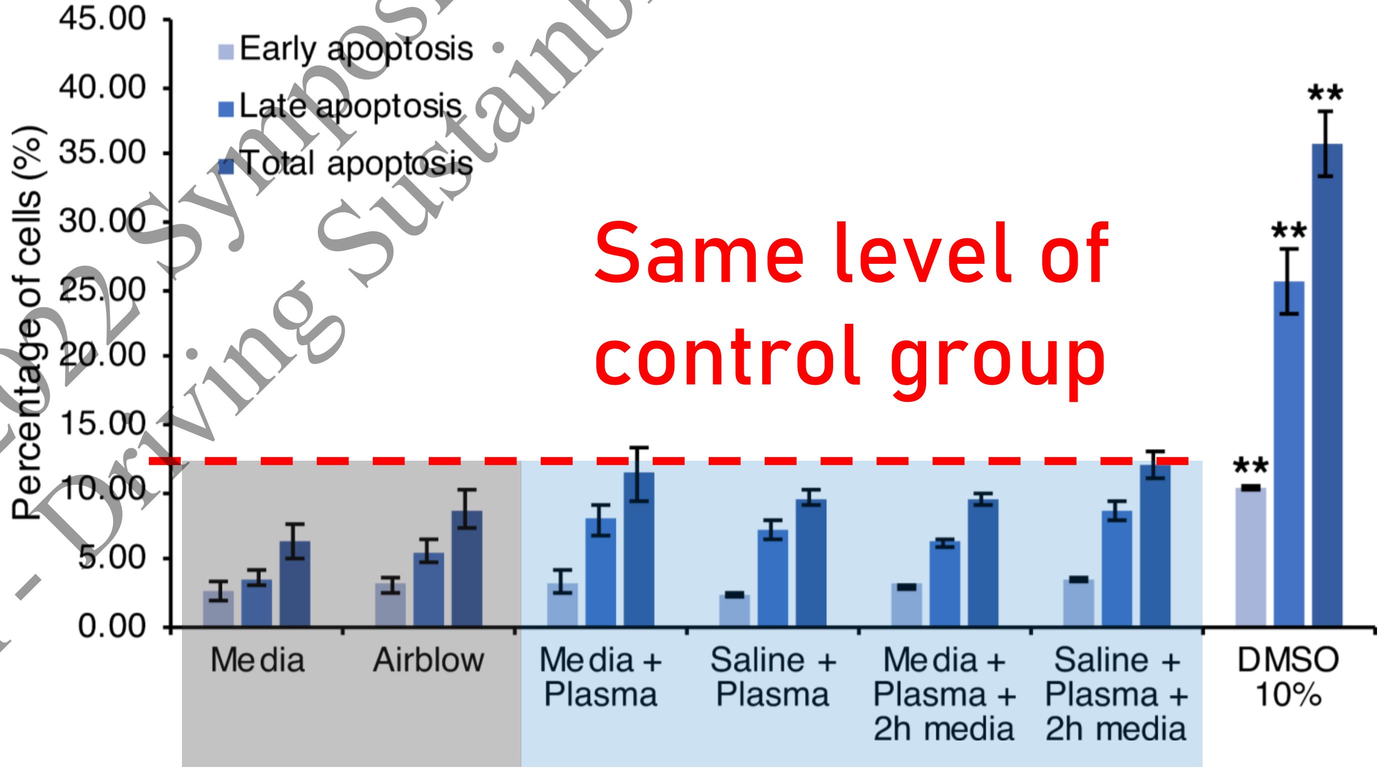
Number of pulses	Exposure time (s)		
	30	120	180
5			
10			

Methicillin-resistant S. Aureus (MRSA)

Preclinical Tests

(Cell Toxicity)

Plasma did not induce apoptotic cell-death in adult Human Dermal Fibroblast (HDFa) cells



Pilot Clinical Trial

(Sub-district Health Promoting Hospital)

Donkaew Community Hospital,
Chiang Mai

Volunteer with 3-month Diabetic Ulcer

Right foot

Before	3 Weeks + Debride	10 Weeks	11 Weeks

smaller wounds and closure in week 11

Left foot

Pilot Clinical Trial

(General hospital, 120-500 beds)

