

添付2 第1回WG配付資料

資料1-1 Thor Energy AS

資料2-2 トリウム燃料WG活動計画案

資料1-3 トリウムWG\_OECDレポートレビュー分担



# Thor Energy AS

The Norwegian Thorium Initiative

Oystein Asphjell, CEO, Jan 2016



## Thor Energy is a nuclear fuel technology company

- Advanced, Thorium-based oxide fuel for use in today's and tomorrow's Light Water Reactors
- Near-term benefits to nuclear utilities
- Long-term benefits for the good of society
- Established in 2006 in Oslo, Norway
- Established the «International Thorium Consortium», Dec 2011.
- Loaded Thorium-oxide into the Halden Reactor on 25. April 2013 & 11. Dec 2015

## Thor Energy is part of the SCATEC group

### Climate neutral energy



- Solar
- Thorium
- Wind



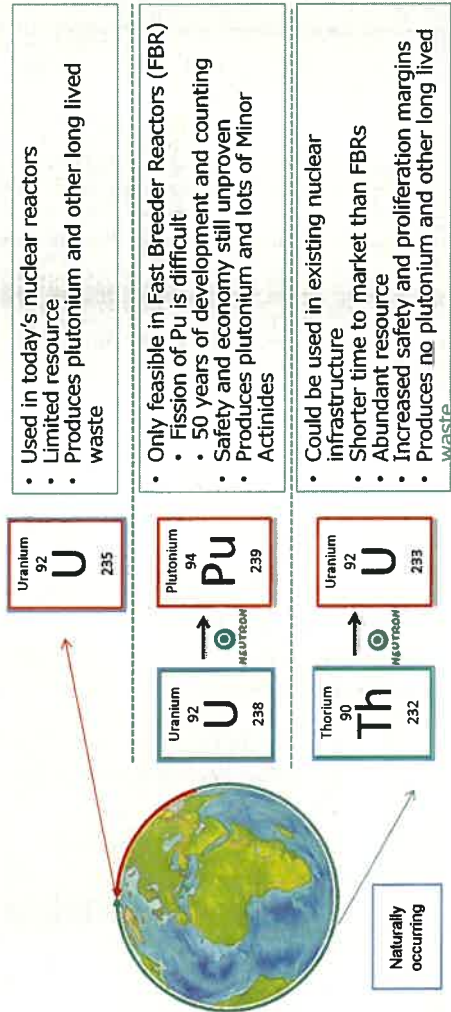
Alpha Ventus

### Advanced materials

- Titanium
- Nano carbon
- Rare Earth Elements



# Nuclear fuel: Natural fertile to man-made fissile:



# Thorium as a fertile supplement to Uranium

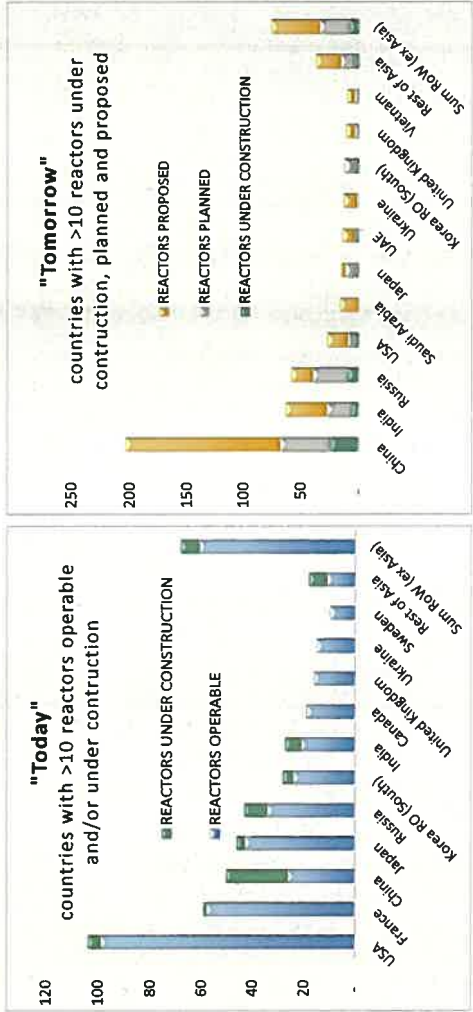
## Stepwise introduction of Thorium

- Every step with stand-alone benefits and profits



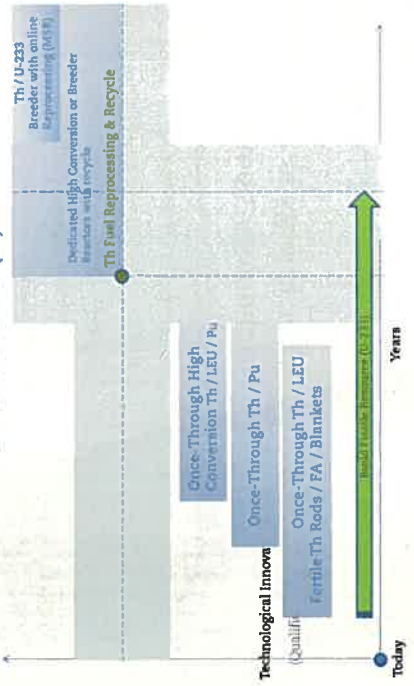
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120		
Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr																	

# LWRs will dominate nuclear energy the coming decades:



OECD Nuclear Energy Agency NEA

# Conclusions (2)



## The Market for Thorium is emerging



- EU and USA are preparing for introduction of Thorium in LWRs
- Three countries have defined Thorium utilization as part of their national energy policy:



## Thor Energy focus on first two steps of Th introduction:

### Fuel types

#### ThAdditive

- 5-10 % Th in Uranium fuel