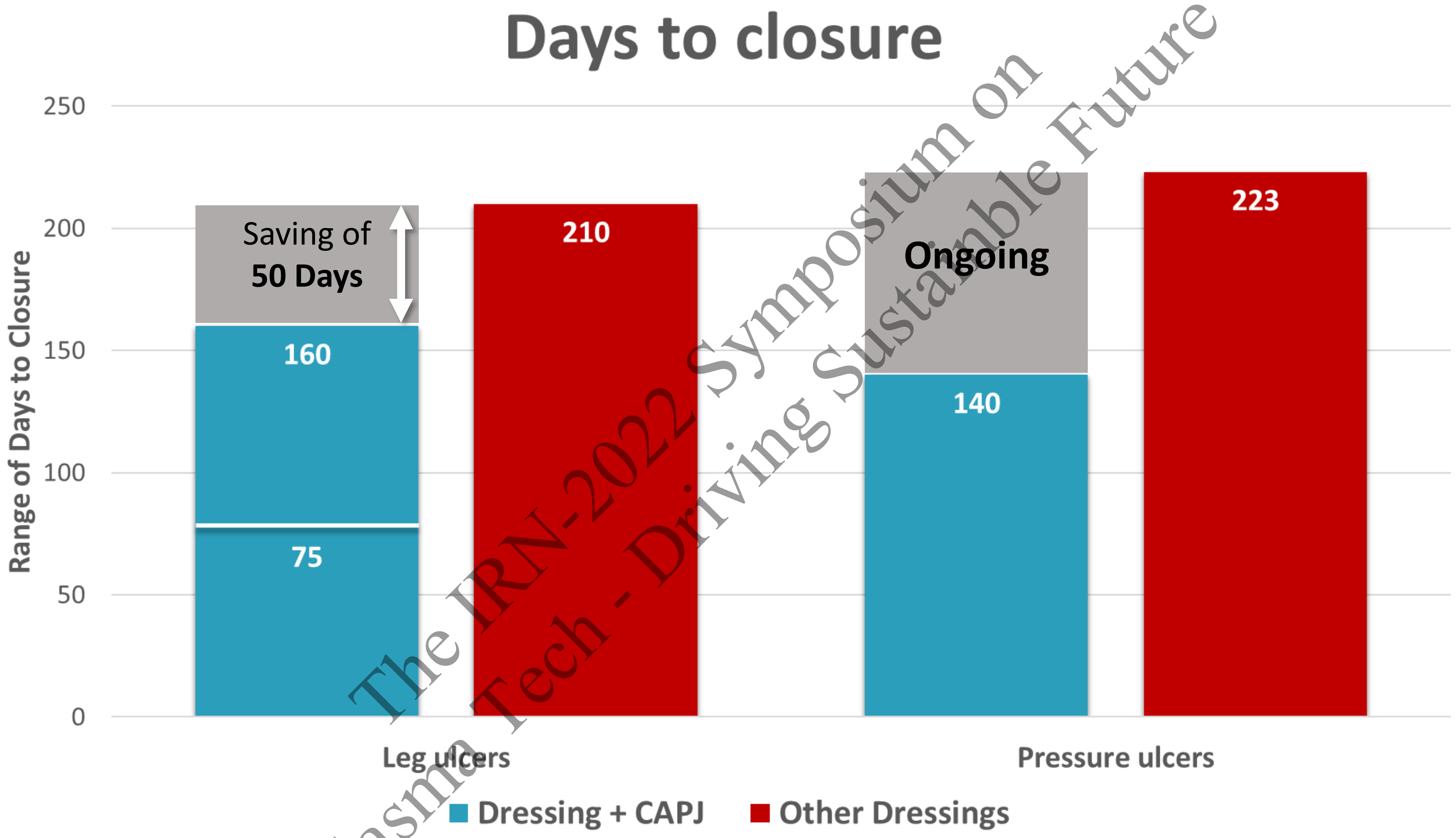
Somdej Prasangkharach 17th Hospital, Suphan Buri

Trauma wound (better and ready for graft in 6 weeks)

Before | 2 weeks | 4 weeks | 6 weeks

Diabetic wound (closer in week 5)

Before | 2 weeks | 3 weeks


Days to closure
Range of Days to Closure
250
200
150
100
50
0
Saving of
50 Days
160
75
210
Ongoing
140
223
Leg ulcers
Pressure ulcers
Dressing + CAPJ
Other Dressings

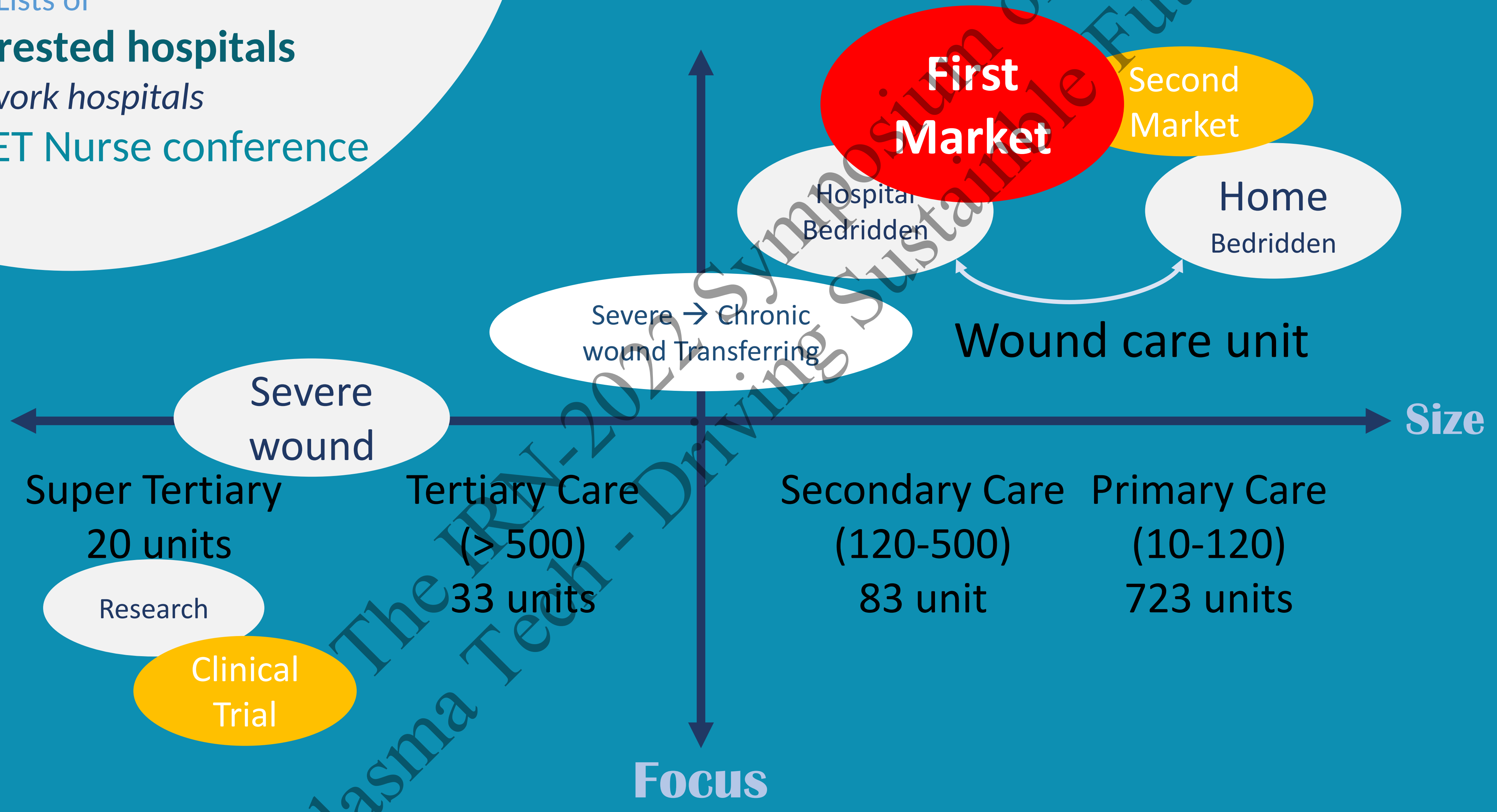
THAILAND Market Segmentation

Awaiting Lists of

38 interested hospitals

350 network hospitals

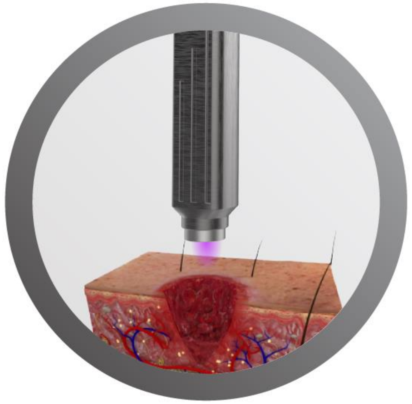
*from ET Nurse conference

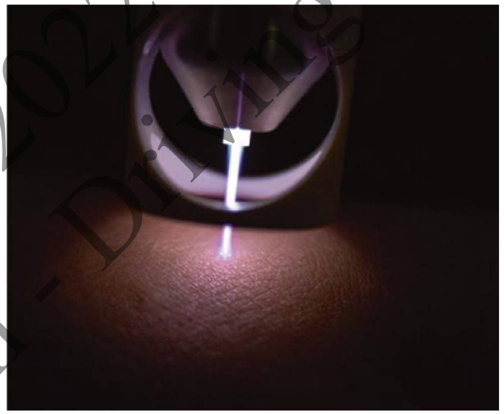


Business Model and Market Segmentation

Customers	Number	Min out patient/month	Potential Sales	Price/Unit	Revenue @ 10% Penetration	Rental Model (@10%) Revenue/month
Secondary hospital (120-500)	83	10	83 x 4	350,000	11,620,000	
Primary hospital (10-120)	732	5	732 x 2	250,000	36,600,000	
Community hospital (<10)	9800	1	9800 x 1	150,000	147,000,000	
Household	14,290			400 pcm		571,600
TOTAL					≈ 200,000,000	

What's Unique



CAPJ	PlasmaDerm	kINPen	SteriPlas	Bioplasma
Air	Air	Ar/He	Ar/He	Ar/He
฿5/person/month	N/A	N/A	N/A	N/A

Manufacturing Certification by Engineering Production Equipment Medical (EPEM)

- Electrical safety test IEC 60601-1 and IEC 60601-1-2
- Software validation IEC 62304