- Improved safety margins
- Improved economy

#### ThMax

- Uranium substitute
- Improved safety
- Pu incineration
- Reduced waste generation - no new Pu or minor actinides

### Products and services

#### Validated fuel design

- Pellet recipe & process
- Pellet geometry patent
- Bundle geometry patent
- Validated irradiation data
- Regulatory license

#### Engineering services

- Design implementation
- Validated software tools



The Thorium Irradiation Campaign in the Halden Reactor

90 +4  
Thorium  
232,09806  
**Seven-Thirty**

...the Thorium evolution....



**IFE**

Institut für energietechnik

## The International Thorium Consortium



- Established in 2012 by Thor Energy
- Objectives:
  - Fabrication of Th-fuels
  - Instrumented irradiations
  - Analysis of data & results
  - Verification of Th-fuels
- Total budget 96 MNOK including 21 MNOK from Norwegian Research Council

Seven-Thirty



- The "SevenThirty" International Consortium
- Steering Committee with 1 rep from each member meets 2 times a year
- Equal access to all results generated
- Option for new fuel testing
- Japanese participation highly desired;
  - Expertise on all aspects of LWR fuel cycles
  - The export of Japanese reactors to Th-markets (TU, UK)

The Thorium Irradiation Campaign in the Halden Reactor

Seven-Thirty

## Irradiation experiment objective

... to yield data that can be used to demonstrate the safe, long-term performance of thorium-plutonium oxide fuels for Light Water Reactors, and that this information can support the planning and approval of a commercial a fuel...

Regulator and Operator requirements in focus:



By early 2017:

55 GWd/tHM burn up and 2 batches of fuel

**Fuel Fabrication Program**

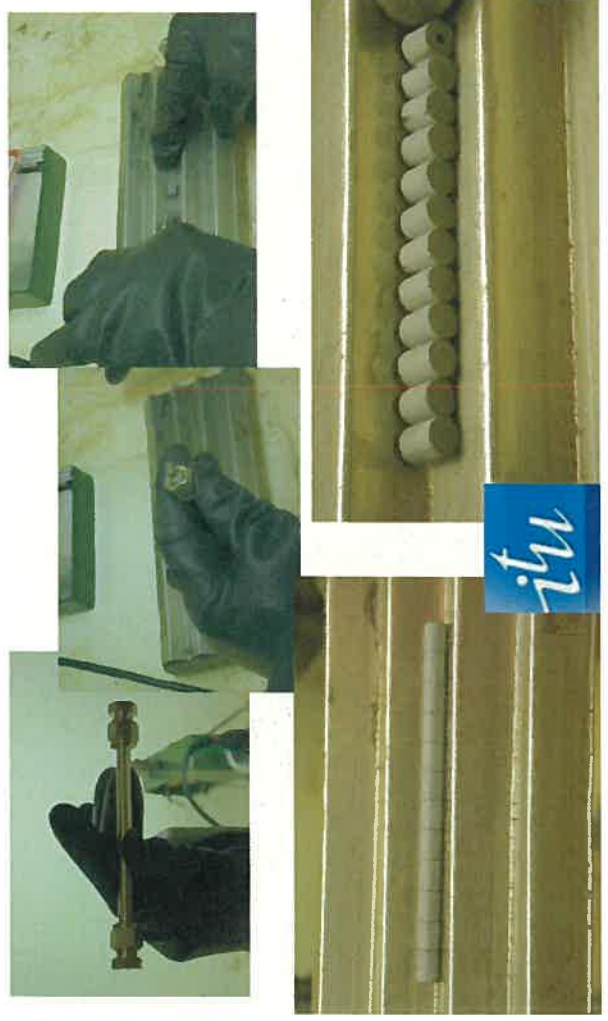
The Thorium Irradiation Campaign in the Halden Reactor

Seven-Thirty

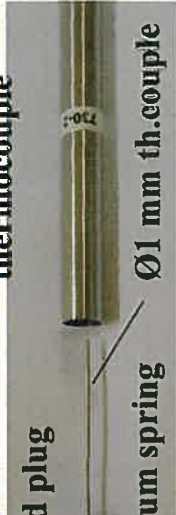


## The Thor Energy Alpha Fuel Manufacturing Lab

- Commissioned Aug 2014
- ThPu mfg campaign ongoing (Q1 '16)
- Options for advanced pellet mfg programs



**The IFA-730 Fuel Test Rod**



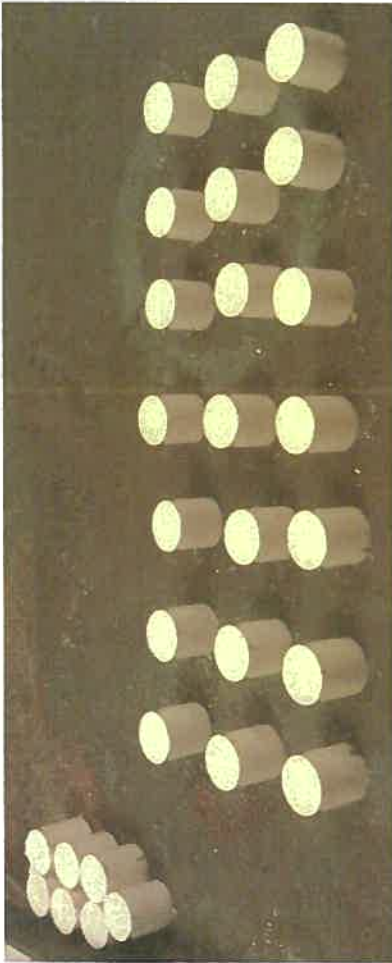
Ø1 mm th.couple





## Phase 2 Pellet Mfg (Pu-Th) Campaign:

Recent «dry-runs» with Th-Ce: (67% TD after pressing / 96%(?) post-sint.);



## Fuel Irradiation Campaign

The Thorium Irradiation Campaign in the Halden Reactor

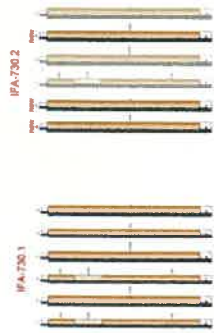
90 44  
The Halden Reactor  
Z33-033006



## Two Instrumented Fuel Assemblies:

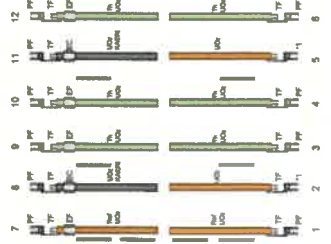
### 730:

6 pins since April 2013  
3 new pins in Q2 2016  
ThPu-focus



### 790:

12 pins since December 2015  
ThU-focus

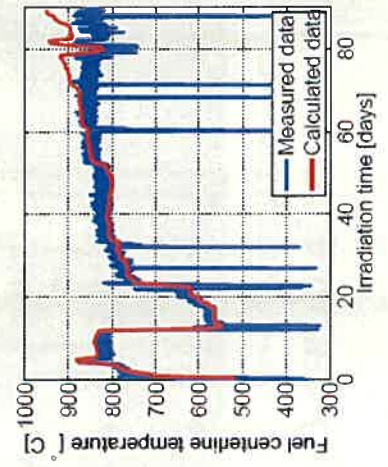
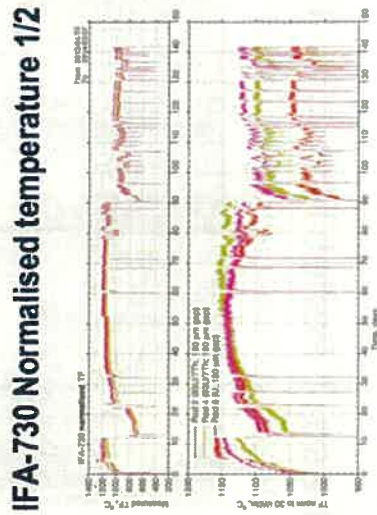




25. April 2013

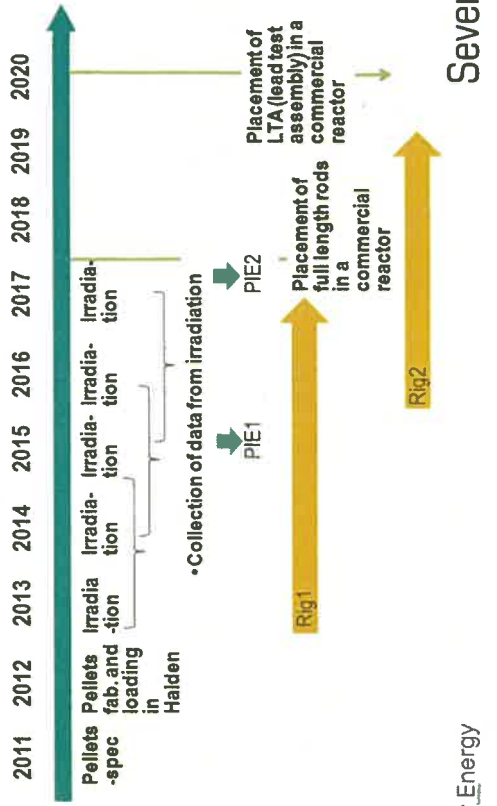
## SevenThirty – early results:

Sept 2014: Approx 200 days accumulated  
 New findings – i.e. thermal conductivity as a function of burn-up:



## World wide media interest

## Project timing

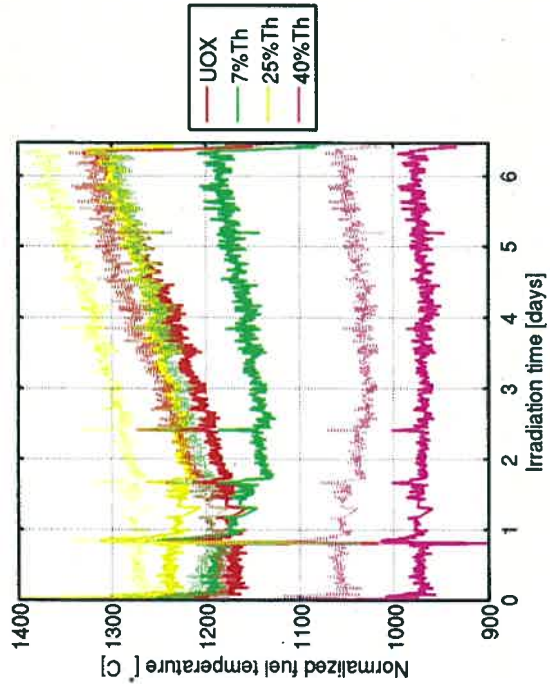


11. December 2015:

## Second test rig loaded!

«The SevenThirty 790-rig»

- 12 new fuel pins:
  - 8 ThAdditive variants
  - 2 ATF fuel
  - 2 reference UOX pins
- Provides redundancy in the data for regulatory approval of ThAdditive fuel



TU Norges smarteste bjørn. Nye dronerogler



THORIUMKRAFT

## Testingen er i rute: Vi kan ha thorium i reaktorer i 2018

Thor Energy har lastet inn sin andre runde med brennstaver. Neste år kan dataene være klare for endelig godkjenning.