- By Elettra s.r.l. Testing Laboratory Italy.

Elettra s.r.l. Testing Laboratory

Test Report R-EL-197-0620-02A

Test Report

SAFETY

Issued to:

Client's Name:	EPEM S.R.L.
Address:	VIA G. GALLIANO, 2 – 50144 FIRENZE

Item under test:

Type of item:	COMPACT AIR PLASMA JET
Manufacturer:	INNOPLASCM CO. Ltd
Address:	3FL Central Science Laboratory, Chiang Mai University – 50200 Thailand
Model:	PLASMA-CUP
Part number:	PLCP XXXXXX-X
Serial Number:	COMPACT AIR PLASMA JET

Test specification:

Reference standard:	EN 62304:2006/A1:2015 IEC 62304:2006/A1:2015
Type of test:	Safety
Result:	Pass

Tested by: Doct. Eng. L. Donati (Firma)

Approved by: Doct. Eng. L. Spinelli (Firma)

Revision: 1st

Date of issue: 22/06/2020

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ELETTRA s.r.l. P.Iva e C.F. 05541190483 www.elettrasrl.eu | Via Matteucci, 10 50041 Calenzano Tel. +39-055-8827323 Fax. +39-055-8839756 | Testing laboratory in compliance with EN ISO/IEC 17025:2017 Certification Body in compliance with EN 17065:2012

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Manufacturer Certification : ISO 9001: 2015 EN 13485: 2016

Reference Standard : EN 60601-1: 2006 / A11: 2011 / A1: 2013 / A12: 2014
EN 62304:2006/A1:2015
IEC 62304:2006/A1:2015
EN 60601-1-2: 2015