Av: Odd Richard Holmset

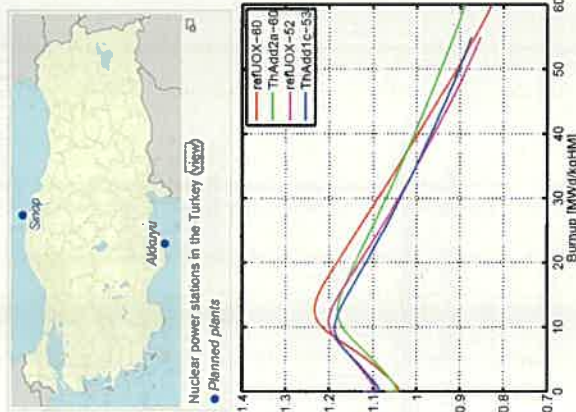
# Japanese partnership

**Seven-Thirty**  
Thorium  
372.0106

The Thorium Irradiation Campaign in the Halden Reactor

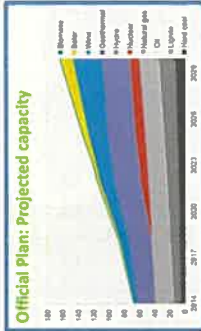
## First step: Th-Additive

- Thorium as «fertile absorber» in UOX assemblies in Turkish LWRs
- Displacing U238 and Gd
- Cooperation focus on:
  - Ore extraction
  - Powder chemistry
  - Fuel fabrication
  - Fuel irradiation
  - Fuel designs
  - Core designs
  - Strategic considerations



## December 2014: National Energy Plan

MINISTRY OF ENERGY AND NATURAL RESOURCES REPUBLIC OF TURKEY



### Goal 2: Optimum Resource Diversification

4. Nuclear energy shall be included into electricity generation portfolio.

Year	Share of nuclear energy in electricity generation (%)	Share of nuclear energy in electricity generation (%)
2015	0	0
2020	10	10
2025	20	20
2030	30	30
2035	40	40
2040	50	50
2045	60	60
2050	70	70

### Goal 2: Optimum Resource Diversification

11. Domestic uranium and thorium resources shall be explored and developed so as to be used as fuel in nuclear power plants.

Determination of domestic uranium and thorium resources and the domestic nuclear industry policy based on these sources and preparation of road map  
31.12.2019

1. Determining domestic resource
2. Defining nuclear policy
3. Defining road map

## Proposed partnership:

- Specific study to utilise Th as supplement / additive to UOX in Turkish reactors
- Use Turkish situation to support case for export of JP reactors
- Japan WG joins as members in SevenThirty Consortium
- Japan WG forms partnership with Turkish partner(s)
  - Expertise on all aspects of nuclear fuel cycle
  - Real reactor core models
- Turkey:
  - Specific needs for Th utilisation
  - Focus on ore extraction & processing
- Norway:
  - Irradiation data & results
  - Fuel mfg capacity
  - Accumulated LWR core designs



90 +4  
**Seven-Thirty**  
Thorium  
232.03806

The Thorium Irradiation Campaign in the Halden Reactor

*...the Thorium evolution....*



H28年1月27日

トリウム燃料の利用に関するワーキンググループ活動計画(案)

## 1. 活動の目的

東京電力福島第一原子力発電所の事故以降、我が国のウラン燃料の利用は停滞を余儀なくされているが、世界的には原子力発電所の建設計画は膨らみ、平成22年にワーキンググループを発足させたときの将来的なウラン資源の枯渇問題に備えてのトリウム資源の有効利用検討の必要性は増加している。これを受け、OECD-NEA からトリウム燃料サイクルに係る本格的な技術レポートが刊行され、軽水炉でのトリウム利用の研究開発として、ノルウエーの Thor Energy 社が組織した世界的なコンソーシアムのもとでハルデン炉でのトリウム燃料の照射試験が着実に進行している。こうした世界の状況に遅れることなく、トリウム燃料開発に係る海外との連携も視野に入れた取り組み方法について議論し、トリウム燃料の位置づけを検討・整理する。