Nightingale Delivered at Network Hospitals

Lamphun Hospital

Collecting data

1 Feb 2021

Sansai Hospital

Collecting data

22 Mar 2021

Phrae Hospital

Not interested

(17 Feb 2021)

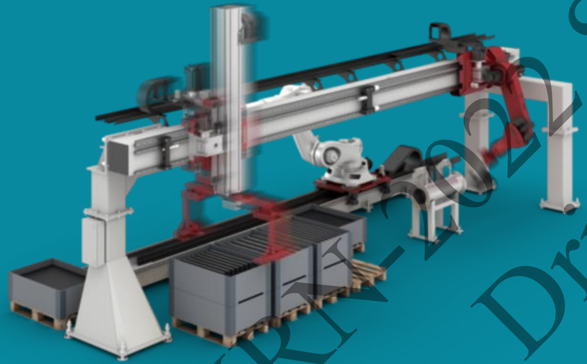
Nightingale Current Phase

Prototype
3rd Model

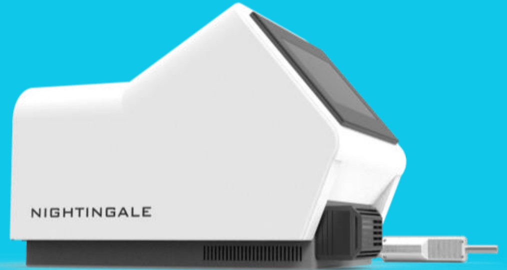
Manufacturing
ISO-13485

Standardization
IEC 60601-1, -2

Commercialization



Biocompatibility



Clinical Trial

EGAT Research Center and Carbon Neutrality

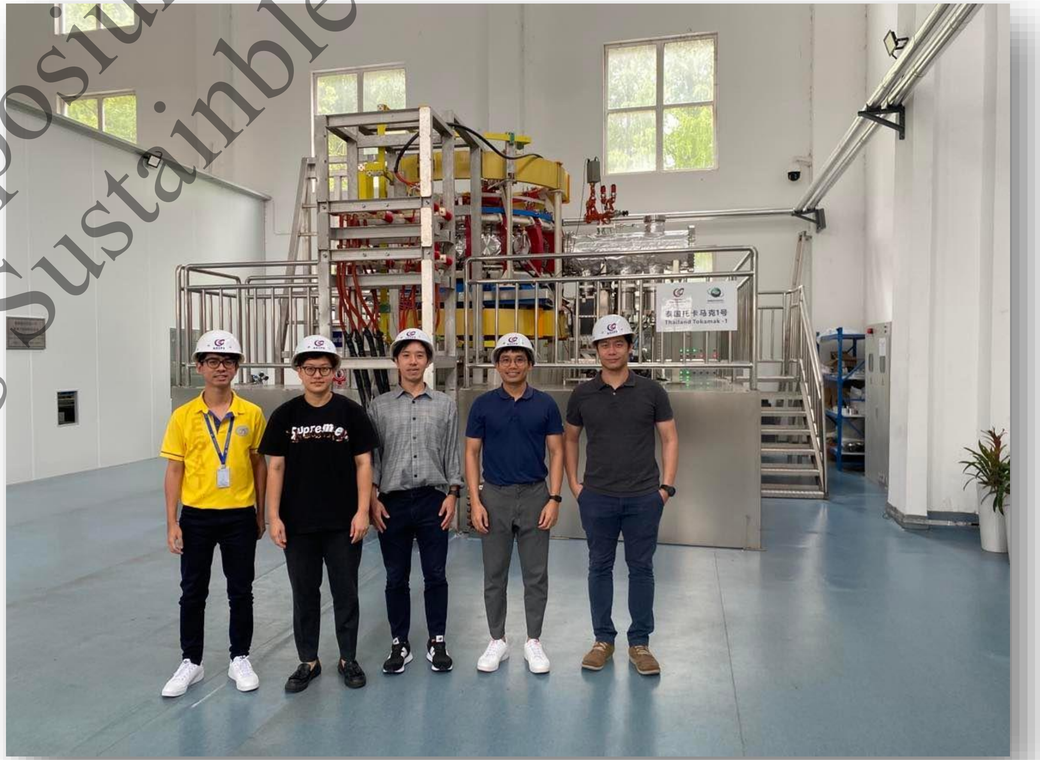
- Establishing EGAT Research Center
- Short-Medium-Long Term Strategies
- Industrial Scale

Where Plasma Technology Really Fit In?