## 2. ワーキンググループ(WG)の構成

核燃料部会の部会員が中心となりWGを開催し、他に関心をお持ちの他の部会員のWGへの参加も歓迎する。

WGの主査を阪大山中先生、幹事を阪大北田先生、牟田先生、東大小宮山先生、元 MHI 安部田委員、NDC 伊藤委員(事務局も兼務)とする。

## 3. 開催期間、開催頻度

平成28年1月から平成29年3月までの期間とし、3ヶ月に1回程度WGを開催する。

## 4. 活動内容

- (1) OECD-NEA の報告書の精査、専門家からの報告受け、ハルデン炉照射データの分析等を通しての、トリウム燃料利用の具体策案の提示、課題・問題の把握と解決策案の取纏め
  - (1.1) OECD-NEA 報告書の精査
  - (1.2) 専門家報告
  - (1.3) ハルデン炉照射データ分析
  - (1.4) トリウム燃料利用具体策案作成
  - (1.5) 課題・問題把握、解決策案
- (2) ハルデン炉等の海外機関との連携方策の検討、国際セミナーの開催、学会企画セッション報告の実施、等

- (2.1) 海外機関との連携方策検討
- (2.2) 国際セミナーの企画
- (2.3) 学会企画セッション報告
- (3) トリウム の位置づけの検討・整理を通してのトリウム燃料の利用の形態の提言案の取纏め

OECD-NEA 報告書精査およびハルデン炉照射データ分析については、別途サブワーキンググループを設置して作業を行う。OECD-NEA 報告書サブワーキンググループを北田委員、ハルデンデータサブワーキングを牟田委員にて、それぞれ組織する。

各種企画、報告書案取纏め等は幹事団で行う。

工程案を添付-1に示す。

以上



添付-1

トリウム燃料利用に関するWG検討工程(案)

	2016.1~2016.3	2016.4~2016.6	2016.7~2016.9	2016.10~2016.12	2017.1~2017.3
(1)利用具体策案、課題等の取纏め					
(1.1)OECD-NEA 報告書精査	[Progress bar]				
(1.2)専門家からの報告	[Progress bar]	[Progress bar]	[Progress bar]	[Progress bar]	[Progress bar]
(1.3)ハルデンデータ分析		[Progress bar]			
(1.4)利用具体策案作成					[Progress bar]
(1.5)課題・問題、解決策案					[Progress bar]
(2)連携方策検討、企画セッション報告、等					
(2.1)海外機関等との連携方策検討	[Progress bar]				
(2.2)国際セミナー企画					[Progress bar]
(2.3)学会企画セッション報告					[Progress bar]
(3)利用形態提言案					[Progress bar]



OECD/NEA\_No.7224 Introduction of Thorium in the Nuclear Fuel Cycle \_Short- to long-term considerations

1	Introduction	北田(阪大)	1
2	Perspective on the use of thorium in the nuclear fuel	北田(阪大)	2
3	Front end of the thorium cycle	平井さま(NFD) 牟田先生(阪大)	3
4	Thorium fuel testing and qualification	園田さま(電中研) 手島さま(MNF) 草ヶ谷さま(GNF-J)	4
5	Thorium fuel cycles in present day reactors	後藤さま(GNF-J) 青木さま(MNF)	5
6	Thorium fuel cycles in molten salt reactor designs	川島さま(東芝) 北田(阪大)	6
7	Spent fuel reprocessing	深澤さま(日立GE) 鷹尾さま(東工大)	7
8	Waste management issues	佐々さま(JAEA)	8
9	Non-proliferation issues		9
10	Economic aspects of thorium fuel cycles	小宮山先生(東大)	10
11	conclusions	北田(阪大)	11
A	Annex_A Thorium recovery		A
B	Annex_B A transition scenario study of light water reactors to thorium-fueled heavy water reactors		B
C	Annex_C A transition scenario study of molten salt fast reactors		C