ยุทธศาสตร์ย่อย	กลยุทธ์	แผนงานหลัก
ยุทธศาสตร์ 1.1 พัฒนาระบบไฟฟ้าปัจจุบันของ กฟผ. เพื่อเพิ่มศักยภาพในการแข่งขันและความมั่นคง	1. เพิ่มประสิทธิภาพและลดต้นทุนในกระบวนการผลิตและส่งจ่ายไฟฟ้า รวมถึงการบำรุงรักษา ด้วยนวัตกรรมใหม่	A. แผน Transmission System B. แผน Mae Moh Smart Mining C. แผน Digital Twin
	2. พัฒนานวัตกรรม เพื่อเพิ่มประสิทธิภาพการบริหารจัดการภายในองค์การ ด้วยเทคโนโลยีดิจิทัล	D. แผนโครงการ EGAT Unbox E. แผนโครงการ TMO
ยุทธศาสตร์ 1.2 สร้างสรรค์นวัตกรรมเพื่อขยายโอกาสทางธุรกิจและรองรับภาพอนาคตของ กฟผ.	1. มุ่งพัฒนานวัตกรรมด้านพลังงานหมุนเวียน เพื่อผลิตและควบคุมไฟฟ้าอย่างมีประสิทธิภาพ ตอบสนอง Power Consumer Solution	F. แผน National Energy Trading Platform G. แผน Virtual Power Plant H. แผน Grid Modernization I. แผน Microgrid
	2. มุ่งพัฒนานวัตกรรมระบบยานยนต์ไฟฟ้า สถานีอัดประจุไฟฟ้าและระบบกักเก็บพลังงานไฟฟ้า	J. แผน EV ดัดแปลง K. แผน Battery
	3. มุ่งพัฒนานวัตกรรมการผลิตไฟฟ้าในอนาคต	L. แผนโรงไฟฟ้า sCO2 M. แผนโรงไฟฟ้า Fusion N. แผนพลังงาน Hydrogen, BHD
ยุทธศาสตร์ 1.3 เสริมสร้างคุณค่าแก่สังคมและเป็นมิตรต่อสิ่งแวดล้อมด้วยนวัตกรรม	1. สร้างมูลค่าและลดปัญหาด้านสิ่งแวดล้อมจากระบบไฟฟ้า ด้วยนวัตกรรม	O. แผน EGAT Excellence Center P. แผนโรงไฟฟ้าชุมชน Q. แผน Circular Economy R. แผน Carbon Capture Utilization and Storage (CCUS) S. แผนโรงไฟฟ้าขยะเคลื่อนที่
	2. พัฒนาคุณภาพชีวิตของสังคมอย่างเป็นระบบและยั่งยืน	T. แผน Bangkruai Green Community U. แผน PM 2.5

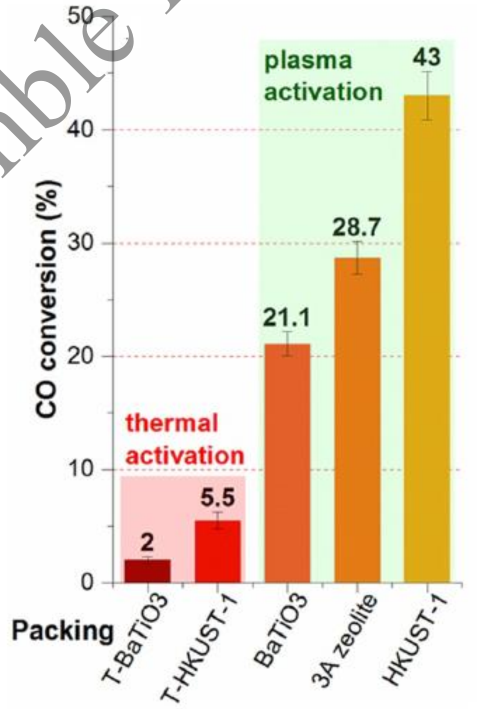
EGAT Plasma Fusion Long-Term Target

- Aimed for Fusion Power Plant
- Staring point on Thailand Tokamak 1 (China’s HT-6M tokamak)
- Collaboration with Thailand Institute of Nuclear Technology (TINT) and Institute of Plasma Physics Chinese Academy Of Sciences (ASIPP)
- Plasma Diagnostic and Engineering Systems (HV, Vacuum, DAQ and operating)



EGAT Plasma Application Medium-Term Target

- Carbon capture, utilization and storage (CCUS) and Hydrogen
- Searching for industrial-scale technologies to remove CO_2 from the flue gas and generated H_2 from EGAT resources
- Challenges of emerging plasma technologies on direct and indirect competitors



CO conversions of the water-gas shift reaction for a DBD packed-bed reactor using barium titanate, 3A zeolite and the MOF, HKUST-1 packing by thermal (at 100 °C) and plasma activation. *(A Bogaerts et. al., The 2020 plasma catalysis roadmap, J. Phys. D: Appl. Phys. 53 (2020) 443001 (51pp))*

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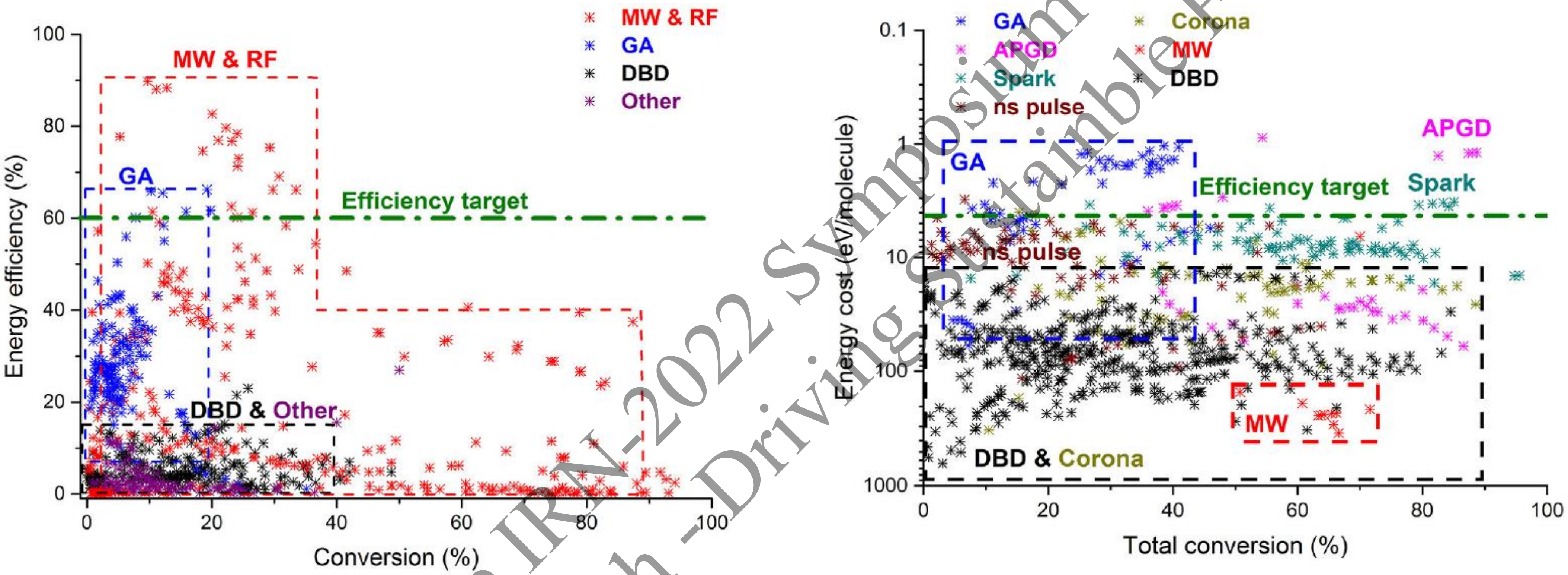
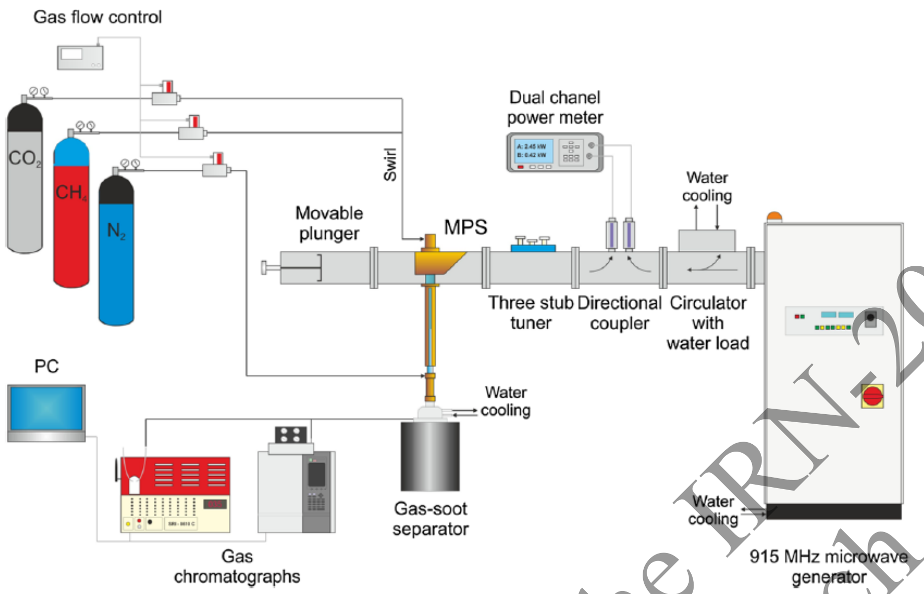
Plasma Technology for CO_2 Conversion



Comparison of all data from literature for CO_2 splitting in different plasma reactors, illustrating the energy efficiency and the energy cost as a function of conversion *(Bogaerts A and Centi G (2020) Plasma Technology for CO2 Conversion: A Personal Perspective on Prospects and Gaps. Front. Energy Res. 8:111.)*

Plasma Technology for H_2 Production

- Target on small-scale (Distributed) production (100-1500 kg(H_2)/d)
- Currently at 2 kg(H_2)/d for plasma tech



Production method	Initial composition	Production rate g(H2)/h	Energy yield $g(H_2)/kWh$
		Gaseous fuel	
Conventional steam reforming of methane (catalyst)	$CH_4 + H_2O$ + air		60 Established industrial process
Electron beam radiolysis	$CH_4 + H_2O$		3.6
Dielectric barrier discharge	CH_4 + air	0.13	6.7
Dielectric barrier discharge	$CH_4 + CO_2$	0.25	5.2
Dielectric barrier discharge	$CH_4 + CO_2/H_2O$		0.5
Spark discharge	$CH_4 + CO_2$	0.4	17.3
Gliding arc	$CH_4 + H_2O$ + air		40
Plasmatron arc	$CH_4 + H_2O$ + air		280
Metal-cylinder-based microwave plasma	$CH_4 + CO_2 + H_2O$	180	42.9
Waveguide supplied resonant-cavity-based microwave plasma with catalyst	$CH_4 + H_2O$	169	62.8

Conventional and plasma methods of H_2 production. Comparison of the hydrogen production rates and energy yields. *(J Mizeraczyk and M Jasinski, Plasma processing methods for hydrogen production, Eur. Phys. J. Appl. Phys. (2016) 75: 24702)*

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Summary

Pathways to Plasma Technology Commercialization for Sustainable Future

Spin-Off & Start-Up Company
- Business model
- Funding
- Convincing Partners
- Regulation

EGAT Enterprise
- Candidate for medium- and long- term strategies
- Feasibility and Upscaling